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Section 1. Biology

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ECOLOGICAL AND FAUNISTIC ANALYSIS OF IXODIDAE [ACARI: PARASITIFORMES] ECTOPARASITES OF ANIMALS OF UZBEKISTAN

Abstract. Some specific features of the fauna of ticks Ixodidae Murr 1890, their landscape distribution and ecology. Total found 18 species ticks belonging to 6 genera: *Ixodes, Haemaphysalis, Boophilus, Dermacentor, Rhipicephalus, Hyalomma,* families – Ixodidae. Determined the habitat distribution of ticks community and seasonal reproductive dynamics in domestic, wild, game animals and birds.

Keywords: Ixodidae, taxonomy, fauna, Uzbekistan.

Material and methods

Ixodidae mites – one of the most studied in the medical and veterinarian against groups of parasitic arthropods. It is well known that the nature of relations with the hosts and habitat types among Ixodoidea mites distinguish groups of species with pasture and lie in wait for nested – rodent parasitism types (Beklemishev [8]; Balashov [5]; Alekseev, Kondrashova [4]). According to this concept, ixodid ticks attaches nest – strive to parasitism, and their whole life cycle, including the power to the host, going inside burrows, nests, habitat structures populated by them. Ticks peculiar pasture – insidious – parasitism. Ixodidae mites represented the subfamilies of Ixodidae andAmblyomminaein Uzbekistan. They are widely distributed terrestrial cenoses and parasites in domestic and wild animals (Uzakov [15]; Kuklina [11]). Considered, as ticks are carriers of a number of dangerous transmissible diseases of animals and humans (Alekseev [3]; Lacey, Frutos [12]; Rasulov [14]; Abdurasulov [1]).

Spending most of their life outside the host body, studied mites, as well as other free-living organisms

that depend on the joint exposure to a plurality of abiotic and biotic factors. The geographic ranges of species of these mites largely correspond to the distribution in zones suitable for their existence (Agrinskiy [2]; Balashov [5]). Landscape image of Uzbekistan consists of plain (irrigation, steppe, and desert), foothill and mountain areas. It is characterized primarily by climatic conditions and is reflected in changes of the zonal type of vegetation and soil cover. The study of faunal assemblages Ixodidae mites in the modern environmental background is particular relevance.

The material collected in 2008–2016 years in natural and urban areas of the Republic of Uzbekistan. Research samples were collected by conventional parasitological methods (Agrinskiy [2]; Balashov [7]; Beklemishev [8]; Alekseev, Kondrashova [4]). In total, 59643 copies mites have been collected and studied. Collection of ticks carried out in accordance habitats, directly on the pastures, agricultural, domestic, wild animals andbirds. Identification of ticks carried by the determinant of V. N. Beklemishev [8]).

Results and discussion

The studies identified 24 species of ticks 9 genera belonging to two families – Ixodidae and Argasidae. The family IxodidaeMurr, 1877 is represented by 18 species of 6 genera – *Ixodes, Haemaphysalis, Boophilus, Dermacentor, Rhipicephalus, Hyalomma*. From total number of species (18) ixodids 17 are registered in the flat area, 13 – in the foothills and 10 – on the mountains. Dominating on the species diversity and quantitative distribution of ticks in a flat area were members of the genus *Hyalomma*. This kind of in our collections is the basic background of the fauna of ticks (62.6%) consisting 6 species – *H. asiaticum, H.anatolicum, H. detritum, H. dromedarii, H.scupense*and *H. plumoeumturanikum*. The most common domestic animal parasites are *H. asiaticum* (33.7%), *H. detritum* (22.6%), and *H. anatolicum* (about 20.0%). These species are marked, in practice, in the milestones regions of Uzbekistan. The highest number observed in South, Central and Northeastern regions.

The flat area with different climatic factors is also favorable to Ixodesectoparasites of animals – *Boophiluscalcaratus* (17.5%), *Rhipicephalusturanicus* (12.7%) and *Dermacentorpictus* (3.2%). There are also some common species of tick genera *Ixodes* and *Haemaphysalis*.A peculiar fauna of ticks, various ecological features, characterizes foothill zone. It marked the representatives of *Ixodes* (2.8%), *Boophilus* (17.6%), *Rhipicephalus* (17.1%) and *Hyalomma* (18.9%).

In the mountain zone registered 10 species of ticks, representatives – *Ixodes* (2.4%), *Boophilus* (35.6%), *Rhipicephalus* (5.2%) and *Hyalomma* (4.0%). This is not the marked species *Haemaphysalis* and *Dermacentor*. In this zone, the number of population exposed to ticks rare fluctuations under the influence of air temperature during the day on the one hand, and a limited number of small animals – feeding – on the other hand, conditions for creating of the essence some species.

It was revealed that species diversity ixodids in different landscape-geographical zones was different. The genus *Ixodes* were found mainly in foothill and mountain areas. Representatives of the genera *Dermacentor, Haemaphysalis* and has shown affinity to the plain.

Most of the species *Boophilus, Rhipicephalus*and *Hyalomma* adapted to all landscaped areas. Consistently, high numbers marked in South, Central and Northeastern regions of Uzbekistan. Presented abundant grassy vegetation in these regions contributes to broad development of cattle breeding and habitation of different groups of animals.

Given below is the description of the discovered dominating species from each of the 5 genera of the subfamily Amblyomminae.

Genus *Haemaphysalis* Koch [10].

Haemaphysalissulcata Can. et Fanz, 1877.

Hosts: cattle, sheep, hare, fox, tortoise, snake, sheltopusik, souslik, roller, sparrow.

Location: body of the animal.

Geographic distribution: Karakalpakstan, Khorezm, Samarkand, Navoi, Bukhara, Kashkadarya and Surkhandarya Provinces.

Biology.H. *sulcata* is a three-host tick, which, however, can develop on two hosts. The development cycle of *Hт. sulcata* lasts for at least one year. The spring maximum of adult ticks is conditioned by imagos that have spent the winter on the animals, as well as by nymphs. The autumn peak of infection with tick is reached through larvae developing during the summer and through nymphs. The maximum rate of infection with ticks in summer is conditioned by spring female ticks, which have produced a new generation. Some of the adult ticks can stay on the animals during the whole winter.

Adult forms parasitise mammals, while larvae and nymphs – reptiles and birds.

Genus *Boophilus* Cur, 1891.

Boophilus calcaratus Bir., 1895.

Hosts: cattle, sheep, goat, horse, dog and cat; wild mammals and birds can only be occasional hosts.

Location: parts of the body covered with thick hair, on the dewlap and neck; the ticks are not so frequent on the other parts of the body; however, they can even be found on the eye-lids, legs and tail. The ticks' location is associated with the health of the host's skin.

Geographic distribution: Tashkent, the Fergana Valley, Syrdarya, Samarkand, Navoi, Khorezm, Bukhara, Kashkadarya and Surkhandarya Provinces, Karakalpakstan.

Biology: *B. calcaratus* is a one-host tick; female ticks laying eggs, eggs proper and hungry larvae can be found in the wild, outside a host. After feeding females search for a place to lay eggs, as they drop off their host. Such females can often be found under stones. After dropping off their host the females do not move for some time. *B. calcaratus* can infect an animal almost during a whole year. A female with a live weight of 500–600 mg lays from 4,000 to 5,000 eggs.

The female begins to lay eggs on the 3rd to 6th day after it drops off its host and continues laying for 6 to 10 days.

Genus *Dermacentor* Koch [10].

Dermacentor pictus Herm, 1804

Hosts: primary hosts – cattle, sheep, goat, horse, dog, cat and wild mammals; secondary hosts – wolf, fox, dog and hare. Ticks at early stages often parasitise voles, rats and mice.

Location: On sheep – on the breast between elbow folds, on the dewlap and on the ears; on horses – on the mane, on the bulb of the tail, on the neck at the base of the forelock, on the legs in smaller quantities; on cattle – on the breast and neck, less on the belly, at the base of the horns, on the forehead, chin and tail; it was noticed that if there were no ticks on the end of the tail, the other parts of the body were not infected either.

Geographic distribution: Tashkent, the Fergana Valley, Syrdarya, Samarkand, Navoi, Khorezm, Bukhara, Kashkadarya and Surkhandarya Provinces, Karakalpakstan.

Biology: *D. pictus* is a three-host tick, the circle of its host varying depending on the stage of development. Adult forms parasitise large domestic mammals, young ones – wild rodents. The parasitising seasons for adult ticks in temperate zones are from late March to early June and late August. Larvae and nymphs parasitise animals from June to August. Females started to lay eggs in 3 to 6 days, when the air temperature was between 20 °C and 28 °C, while at lower temperatures they did it in 10 to 14 days.

After feeding the weight of a female ranges between 300 and 350 mg. The laying of eggs continues from 6 to 30 days. The number of eggs laid by one female may reach 3,200.

Genus *Rhipicephalus* Koch 1844.

Rhipicephalus turanicus B. Rom, 1940;

Hosts: cattle, sheep, goat, horse, dog, camel, cat, fox, goitered gazelle; the ticks at young stages usually parasitise murine rodents, such as mouse and common rat.

Location: thecochleae, udder and legs, head and neck, all over the body if the animal is heavily infected.

Geographic distribution: Tashkent, the Fergana Valley, Syrdarya, Navoi, Khorezm, Bukhara, Kashkadarya and Surkhandarya Provinces, Karakalpakstan.

Biology: *R. turanicus*is a three-host tick, which, however, can develop in two hosts. After feeding the minimal weight of a female is 200 mg, the maximal weight is 360 mg. After feeding the female lays eggs, from 1,821 to 5,837 in number. The embryo develops for 35–38 days.

The larvae appear on animals in large numbers from June to August, much fewer larvae appear in October and November.

Hyalomma Koch 1844.

Hyalomma asiaticum P. Schulze, et Echl, 1929.

Hosts: adult ticks parasitise cattle, horses, sheep, camels, donkeys, goats, dogs and goitereddazelles. The larvae and nymphs parasitise cattle, sheep and wild mammals.

Location: groin, udder, hind legs, belly, neck, breast and dewlap, sometimes back and thighs.

Geographic distribution: Tashkent, the Fergana Valley, Syrdarya, Navoi, Khorezm, Bukhara, Kashkadarya and Surkhandarya Provinces, Karakalpakstan

Biology: The tick is a three-host type. The time it parasites animals in its distribution area is mostly from March to October, young forms do it in summer; however, some quantity of adult ticks do not leave their hosts during the whole winter. The maximal weight of females is 1,250 mg, the minimal weight is 1,025 mg. The period of laying eggs depends on the environmental conditions, the shortest having been recorded taking place at a temperature of 26–35 °C. The duration of the egg laying is 20–29 days in spring, 25–33 days in summer.

The number of eggs the female lays after feeding ranges between 1,500 and 16,000. The full development cycle, from the beginning of the egg-laying to the adult stage, continues for 60 days.

In the context of the various natural and geographical areas of Uzbekistan identified 6 species argasid ticks belonging to three genera and two subfamilies (Fig. 1). Selected types can invade both in domestic and wild animals.

It should be noted also the role of animals – feeding in the resettlement of many species of *Ixodes* mites in natural and urban areas of Uzbekistan. Pets and wild animals, migrating from one territory to another, very effectively involved in the resettlement of the studied ticks. In this regard, the majority of species of ticks recorded as ectoparasites of animals, inhabitants of the plains, foothills and mountain areas (Table).

Table 1.– The distribution of ticks Ixodidae and on the landscape of Uzbekistan

Genera	**Landscape**		
	flatness	**mountain near**	**mountain**
Ixodes	–	++	+
Haemaphysalis	++	+	–
Boophilus	+++	++	+
Dermacentor	++	+	–
Rhipicephalus	++	+	+
Hyalomma	+++	++	+

+++– mass; ++– numerous; +– minorities; – missing

The activity of the dominant species ixodids are dependent on seasons and the landscape. Manifestations of tick activity is observed on the plain from the third decade of February and in early March, in the foothill zone – in March – April and the mountain – in late April and early May.

Season mite parasitism is studied in different zones of different periods of the animal settlement. Mites increasing infection of animals (groups) studied ticks stored in a correlation with the seasons of the year (Fig. 1).

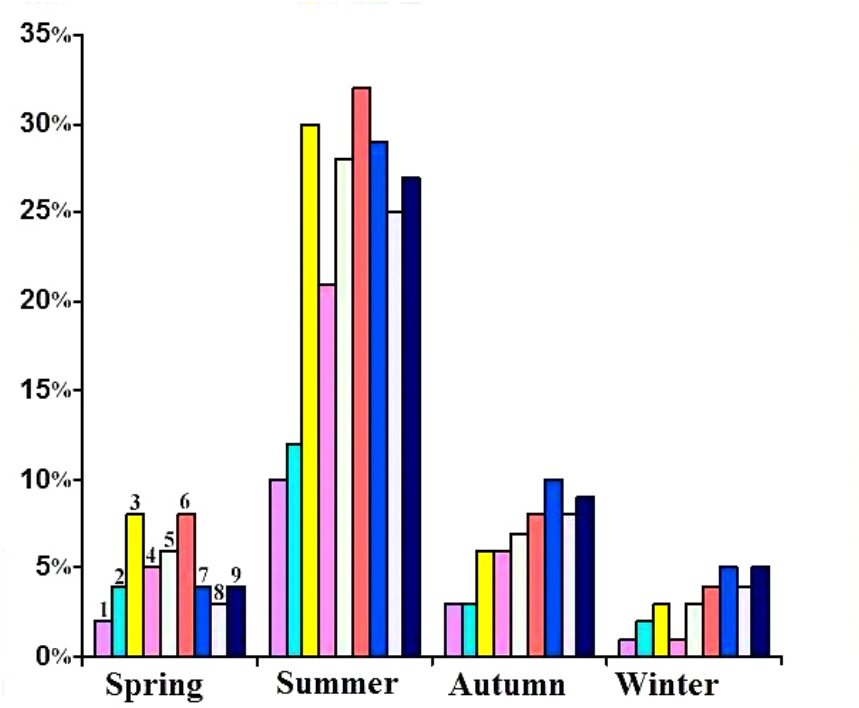

Figure 1. Seasonal dynamics mite infection of ixodids cattle in Uzbekistan condition: 1 – Ixodespersulcatus, 2 – Haemaphysalissulcata, 3 – Boophiluscalcaratus, 4 – Rhipicephalusturanicus, 5 – Dermacentorpictus, 6 – Hyalommaasiaticum

Many infected animals is usually observed summer. High infestation of cattle *H. asiaticum* reached – 32%. Reducing mites reproductive of animals observed in all areas – in the fall and significantly – in the winter.

Ixodes belong to the ecological group of ectoparasites with long time diet. The life cycles are the larval, nymph and imaginable stages that feed on the blood of vertebrates, including humans. By the nature of the known life cycle of ticks are usually subdivided into one -, two – and three hosts. The most common is three hosts cycle inherent in all types of labor *Ixodes, Haemaphysalis* and most species *Dermacentor, Rhipicephalus, Hyalomma* (Balashov [6; 7]; Alekseev, Kondrashova [4]; Haunmante Patil [10]).The presence of a wide variety of animal species in lowland and foothill areas ensures successful reproduction in these mites, developing on two – and three host types. However, as shown by the results of studies in recent years, some genera *Ixodes* ticks and *Hyalomma* observed loss of the original owners of the life cycle. From the development cycle *I. persulcatus, H. asiaticum, H. dromedarii, H. detritum, H. anatolicum*and *H. plumbeumturanikum* dropped wild mammals. Their whole life metamorphosis occurs only on one species of pet. The life cycles of ticks are diverse; their changes are adaptive in nature to the climatic and geographical conditions and the conditions of habitats, characteristic for a specific region. Reported trends in the life cycles of ticks are consistent with the known data of researchers (Balashov [6]; Denisov [9]). The set of factors contributes to a marked faunal assemblages ixodids ticks and in Uzbekistan and operation of a parasitic "ticks – vertebrates" system.

From the research results obtained, we have established that on the territory of Uzbekistan ixodids mites represented by 24 species. Of these ixodids up – 18 species and argasids – 6. In previous studies (Uzakov [15]; Kuklina [11]) in domestic, wild and game animals have been identified 40 species ixodids ticks: Ixodidae – 33 species and Argasidae – 7 species. It should be mentioned that most of the species were

noted at single finds, single instances or immature individuals. To date, the data previous studies significantly out of date, as confirmed by recent studies acarifaunas region (Rasulov et al. [14]; Abdurasulov [1]; Mirzaeva et al. [13]; Umrkulova et al. [16]). According to the results of studies in recent years, we have seen a marked depletion of fauna ixodids mites in Uzbekistan. In our collections, there was no significant number of species of Ixodidae: *Ixodesredikorzevi, Haemaphysalisnumidiana, H. pavlovskyi, H. concinna, Dermacentormarginatus, D.silvarum, Rhipicephalus bursa, R. rossicus, R. pumilio, R. leporis, R. schulzei,* and*Hyalommaanatolicumexcavatum*. In our opinion, the main factor limiting the habitat of mites in ecosystems of Uzbekistan, a human economic activity – large-scale development of natural areas, which contributes to a change in vegetation cover, temperature, humidity, wildlife habitat – feeding of mites.

The spatial distribution of the studied ticks occupies a special place flat area. Ticks are found in almost all areas with a predominantly agricultural type of development. In maintaining the existence of populations of mites marked our species and providing them with high numbers play an important role domestic mammals and birds, the abundance of which is large. Most of the ticks in agrocenoses pets and birds (cows, sheep, goats, horses, camels, dogs, chickens, turkeys).

The presence of diverse landscape and geography contributes to the functioning of the system and the formation of parasitic fauna complexes modern ixodids mites.

3. Conclusion

We reviewed fauna ixodids mites in the modern environmental background of Uzbekistan. The total number of species studied ticks represented by 18 species. Some groups of species are marked in all the landscapes of the country, which form stable populations of different generations, invading various species of mammals and birds.Most species of ticks environmentally associated with mammals, or more precisely their separate groups. Another part of the specialized to parasitic is mainly on domestic and wild birds.Degree mite reproductive of animals are dynamic, which is dependent on environmental factors and biocenotic links components of parasitic system. The complex species composes ixodids mites fauna of Uzbekistan at the present stage involves the systematic monitoring of the number of animal ectoparasites populations with the aim of improving the methods of dealing with them in specific areas.

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Section 2. Geology

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CHARACTERISTICS OF ENGINEERING, GEOLOGICAL AND SEISMIC PROPERTIES OF PALEOGENE CLAYS IN THE MODERN HYPERGENESIS ZONE

Abstract. The article examines the formation and development of engineering and geological properties of the Paleogene clays of North Tamdytau. By examining the features of the geological and tectonic development of the North Tamdytau, we have defined the formation and development of clays within the arid lithogenesis, distribution, thickness, depth of occurrence of lithology and properties. Their study has an important theoretical and practical importance, as these sediments are most often the foundations for various engineering structures.

Keywords: shrinkage, swelling, foundations of structures, wetting, durability, seismic properties, weathering, salt accumulation, weathering agents, hypergenesis, arid lithogenesis, modern hypergenesis.

Introduction. The practice of geotechnical engineering shows that underestimating the swelling and shrinkage of clay soils in the foundations of structures leads to their premature damage. The problem of damage to the foundations of structures, especially thermal ones, occurs when the clay soil under the building is subjected to moisture, begins to swell because of reduced strength properties, increases the pressure on the foundation of the structure. During dry periods of the year, this soil can dry out and settle due to decreased moisture content, which also leads to a reduction in strength and bearing capacity. The cyclical repetition of this kind leads to a reduction in both strength properties and salinisation and physico-chemical transformation. At the same time, soil moistening may occur not only from atmospheric precipitation, leaks from water utilities, but also due to the accumulation of moisture under the watertight screen and changes in the water table due to elevated temperatures at the foundation of the thermal structure. In this regard, we set a research goal – the formation of engineering-geological and seismic properties of Paleogene clays in the zone of modern hypergenesis.

Modern hypergenesis is a global process of physical and chemical transformation of rocks in both subaerial and mainly subaerial conditions [1–3, 4]. The weathering process affects practically all rocks composing the upper shell of the Earth, i.e. eruptive, metamorphic and sedimentary, including carbonate and chemogenic varieties of the latter. The most clear regularities of this process are observed

in the weathering profiles of aluminosilicate rocks (especially erupted ones), some differences of which are characterized by a pronounced contrast in both chemical composition and mineralogical features. However, to elucidate some particular issues of the mineralogy of the weathering crust, with a comparative analysis of different types of residual products, very important data can be obtained by studying the crust on sedimentary rocks as well. The mechanism of hypergenic transformation of various hypogenic minerals is determined by their structural features.

The upper part of the Earth's crust, where hypergenic processes (soil formation, weathering, salt accumulation, geochemical activity of groundwater) take place, is referred to as a hypergenesis zone. It usually includes only natural phenomena, not including technogenesis [8]. Under specific geological conditions, hypergenic and technogenic processes proceed in the same thermodynamic environment. Studying them is of great theoretical and practical importance, since these sediments most often form the base of various constructions.

Discussion of the results. In this regard, of interest are the foothills of the North Tamdytau mountains, on the example of which we will consider the peculiarities of engineering-geological and seismic properties of the Eocene clays. Peculiarities of geological and tectonic development of the North Tamdytau determined the formation and development within their boundaries arid lithogenesis clays, characterized by different areas of outcrops to the surface, distribution, thickness, lithological properties, depth of occurrence. The intensity of the processes of hypergenesis is also determined by the current heat and moisture supply.

The study of changes in the material composition, engineering-geological and seismic properties of clays under the influence of modern hypergenesis made it possible to identify 3 zones.

In the first – strongly changed zone, besides the soil-vegetation layer with thickness up to 0.2 m, enriched with plant remains, the top layers of weathered bentonite clays are attributed. The total thickness is up to 0.2 m. The properties of deposits in this zone are closely connected with the intensity of denudation processes, solar insolation, and are determined by the grain size and mineral composition, and largely depend on the workability of outcrops.

Clays of montmorillonite-hydrosludite composition, covered with a small layer of Quaternary deposits, were under the influence of dry arid climate with deficit of atmospheric precipitation in the last geological periods [6; 7]. Therefore the processes of salt accumulation ($CaSO_4$ up to 10 and more%; $CaCO_3$ up to 20–25%; NaCl up to 0.7–0.8%; Na_2SO_4 up to 2.5%) actively proceeded here.

As a result of aggregation of clay particles, mechanical fragmentation associated with various weathering agents (sharp fluctuations in daily and annual temperatures, constant winds, root systems of plants – saxaul, and many others). Sometimes there are plastic dikes filled with sand and fine gravel – products of weathering of rocks composing the Tamdytau mountains. This zone has comparatively low humidity (from 6 to 12%), skeleton density (to 1,38 g/cm3), low plasticity (to 28%), swellability (to 1.6 times or 3,4%), and decreased seismic wave velocity (to 920 m/s).

The second, moderately altered zone includes clays of montmorillonite-hydrosludite composition. It should be emphasized that the change of engineering and geological properties and material composition is clearly evident along the vertical section of clays. Increase of skeleton density (up to 1.45 g/cm^3), water content (up to 20%), clay fraction content (up to 65%), swellability (by 3.2 times, or 9.4%), plasticity (up to 42.8%) and longitudinal speed (up to 1600 m/s) is observed with increasing depth. This is due to an increase in compaction gravity load. However, even at these depths (up to 3.5 m) hypergenetic changes, related to aridity (salinization of $CaCO_3$ up to 10–15%, $CaSO_4$ up to 5–10%, Na_2SO_4 – to 0.5% and less, etc.) and appearance of desiccation cracks on surface are reflected. Consequently, the influence of hypergenesis processes on Eocene clays gradually weakens with depth and from about 3.5–4 m depth is weak.

General geological and lithological cross-section	Strength in m.	Engineering and seismological characteristics
	2. 0.30 to 1.50	**I – heavily altered zone** 1 – soil layer loosened, not exceeding 0.2. m, sparse vegetation. 2 – montmorillonite clay, predominantly hydrous, strongly fractured, filled with secondary floury gypsum, jarosite, iron hydroxides. There are occasional clastic dikes filled with sand or fine gravel. Clay fraction (up to 42%), humidity (up to 12%), plasticity (up to 28%) and swellability (up to 1.2 times of initial volume) change with depth. Longitudinal wave velocity up to 920 m/sec.
	3. 1.50 to 3.5	**II – moderately altered zone** Clay of montmorillonite-hydrosludite composition. Medium-slit, fractures filled with fine sand, «rubble» or clay laminae. The massif is fractured by large fractures. Limonification, formation of fine-crystalline gypsum and jarosite is observed along the fractures, mostly present on the vertical fractures. An increase in humidity (up to 20.8%), plasticity (up to 42.8%), swellability (3.2 times), longitudinal wave velocity (up to 1600 m/s), and electrical resistance (up to 6.8 ohm.m) can be observed
	4. ≥3.5	**III – slightly altered zone** The clay is massive, fractured by major fractures and tectonic zones. Small weathering zones can be formed, the zones are filled with gaps, secondary newly formed minerals – jarosite, gypsus iron hydroxides, alunite, etc. can be found in the clay. Only pyrite and rare limonite occur macroscopically. They are mainly formed in the lobes of major fractures and zones. There is no definite boundary between zones, presumably from 3–3.5 to 4.0 m. This can be observed in changes in clay fraction (up to 84%), moisture content (up to 30%), plasticity (up to 50%), and swellability (up to 10.5 times of original volume). No further change in their depth is observed. The longitudinal wave velocity is up to 2000 m/s. Specific electrical resistance up to 11.0 ohm.m.
		

Figure 1. General outline of the effect of hypergenesis on the Paleogene clays of the Central Kyzylkum. 1 – cracks; 2 – small cracks with jarosite; 3 – cracks with gypsum, 4 – cracks with powder limonite; 5 – clastic dikes; 6 – soil-vegetation layer

The third, slightly altered zone, includes clays of montmorillonite composition. In connection with depth, due to pressure of overlying formations, clays of this zone are little changed and are characterized by high values of clay fraction (to 84%), humidity (to 30%), plasticity (to 50%), swellability (to 10.5 times, or to 19.7%), P-wave speed (to 1800 m/s), and on the other hand by lower water soluble salt content and fracturing.

Conclusion. Therefore, an important role in changing properties of Eocene clays belongs to the speed and duration of tectonic movements, which is reflected in acceleration or weakening of the described processes. Comparative analysis of the above-mentioned zones shows that, along with mineralogical peculiarities of source rocks and hydrogeochemical conditions of the environment, the following three factors are important in formation of engineering-geological and seismic properties of Paleogene clays. The first one is the degree of structural ordering of primary minerals. The second is the inheritance of these properties by the newly emerging phases. The third one is the universality of the process of transformation of hypogenic and formation of hypergenic minerals in the zones of hypergenesis, developed at different depths of clays. In further studies, the use of the three formulated above additional provisions for the objective identification of the regularities of the zonal structure of hypergenesis in the clay sequence, will be based only on the study of Paleogene clays complex optical-electron-microscopic and structural-crystallochemical studies.

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Section 3. Political science

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INTERNATİONAL EXPERİENCE İN THE FİELD OF LOCAL SELF-GOVERNMENT: REALİTİES AND PERSPECTİVES

Abstract. The article refers to international experience in the field of local self-government, various models in this field have been studied and their specific features have been shown. The article also examines the activities of municipalities as a form of local self-government in the Republic of Azerbaijan.

Keywords: local self-government – activities related to the solution of issues of local importance: municipalities, neighborhood committees, associations, utilities.

Statement of the problem. Formation of a democratic, legal state characterized by the establishment of civil society being a form of a democratic state structure in itself, ensuring the close participation of citizens in the management of society, as well as creating conditions for meeting the socio-economic and cultural needs of the population, thus helping to ensure the rights and freedoms of people and citizens require the formation of a system of local self-government. Local self-government is the beginning of a free, democratic society.

Local self-government is an essential feature of any modern democratic society. Differences in the formation of local self-government systems depend on many factors, at the same time political regime, organization and, management of the dominant power in the country, state structure, administrative-regional division of the state, national traditions. In most modern countries, all local affairs are managed by special local government bodies established based on general, equal and, direct voting rights, as well as specially appointed local government bodies from the center through a secret ballot. Local or municipal autonomy means a local problem management system run by specially elected bodies that directly represent the population of a particular administrative-regional unit of the country. The European Charter of Local Self-Government, adopted by the

Council of Europe on 15 October 1985 and serving as the main legal basis for self-government for all European States, provides a general definition for local self-government that is almost universal and accepted by all democracies. According to the Charter, local self-government means "the right and genuine ability of local self-government bodies to regulate the majority of public affairs and act within the law and take responsibility in the interests of local people."

The purpose of the article: Establishment of local self-government bodies in the Republic of Azerbaijan by referring to the international experience in the field of local self-government and to review their areas of activity

Material analysis: Nowadays, the most important features of local self-government systems in foreign countries are their universal choice and considerable freedom in resolving local issues. This freedom includes municipal property, the right to collect and dispose of local taxes, the ability to adopt regulations on local government, and so on. Local self-government bodies are given the right to elect local self-government bodies and adopt normative legal acts, financial autonomy, independence in conducting personnel policy and, communal planning. Such principles reflect the most characteristic features of the system of local self-government in European countries. At the same time, the European system of local self-government has significantly influenced the formation and functioning of local self-government in other regions. Various models and types of organization of local self-government are shown in foreign municipal law. Several main models (systems) of local self-government known in the world practice: – Anglo-Saxon system; Continental (French system); German (mixed) can be considered.

The Anglo-Saxon system is mainly used in countries with the same legal system, including the United Kingdom, the United States, Canada, India, Australia, New Zealand, and so on. In the states that follow this model, the relationship between the central government and local self-government is determined by the principle of "inter vires" («inter vires»), so local self-government bodies. Other activities are considered abuse of power and are considered illegal by the court. This model does not provide for the presence of any official appointed to local self-government bodies for centralized control [6, 34–38]. Local councils resolve issues that are not within the competence of the central authorites, independently and within their responsibility, within the framework of law, tradition (gained experience), judical precedent.

The continental local self-government model differs significantly from the Anglo-Saxon model. This model is common not only in continental European countries (France, Italy, Spain, Belgium) but also in Latin America, the Middle East, and French-speaking African countries. For France, the founder of the continental model, the high degree of centralization of local self-government has been traditional throughout history. For a long time, France had a system of multi-level local government and here the activities of the lower echelons had significantly depended on the higher governing bodies (primarily in the administrative and financial sense). At present, the main stage of local self-government in France is the communes, which are municipalities created by residents of small towns and rural settlements [7, 99–100]. Each commune has its own representative body, the council, and a mayor, who is elected among the deputies of the council, as well as a civil servant and head of the local self-government. The mayor and deputies of the municipal council, acting permanently, form the municipality. Its activity is carried out under the control of the municipal council and the administrative control of the republican commissioner. It monitors the legality of the decisions taken by the second committee and, if necessary, applies to the court to annul them.

In addition to the mentioned models, there are other options for the organization of power in places that have accumulated features to some degree and have their characteristics. Such models include lo-

cal self-government in Germany, Austria, Japan, and several post-socialist and developing countries. These models are called mixed. A distinctive feature of the mixed model is a combination of autonomous local self-government and a higher level of governance at a much lower regional level.

In modern states, local self-government systems are based on the administrative-territorial division of the state. The administrative-territorial division itself of any state is an important part of a state organization. This structure is often very conservative. Even in the context of the adoption of such new constitutions and constitutional laws, which affect other aspects of the organization of the state, it is rarely infringed and does not undergo significant changes.

The administrative-territorial division of the state, as a rule, was formed under the influence of purely geographical factors by taking into account the economic, social, and demographic situation. Changes in these factors, especially in exchange for scientific and technological progress, will undoubtedly affect the restructuring of the administrative-territorial structure of the state, but this is mostly about industrial regions.

The modern system of administrative division in large foreign countries (USA, Germany, Spain, Switzerland, etc.) were established in the XIX century, in the UK these foundations date back to the early feudal period. Therefore, in the system of administrative-territorial division of foreign states, territorial units that are still outdated, small in area, and have lost their economic and sometimes demographic basis for existence may remain. In most cases, the regulatory framework of different areas lags behind socio-economic potential. As before, significant differences remain in the size, population, and economic potential of the administrative-regional units of the same category. The regulation of the administrative-regional structure in unitary states is the jurisdiction of central authorities and federal states – the matters of the federation, but The general principles of the organization of the administrative-regional department should be based on the principles of the entire federal constitution. The detailed regulation of the local administrative-district section is carried out by special laws. In modern states, the system of local self-government can include two to five vertical levels. The two-tiered (Denmark, Costa Rica, etc.) and three-tiered, India, etc.) structure of the administrative-territorial division was considered the most common and advantageous in terms of local self-government [8, 66–67]. Four-tier and five-tier systems of administrative-territorial division are less common. Local self-government bodies differ in the degree of centralization of their relations with higher authorities. A system of local self-government is based on the principle of subordination of lower bodies to higher bodies (Italy, France, Germany). At the same time, several states support the autonomous system and there is no direct vertical subordination in this system, but it is realized in a very limited way in practice. In the second case, local governments have considerable freedom over higher authorities. In this case, a fairly broad system of electing these bodies has been established. Sometimes the activities of local self-government bodies are under the direct control of special state bodies. In most cases, they are subordinated to the Ministry of the Interior (the UK), in other countries, even a special unit within the government (the Ministry of Local Self-Government) may be established [6, 43–46].

In modern countries, there is a great diversity in the administrative-territorial division that often dictated by historical traditions and economic expediency, and that's why the characteristic of local self-government is the extreme diversity of the organizational forms and direct dependencies of the local conditions (geographical, socio-economic, production, demographic, etc.). In the UK, the district is divided into districts, districts are divided into areas covering both urban and rural areas. In England, the lower divisions are parishes, while in Wales and Scotland they are communities. In all territorial-administrative units, except for small parishes, there

are councils with local government bodies. In small parishes, the functions of local governments are carried out by the assemblies of voters convened periodically by that parish.

The administrative-regional cleavage in the Federal Republic of Germany is determined by the constitutions of the territory. According to land constitutions, territories are divided into districts, districts into circles, and the latter into communities. Districts and communities have their councils, which are elected local governments. In sparsely populated communities, electoral councils are convened periodically to address local governance issues. There are no local governments in the constituencies.

Public administration and local self-government are institutions that are constantly interconnected and interact with each other. This is due to their place in the system of public administration and their role in social development.

The following important issues must be resolved for the mutual development of state and municipal governance. In this case, the solution of two groups of problems is considered: The first group of problems is related to the state's support for the development of local self-government. It envisages the creation of political, normative-legal, organizational, financial-economic, and administrative management conditions that necessary for the implementation of the constitutional principles of local self-government. The second group of problems is to ensure the unity of local self-government with the system of state power, its accountability to the state and the population.

The interaction and cooperation of public authorities and local self-government bodies have been accepted in world practice as one of the principles that facilitate the solution of both groups of problems. This principle envisages the joint action of local self-government bodies in completing the organizing process and creating conditions for them to exercise their constitutional powers.

The historical experience of developed countries shows that the complex issues of systematic transformation of society and economy to achieve sustainable development of the country are only possible in the presence of an effective system of governance at all levels of government. In this regard, the process of forming a system of local self-government through the implementation of the policy of decentralization of public administration in the Republic of Azerbaijan should be considered as one of the most important steps for democracy, rule of law, and civil society.

The main goal of the decentralization policy implemented in Azerbaijan is to democratize the foundations of public administration, create conditions for effective fulfillment of duties at the appropriate government levels while addressing the current and future socio-economic development challenges both. The decentralization of central government and establishment of local government structures are important for political stability, serviceability, poverty reduction, and development and adoption of governance decisions. The drafting of the Constitution of the Republic of Azerbaijan and its adoption by popular vote on November 12, 1995, marked the beginning of the process [1, 78]. Currently, the state sovereignty and independence of Azerbaijan are the transformations of democracy, secularism, and the rule of law through reforms. The main goal of the reforms is to determine the main aspects, ways, and methods of decentralization of public administration, which is one of the conditions for the building of a legal, democratic state in Azerbaijan, and the formation of an effective local self-government system.

According to the Constitution of the Republic of Azerbaijan, despite the broad powers of the local self-government bodies, the Law on the Status of the Municipalities adopted on July 2, 1999, considers the activities of the municipalities to be a form of activity within the civil society system. Article 10–11 of this law was amended by the Law of July 9, 2019, which obliges the Ministry of Justice to organize experience exchange with local self-government bodies, their associations, and specialized agencies of foreign coun-

tries in order to improve the professionalism of municipal members and employees [4, 96–98].

Today a solid legislative framework has been created in the Republic of Azerbaijan for the activities of municipalities. One of the first steps is our country's participation in the European Charter of Local Governments Autonomy. The condition was approved by the National Assembly of the Republic of Azerbaijan on April 15, 2002, and submitted to the Council of Europe. The Law of June 21, 2013, adopted by the National Assembly is in line with 19 October 2011 Recommendation from the Council of Europe's Congress of Local and Regional Governance, titled "Regards and Declarations on Local Autonomy Requirements of Europe", by joining in paragraph 3 of Article 10 of the European Charter, our country has assumed another obligation and cooperates with other municipalities, joining them, becoming a member of associations and international associations of local self-government bodies, and cooperating legally with other states' local self-government bodies [4, 127–128].

Under the October 19, 2011 recommendation by the Council of Europe Congress of Local and Regional Governments, entitled "Regards and Declarations to the European Local Autonomy Charter", the National Assembly took part in Paragraph 1 of the Law of 21 June 2013 adopted by the National Assembly, assuming a different obligation and cooperating with other municipalities, participating in their associations of local self-government Participation in international associations has granted the right of other states to co-operate with local self – government bodies in accordance with the law.

The system of local self-government in Azerbaijan is one-tier and has equal rights and equal powers, regardless of the status of the administrative-territorial unit (village, settlement, district, city), territorial size, financial potential, and population. There is no subordination between municipalities [5, 112–116]. Their bodies are equally independent, have independent financial resources, carry the same authority, have the right to freely possess and dispose of their property, make independent decisions, and are finally formed as a result of nationwide elections. The regional and population principle is not required for the establishment of a municipality in our country. The population is only important for the number of municipal assemblies

Municipalities develop and implement local social protection and social development programs, local economic development programs, and environmental programs to address issues of local importance.

The development of local democracy and self-government attaches particular importance to co-operation with relevant bodies of the Council of Europe and other international organizations. The interaction with the relevant structures of the Council of Europe in the field of decentralization has been further strengthened. The Azerbaijani delegation has duly represented our country at international events and made recommendations on current issues in accordance with the interests of our country and these proposals have been adopted in many cases [4, 78]. Measures taken to improve local self-government have expanded the capacities of municipalities and created more favorable conditions for their development.

Conclusion. State activity in the field of local self-government should be accomplished through a state policy in the area of local self-government development, with the main objective of securing the future development of local self-government in the country. Soon, successful implementation of state policy in the development of local self-government in Azerbaijan will lead to the formation of a system in which the population, local self-governments, and the government interact.

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Section 4. Agricultural sciences

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THE ENGINEERING AND RECLAMATION STATE OF MIRZACHO'L AREA OF SIRDARYO REGION

Abstract. The article examines land degradation in the drylands as a result of various factors, including climate change with human activities. At the same time, the particularity of the problem of desertification, which was an integral part of land degradation, is examined. In general, "Land degradation" is considered as a decrease or loss of biological and economic productivity of irrigated land or areas under the influence of natural and anthropogenic factors.

Soil degradation of Mirzacho'l is currently caused by:–depletion of the surface soil layer due to wind and water erosion and induced-changes in soil chemistry and biological environment caused by acidification, salinity or pollution-accelerated loss of nutrients from mineral and organic soil matter and loss of organic matter itself-soil compaction and loosening due to infrastructure development and housing development.

Keywords: degradation, hypergenesis, groundwater, desertification, reclamation conditions, hydrogeological and engineering geological conditions.

Introduction. Desertification and drought holds special place among modern global problems of mankind, which impede sustainable development of economy, that was reflected in regional researches on estimation of hydrogeological and meliorative conditions of territory and study of predicted groundwater resources of Neogene-Quaternary deposits in view of water management conditions change on area of Mirzacho'l of Sirdaryo region. And groundwaters of Mirzacho'l are an exhaustible resource, and every citizen of the Republic is its consumer, although not everybody realizes it. 98% of the products we consume originate from these lands [1; 2; 3].

Desertification means land degradation in arid areas due to various factors, including climate change and human activities. At the same time, particular importance is given to the problems of desertification, of which land degradation is an integral part.

Soil degradation of Mirzacho'l at present is caused by: – depletion of the surface layer of soil due

to wind and water erosion and caused by; – changes in the chemical composition of soil and biological environment caused by salinization or pollution.

Research subject. Irrigated areas of Mirzacho'l belonging to Sirdaryo region were the research subject. Here significant rise of ground water of 1.5-3m and more is observed, in comparison with natural conditions of 5.0-10m in 1960. The flooding caused in the last decade by groundwater rise in considerable areas of Mirzacho'l, mainly due to irrigation system operation rules violation, creates additional difficulties both in development and in construction of engineering structures, underground utilities and drainage.

Purpose and method of the research. Sirdaryo region's natural, anthropogenic and economic conditions have an approximately uniform natural and soil-reclamation environment for the desert zone of Mirzacho'l [9; 10, 13-15].

The purpose of the research is to study soil-reclamation state of irrigated soils and grounds taking into account natural conditions and anthropogenic factors. For achievement of the purpose, the following tasks have been set: – to identify causes, regularities of formation and geographical distribution of saline soils and grounds; – to establish regional peculiarities of salt accumulation; to assess reclamation state of grounds in Sirdaryo region.

There is an all-round increase of ground water level on the studied territory. If we take into account that the groundwater recharge area of Mirzacho'l as a whole, is through precipitation and infiltration from irrigation canals. And it should be noted that in the central and eastern parts of the studied area there is no groundwater recharge, except capillary rise and evaporation. Similar conditions have been mentioned in works of different authors in different years [8; 9; 16].

Approximately the same approach was adopted in Russia even earlier [2]. However, the set of physical degradation indicators was a little wider here. In addition to those mentioned above, porosity, filtration coefficient, reduction of soil thickness and others were used here.

Some Russian agencies (e.g., State Committee on Land Resources and the Ministry of Ecology) recommend using their methods for assessing physical degradation of soils [3], the idea of which is approximately the same-assessment of soil deterioration with respect to some initial condition.

In fact, the only sources of information for judging the presence of physical degradation and subject to hypergenic changes are the results of comparative observations in non-irrigated and irrigated areas of long-term field engineering and geological studies accompanied by experimental experiments. Based on these sources of information, we consider it important to systematize the processes in soils related to hypergenesis and physical degradation, to establish its causes, a clearer diagnosis, possible areas of distribution and the search for ways to prevent it.

Discussion of results. The article uses the results of mining and test-filtration studies of irrigated and newly irrigated areas of Mirzacho'l, pertaining to Sirdaryo region. Based on these comparative studies conclusions will be drawn about changes in physical properties, which we interpret as degradation and hypergenic changes in soils. The results of macro- and micro morphological and textural structure of soils and individual soil aggregates, structural-textural composition, water resistance of aggregates, porosity, about the ratio of vertical and horizontal pores -anisotropy are used as indicators of these processes.

According to the guidelines for hydrogeological and engineering geological investigations [1; 4; 5; 6; 7], the lithological composition of rocks in the outcrop and their stratigraphic position are recommended to be described with little detail. The order in which rocks are described is as follows: a) petrographic name; b) mineralogical composition of the rock; c) rock colour; d) impurities and rock cement; e) density; f) structure and texture; g) layering and various features associated with the rock formation conditions; h) inclusions; i) fractured rock; j) fauna and flora; k) assumed age.

The colour of a rock can often indicate the genesis of the rock and its properties. Therefore, in our studies, the bright red hues due to the presence of anhydrous iron oxide (Fe_2O_3) or hydroxides ($2Fe_2O_3 \cdot H_2O$) and gypsum ($CaSO_4 \cdot 2H_2O$) indicate continental conditions of formation, rather dry and hot climate. It should be taken into account that rocks in fresh fracture often have a colour or hue that differs from the colour of rocks on the surface. This last circumstance is caused by weathering processes: oxidation, reduction and decomposition of the main rock-forming minerals.

Many features of rocks were identified by eye and to the touch; e.g: Sandy and clayey rocks were identified by touch by rubbing or rolling; ferruginous rocks were identified by the rusty colour of the rock; mica was identified by glistening mica plates; the presence of water-soluble salts by the content of potassium and sodium hydrates in the soils which contributed to the so-called "puffed" separates of bright white in the section, representing a loose, dusty medium.

Soil density was described as follows: sands and sandy loams are classified as loose, compacted (caked), clays, clay loams in terms of ductility, plasticity.

When describing rock structure and texture, the shape, location and size of the constituent minerals are noted.

If there are different grain sizes in the rock, the secondary formations are described as different grains. Grain sizes are determined by means of a pie chart and, with some skill, can be determined by eye.

To determine the filtration coefficient of non-water-saturated soils, i.e. soils in the aeration zone, the water infiltration method is used in a sump. The point of the method is to create a vertical filtration flow through the dry soil down from the bottom of the sump and to measure the cross-sectional area of the flow and the flow rate. Water is absorbed into the dry soil and moves in it not only by downward forces of gravity, but also by capillary forces, which can act in all directions. As the depth of wetting increases, the rate of change of the wetting figure slows down and the flow rate of water for infiltration from the sump stabilises. Therefore, this method only approximated the value of the filtration coefficient, but with an accuracy that is quite acceptable for practical purposes.

Experimental and filtration studies of the filtration coefficient of various genetic types (in our case a Q_{IV} sd and ap Q_{III} gl of Quaternary age) of saline sandy loam and sandy loam soils have shown that the filtration coefficient is determined by a natural combination of their composition, state and nature of structural relationships.

Conducted comprehensive research in the territory revealed that groundwater has a multifaceted influence on the formation of secondary salinity zones in the soil section. In the studied reference areas ground waters occur at depths from 0.5–0.75 to 2.0––2.5 m. Depending on the general salinity the ground waters of the territory have-medium salinity from 5 to 15 g/l; – high salinity from 15 g/l and more. According to the chemical composition, groundwater is mainly chloride-sulphate-sodium-magnesium, and rarely sulphate-potassium-sodium.

An increase in the "critical" groundwater level with increased salinity drastically worsens the soil-reclamation conditions. This in turn is a consequence of intensification of desertification processes and secondary salinization. In addition, groundwater is not discharged in the operational and reclamation periods to the drainage systems. The provision of surface natural runoff to drainage systems is not yet effective enough. On the background of groundwater table increase of Mirzacho'l there is widespread deterioration of reclamation state of soils due to secondary salinization. This is caused by the impact of large canals and irrigation systems contributing to increase of groundwater table. Salinization leads to the formation of gypsum horizons at depths of about 0.75-1.0 to 1.5m (Table 2). It is interesting that private farms (Khavast, Mirzaabad and Bayaut districts) extract the gypsum horizon and set up mini greenhouses at a depth of 1.0 – 1.5m.

The data shown in (table 2) show that the quantitative values of the dense residue are very wide rang-

ing from slightly saline from 0.35 – 0.485 % to highly saline 2.02 – 2.65 %.

The composition of water soluble salts in saline soils is very diverse but in this case these salts are combinations of only three sodium (Na^+), magnesium (Mg^{++}) and calcium (Ca^{++}) cations and four chlorine (Cl^-), sulphate (SO_4^-) and hydrocarbonate (HCO_3^-) anions. It is obvious that the following salts can be formed from them: NaCl, Na_2SO_4, $NaHCO_3$, $MgCl_2$, $MgSO_4$, $Mg(HCO_3)_2$, $CaCl_2$, $CaSO_4$ and $Ca(HCO_3)_2$.

Thorough study of saline soils of the territory of Sirdaryo region allowed to reveal their different sensitivity in relation to water. On the studied territory everywhere depending on texture, structure, content and composition of secondary formed salts (amorphous silica -SiO_2, gypsum - $CaSO_4$. $2H_2O$, etc.) dense saline zone at depth from 0.75 – 1.0 to 1.5m is established (tab. 2). The formation of the zone is probably due to capillary rise of saline groundwater and due to the influence of arid climate a dense zone of secondary salts appears. This zone negatively affects the reclamation state of irrigated area soils. In our case, according to schedule of water discharge change from time, sandy loam, being strong enough in saline state, in the process of leaching in different degree is additionally hydrated, decompacted and sharply deconsolidated, passing from initial, their meliorative condition is improved.

And on sections of settlements and central homesteads of district, the relationship of soils with water leads to leaching of salts, coagulation-crystallization structural connections in sandy loam are weakened and broken that leads to sharp decrease of strength and change of deformation behavior of soils.

Conclusion. Hydrogeological conditions of the study area contribute to the fact that the formed groundwater in the "critical" state, as well as a large amount of surface irrigation water used for irrigation does not have sufficient outflow and is spent mainly on evaporation and transpiration, which creates the preconditions for the development of secondary salinization, especially intensive on the poorly drained areas.

The unsatisfactory meliorative condition of irrigated soils in the prevailing part of the territory is largely due to significant shortcomings in the operation of irrigation, especially collector-drainage network. Technical imperfection of irrigation and drainage systems, irregular and uncontrolled water use causes huge overuse of irrigation canals. The salt balance on non-drained and insufficiently drained lands changes towards salt accumulation, which is associated with evaporation of saline groundwater close to the surface.

Irrigated territories of Mirzacho'l in Sirdaryo region are salinized in different degree with weak, middle, in some places strong salinization. Ameliorative well-being of irrigated lands in irrigated part of investigated territory is unstable, i.e. in these lands groundwater remains moderately (3–10 g/l) and strongly (> 10 g/l) mineralized.

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Section 5. Physics

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SPECIFIC FEATURES OF THE DISPERSION OF MIXED EXCITON-POLARITON MODES IN UNIAXIAL CRYSTALS OF THE CdS TYPE

Abstract. The dispersion of mixed exciton-polariton modes of single-axis crystals of the CdS type has been theoretically considered in the case where the boundary conditions of Boltzmann's kinetic equation do not apply. It is shown that different mechanisms of irradiated states occur.

Keywords: semiconductor, mixed exciton-polariton, transverse-longitudinal splitting, weak polariton effect, anomalous dispersion, inhomogeneous mode.

We consider the energy spectrum of mixed exciton-polaritons in a uniaxial *CdS* crystal near an isolated dipole-active excitons resonance $An = 1$, the optical transition to which is allowed only in the $\vec{E} \perp \vec{C}$ polarization of light (where $\vec{C}$ – is the optical axis of the crystal). A feature of such a spectrum, as is known [1–3], is its strong anisotropy: in an arbitrary direction of wave propagation, different from $\vec{k} \perp \vec{C}$ and $\vec{k} \,//\, \vec{C}$, at a fixed frequency, can be excited two transverse polariton modes (T_1, T_2) and two exciton-polariton modes mixed type (M_1, M_2), the variances of which are schematically shown in (Fig. 1).

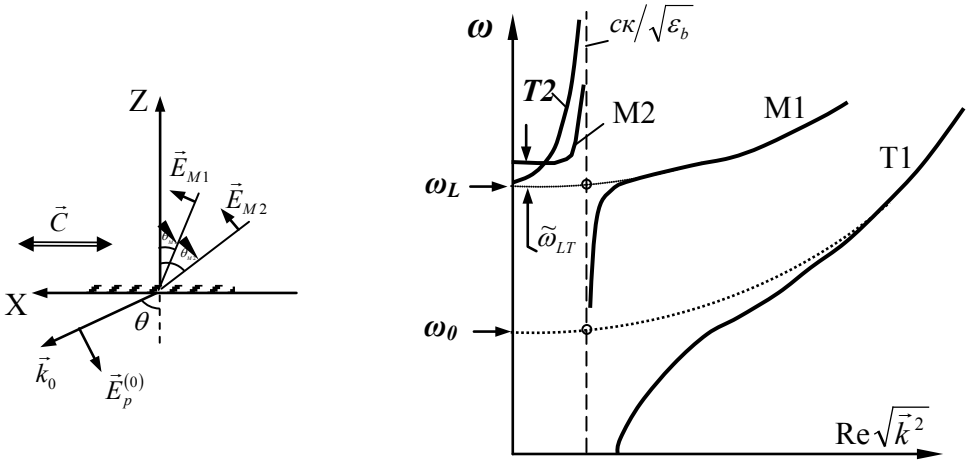

Figure 1. A schematic representation of the dispersion curves of emitting mixed (M_1, M_2) and transverse (T_1, T_2) polariton modes with a fixed direction of radiation into vacuum at an exit angle θ without taking into account the attenuation. Dashed line – photons in the crystal, dotted – transverse and longitudinal excitons. The inset on the left shows the geometry of recording mixed-mode radiation (*CXP* geometry, i.e., *C* // *X* and *p*-polarized radiation is recorded in the *XZ* plane)

The dielectric tensor of interest to us $\varepsilon_{jj}(\omega,\vec{k})$, of a crystal with spatial dispersion (SD) in the coordinate system shown in the inset to (Fig. 1) is characterized by only two components $\varepsilon\perp(\omega,\vec{k})$ and $\varepsilon//(\omega,\vec{k})$, corresponding to the polarizations of light $\vec{E}\perp\vec{C}$ and $\vec{E}//\vec{C}$. Near the resonance frequency ω_0, we can assume that $\varepsilon//(\omega,\vec{k})\approx\varepsilon_b=const$ and the entire dependence of ε_{ij} on ω and $\vec{k}$ is included in $\varepsilon\perp(\omega,\vec{k})$:

$$\varepsilon\perp(\omega,\vec{k})=\varepsilon_{b\perp}\left[1+\frac{\omega_{LT}}{\omega_T(\vec{k})-\omega-i\Gamma/2}\right], \quad (1)$$

where $\omega_T(\vec{k})=\omega_0+\hbar k_x^2/2M_{//}+\hbar\left(\vec{k}^2-k_x^2\right)/2M_{\perp}$, (2)

$\varepsilon_b\perp$ – is the component of the background permittivity tensor for polarization $\vec{E}\perp\vec{C}$, $\omega_{LT}=\omega_L-\omega_0$ – is the longitudinal-transverse splitting, $\hbar\omega_0$ and $\hbar\omega_L$ – are the bottom energies of the bands of transverse and longitudinal excitons, k_x – is the vector projection $\vec{k}$ onto the axis $\vec{C}$, $M_{\perp}^{-1}$ and $M_{//}^{-1}$ – are the components of the inverse effective mass tensor exciton for the directions of propagation $\vec{k}\perp\vec{C}$ and $\vec{k}\perp\vec{C}$.

When writing (1) and further, the inequalities ω_{LT}, $|\omega-\omega_0|<<\omega_0$, which are valid for many semiconductor crystals in the actual spectral region for resonant exciton luminescence, are considered to be satisfied. Taking into account these inequalities and (1) the dispersion equations for the considered modes

$$c^2\vec{k}^2/\omega^2=\varepsilon\perp(\omega,\vec{k}),\ (\text{mods } T_1,T_2)$$

$$\frac{c^2k_x^2}{\omega^2-c^2\left(\vec{k}^2-k_x^2\right)/\varepsilon_{//}\left(\omega,\vec{k}\right)}=\varepsilon_{\perp}\left(\omega,\vec{k}\right)(\text{mods } M_1,M_2)$$

can be represented as dependencies

$$\omega=\omega_{\vec{k}}^{(T)}\equiv\omega_T\left(\vec{k}\right)-\frac{\varepsilon_b\omega_{LT}}{\left(c\vec{k}/\omega_0\right)^2-\varepsilon_b}-i\frac{\Gamma}{2}, \quad (3)$$

$$\omega=\omega_{\vec{k}}^{(M)}\equiv\omega_M\left(\vec{k}\right)-\frac{\varepsilon_b\tilde{\omega}_{LT}}{\left(c\vec{k}/\omega_0\right)^2-\varepsilon_b}-i\frac{\Gamma}{2}, \quad (4)$$

where

$$\omega_M\left(\vec{k}\right)=\omega_T\left(\vec{k}\right)+\omega_{LT},\ \tilde{\omega}_{LT}=\omega_{LT}k_x^2/\varepsilon_bk_0^2 \quad (5)$$

and it is accepted that $\varepsilon_b=\varepsilon_b\perp\approx\varepsilon_{b//}$.

Dispersion curves of the polaritons of the upper branches T_2 and M_2 in (Fig. 1) are described by expressions (3), (4) at $\Gamma\to0$ in the range of values of the wave vector $|\vec{k}|<\sqrt{\varepsilon_b}k_0$, and the curves T_1 and M_1 of the polariton branches – by the same expressions at $|\vec{k}|>\sqrt{\varepsilon_b}k_0$. Expressions (3), (4) with a real frequency ω can be considered in the region of complex vectors (Fig. 2, curves M'_1 and M'_2), even at $\Gamma=0$, corresponding to solutions for surface radiation modes with $Re\ k^2<0$ and $\mathrm{Im}\ k^2=0$ (in this case $(\mathrm{Im}\,\vec{k}\cdot\mathrm{Re}\,\vec{k})=0$), which are excited at the crystal – vacuum interfaces (surface- radiation modes). At $\Gamma=0$, such waves are not associated with energy transfer in the medium and therefore do not directly contribute to external radiation. However, when $\Gamma\neq0$, surface radiation modes are partially included in the energy transfer in the medium (see also Fig. 2), therefore, these modes should be taken into account in the crystal luminescence [4–6].

Areas of dispersion of inhomogeneous surface-radiation waves are actually shown in (Fig. 1) in the area to the left of the point of intersection of curves T_2 and M_2. To the right of this point at $\Gamma=0$, the dispersion curves depict well-defined quantum (polariton) states of the crystal. The point of intersection itself corresponds to zero values of the normal components of the wave vectors of the modes at the interface.

When analyzing the process of light emission taking into account the dissipative damping $\hbar\Gamma$, it is necessary to take into account that, near the frequency ω_L, the values $|\mathrm{Im}\,\vec{k}_\beta|$ for the polaritons of the upper branches becomes comparable with $|\mathrm{Re}\,\vec{k}_\beta|$, and the modes under consideration are, generally speaking, inhomogeneous (branches M'_1 and M'_2 in (Fig. 2) characterize the spatial attenuation of waves). In addition, in the same region of the spectrum, the real parts of the wave vectors of the mixed modes M_1 and M_2 take close values, especially when it comes to propagation directions close to $\vec{k}\perp\vec{C}$, which is clearly demonstrated by the numerically calculated dispersion curves in (Fig. 2). This leads to the fact that the criteria

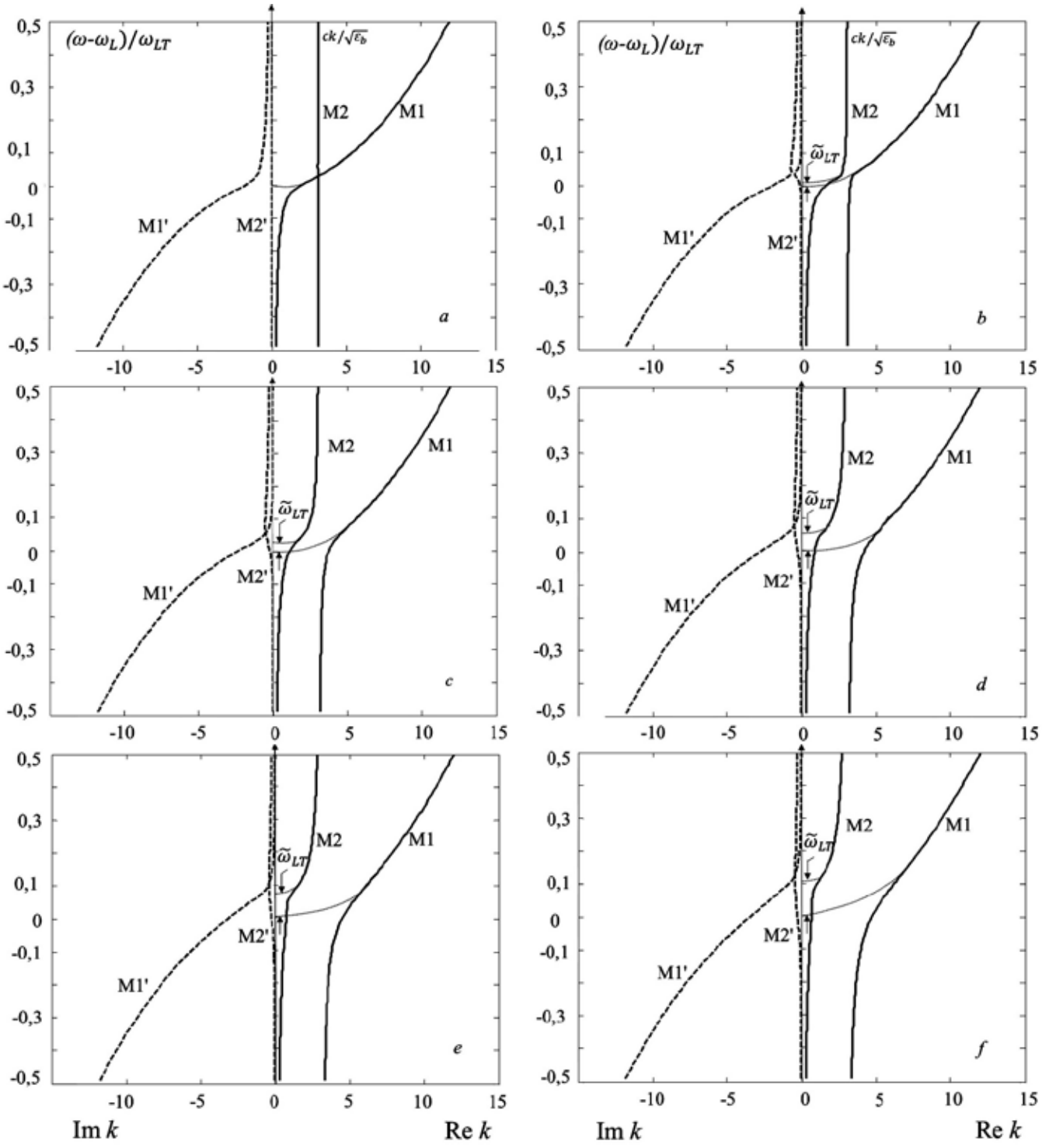

Figure 2. The calculated dispersion curves of mixed exciton-inhomogeneous (a) and exciton-polariton (b-f) modes near in a uniaxial *CdS* crystal, corresponding to the angles of exit from the crystal to vacuum θ = 5º (a), 15º (b), 30º (c), 45º (d), 60º (e) and 80º (f) for the following values of optical parameters: $\hbar\Gamma$ = 0.1 meV, $\hbar\omega_0$ = 2552.4 *meV*, $\hbar\omega_{LT}$ = 2 *meV*, $\varepsilon_{b\perp} = 9.4$, $M_\perp = 0.9\,m0$, $M_\perp = 2.85\,m0$. *At* θ→0, the curves M_1, M'_1 and M_2, M'_2 correspond to longitudinal excitons and transverse photons

$$Re\, k_{\beta} >> a_{\beta} = 2|\mathrm{Im}\, \vec{k}_{\beta}|,$$
$$\left|\vec{k}_{\beta'} - \vec{k}_{\beta''}\right| >> \alpha_{\beta'}, \alpha_{\beta''}$$

(where $\beta' \neq \beta''$, and a_{η} – is the absorption coefficient for the polariton of the dispersion branch $\eta = \beta, \beta', \beta''$) the applicability of the kinetic equation near the frequency ω_L is clearly violated for the polaritons of the T_2, M_2, and M_1 branches.

The left inset to (Fig. 1) shows the geometry of recording the emission of mixed modes M_1 and M_2. In such a geometry of the experiment, it becomes possible to change the "longitudinal-transverse" splitting $\tilde{\omega}_{LT}$ (see (4), (5) and Fig. 2, a–f) by choosing the angle θ of radiation exit into vacuum (i.e., the angle $\tilde{\theta}_{M\beta}$ inside the crystal, $\sin\theta = k_x / k_0$, $\sin\tilde{\theta}_{M\beta} = k_{M\beta x} / k_{M\beta}$, where $\beta = 1,2$).

In this regard, writing the dispersion equation for mixed modes in the form (4) turns out to be the most convenient. In this case, the formal equivalence of the dispersion equations for transverse (3) and mixed (4) waves is achieved. The difference between (4) and (3) lies only in the fact that (4) contains another "resonant" frequency (ω_L instead of ω_0) and another "longitudinal-transverse" splitting ($\tilde{\omega}_{LT}$ instead of ω_{LT}).

It should be added here that under experimental conditions the radiation spectrum is recorded at a fixed value of θ (or $\tilde{\omega}_{LT}$), i.e. with a fixed projection k_x of the wave vector (the same for all emitting modes $k_{0x} \equiv k_{M\beta x}$). This leads to the fact that for the emitting modes the angles $\tilde{\theta}_{M\beta}$ between $\vec{k}_{M\beta}$ and $\vec{C}$ inside the crystal turn out to be variable (depending on the frequency ω) and the dispersion equation (4) determines the states emitting light in the external direction specified by the angle θ (the corresponding solutions of this equation are presented in (Figures 1) and 2 by curves M_1 and M_2). At nonzero values of $\hbar\Gamma$, the angles $\theta_{M\beta}$ become complex. In addition, when the condition $\mathrm{Re}\tilde{\theta}_{M\beta} \geq \mathrm{Re}\theta^*_{M\beta}$ is met, mixed polaritons cannot escape into vacuum due to total internal reflection. When $\hbar\Gamma$ is large enough, the concept of wave intensity inside a radiating medium loses its meaning.

As can be seen from (Fig. 2), even at a moderate value $\hbar\Gamma = 0.1\ meV$ of a mechanical exciton, the dispersion curves M_1, M_1 'and M_2, M_2' for emitting states of mixed modes, depending on the exit angle θ, have a number of features. Firstly, at small angles of radiation exit $\theta \leq 10^0$, the polariton effect is practically absent due to its suppression by damping ($\tilde{\omega}_{LT} << \Gamma$), and we have near the frequency ω_L only inhomogeneous surface-radiation modes. Secondly, starting from the value $\theta \approx 15^0$, a noticeable effective longitudinal-transverse splitting (weak polariton effect) is observed, which increases with increasing angle θ, reaching a value at $\theta = 80^0$. Thirdly, when θ varies in the range 30^0–90^0, we have an intermediate light-exciton interaction with $\hbar\tilde{\omega}_{LT} \approx \hbar\Gamma = 0.1$мэВ. Fourthly, at $\theta \geq 15^0$, mixed polaritons practically do not show anomalous dispersion.

In conclusion, it can be concluded that the mechanism of emission into vacuum of states of mixed exciton-polariton modes in the vicinity of the frequency of the longitudinal exciton strongly depends on the ratio of the values of mechanical damping of the exciton ħΓ and the effective longitudinal-transverse splitting $\hbar\tilde{\omega}_{LT}$, which is uniquely related to the angle of radiation exit in vacuum.

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FEATURE OF TECHNOLOGY FOR OBTAINING BY THERMOVACUUM EVAPORATION METHOD OF FILM n-CdS / p-CdTe HETEROSTRUCTURES WITH PHOTOVOLTAIC AND PHOTORESISTIVE PROPERTIES

Abstract. An original thermal vacuum technology is proposed for obtaining an n-CdS / p-CdTe film heterostructure with anomalous photovoltaic and photoresistive properties. It is shown that when a CdS photoresistor is illuminated by illumination from the region of its own absorption ($hv \geq 2.5\ eV$), the photoelectric properties of the active CdTe layer are significantly modulated. This undoubtedly opens up new applied possibilities of this structure in the field of photonics and film optoelectronics.

Keywords: thermal vacuum technology, *n-CdS/p-CdTe* film heterostructure, anomalous photovoltaic effect, photoresistor, electron micrograph.

Introduction. The anomalous photovoltaic (*APV*) effect is closely related to the structure-sensitive properties of semiconductors and manifests itself in the form of generation of anomalously high photovoltages (*AHPV*, of the order of 10–10^4 *V*/cm), as a rule, in specially co-deposited thin films with a thickness $d \leq 1\ \mu m$ on a dielectric substrate under excitation with light from the spectral region of own and impurity absorption [1–3] (see also the bibliographies shown in them). To date, considerable experimental material has been accumulated in the literature on the study of the *APV* properties of *CdTe* films. Thus, the influence of technological parameters on the change in the polarity of the photo-*EMF*, on the angular, spectral, lux-volt, temperature and other characteristics of thin layers with a stoichiometric composition, and with a disturbed stoichiometry, as well as the possibility of their application in optoelectronics has been studied in detail. However, until now, the processes of *AHPV* formation and destruction depending on specific structural inhomogeneities, such as intrinsic lattice defects, porosity, grain boundaries, the presence of an interface layer between grains and surface levels have not been adequately considered. In [4–6], with the participation of the authors of this article, an original method for the technology of obtaining thin polycrystalline *CdTe* films with the APV property was developed. First, polycrystalline *CdTe* layers were grown on a glass substrate by thermal vacuum co-deposition in a quasi-closed volume, generating *AHPV* at $T = 300\ K$ with a maximum value $V_{AHPV} \sim (600 \div 700) V / cm$ at an intensity of $L \approx 10^4\ lx$ of illumination of an incandescent lamp. Then some of these samples were doped with In impurities by the method of ion implantation, as a result of which their V_{AHPV} dropped to 150–300 *V*/cm, and after thermal treatment of these films in vacuum at $T \approx 600\ K$ for 10–20 min, V_{AHPV} increased strongly and reached values *of* ~ 3000 *V / cm*.

Based on the analysis of literature data [1–12], a tempting idea naturally arises to create an optoelec-

tronic device from a film heterostructure, operating based on the simultaneous use of photoconductivity and *APV* effect in thin polycrystalline films. For this purpose, cadmium chalcogenides are suitable semiconductor materials. Thus, polycrystalline film structures made of cadmium chalcogenides are distinguished by high photosensitivity due to the presence of specific photosensitive local centers and special electronic properties of the grain boundary surface. The photoconductivity of *CdS, CdTe* films, and *APV* properties of an obliquely sprayed *CdTe* film are studied in detail. Recently, there has been a growing interest in the study of the *CdS/CdTe* film heterostructure [7–12] as an efficient solar cell. An integral film heterosystem consisting of a highly sensitive photoresist *CdS* layer on a transparent conducting substrate and a *CdTe* film in the form of an upper sandwich layer with the APV property is of great interest from both the physical and the applied point of view for optoelectronics and photonics. Obviously, under a certain optimal condition of the technology for obtaining such an active *CdS/CdTe* film heterostructure by modulating the *CdS* photoconductivity with the help of additional illumination, it will be possible to carry out targeted optical control of the *APV* parameters of the *CdTe* film, which makes it possible to use it as an optical modulator, phototransistor, photoswitch, memory elements, and etc.

The purpose of this work is to develop an original technology for obtaining a film heterostructure $n-Cds/p-CdTe$ with photoresistive and anomalous photovoltaic properties by the thermal vacuum evaporation method for further study of its electrical, photoelectric, and optical characteristics, as well as the fundamental possibility of manufacturing new optoelectronic devices on its basis, in particular film efficient solar cell.

Technology for obtaining the $n-CdS/p-CdTe$ film heterostructure with anomalous photovoltaic and photoresistive properties. The main task of the technology was that, firstly, in the vacuum on a clean transparent substrate by the method of thermal evaporation, it was necessary to grow a thin polycrystalline layer of $n-CdS(d\approx 0.3-0.5\ \mu m)$ with sufficiently high photoconductivity, and its dark resistance was significantly greater than the resistance of the *CdTe* layer $(d\le 1\ \mu m)$. Second, without changing the degree of vacuum, a *p-CdTe* layer with a noticeable *APV* property should be deposited on the surface of a freshly prepared *n-CdS* layer. Preliminary studies have shown that the known methods of film production [1–6] turned out to be unsuitable for obtaining a sharp $n-CdS/p-CdTe$ heterostructure with the required photoresistive and APV properties. A *CdTe* layer grown in this way on a photoconductive *CdS* layer sometimes did not exhibit noticeable APV properties. It was found that, in this case, the determining varying factors for fabricating an integrated $n-CdS/p-CdTe$ heterosystem with the required photosensitive parameters are the relative resistance, the direction of crystal grain growth, and the thicknesses of the *CdS* and *CdTe* layers.

After repeated careful experiments, it was still possible to form an $n-CdS/p-CdTe$ heterostructure (Fig. 1) with the above properties in a single technological cycle by the method of a kind of sequential deposition of powdered *CdS* and *CdTe* with the brand "for semiconductors" on transparent glass substrates (1) in a vacuum with a residual gas pressure of $p\approx 10^{-2}-10^{-3}$ Pa. First, at a substrate temperature of 573–623 K at an angle $\alpha_1=40-60^0$ relative to the normal to the substrate surface, a *CdS* (2) layer with an area of 20×5 mm^2 and a thickness of 0.2–0.4 μm was deposited through special masks. Then it was sensed by subsequent thermal annealing in vacuum at: T = 773–823 K for 10–15 minutes. The dark resistance of the *CdS* film with electronic conductivity reached values of $R\approx 10^{12}\Omega$, and the multiplicity of changes in resistance under the influence of illumination reached $K\approx 10^2-10^3$ rel. units. According to electron micrographs of the transverse cleavage (Fig. 2) and the surface, the grown *CdS* layer had a columnar structure without pores, the sizes of crystal grains along the substrate surface were found to be of the order of $d_{cr}\approx 0.3-0.5\mu m$.

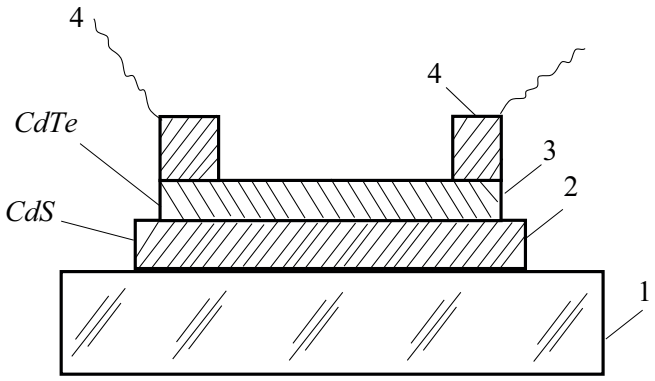

Figure 1. Schematic view of the *n–CdS/p–CdTe* film heterostructure on a transparent glass substrate (1): 2 – CdS photoresistor, 3 –photovoltaic layer CdTe, 4 – current collector ohmic contacts

In the second stage of growing the structure, without destroying the achieved vacuum, a *p-CdTe* layer (3 in Fig. 1) with a thickness $d_{fl} = 0.5 - 0.8\ \mu m$ was deposited directly onto the surface of the photoresistive *n-CdS* film at a rate of $\left|1.5 - 2.0\ \overset{\circ}{A} / c\right.$ at an angle $\alpha = -(50 - 30^0)$ at a substrate temperature T_s = 423–573 *K*. Therefore, according to the conditions of this technology, the directions of the molecular beams of *CdS* and *CdTe* towards the substrate diverged by an angle of $\approx 90^0$. Failure to observe this angle, as well as an increase in T_s and d_{fl}, led to a drop in the maximum value of V_{AHPV} generated by the *CdTe* layer under incandescent lamp illumination. A noticeable generation of photovoltage occurred only in those cases when the dark resistance of the *n-CdS* layer significantly exceeded the light resistance of the *APV* of the *p-CdTe* layer. The upper ohmic contacts (4 in Fig. 1) were formed by deposition of *Ag* in the form of strips through the masks. The active area of the $n - CdS / p - CdTe$ heterostructure was 50–80 mm^2. The stoichiometric composition of the films was achieved by preliminary preparation of the charge with a closed curtain between the substrate and the boat, controlled by the subsequent processing of the X-ray diffraction analysis spectra on a DRON-3 setup.

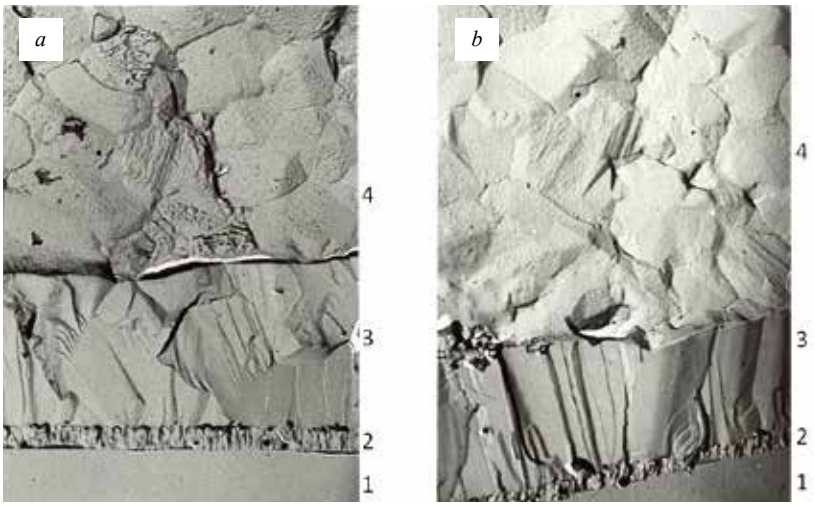

Figure 2. Electron micrographs of a transverse cleavage of the *n–CdS/p–CdTe* film heterostructure from the side of the *CdTe* film surface, obtained at a substrate temperature T_s = 523 *K*(*a*) and T_s = 573 *K*(*b*). 1 – glass substrate, 2 –layer CdS, 3 – layer CdTe, 4 – surface CdTe

The results of electron microscopic studies also show that annealing of the films leads to a change in the crystallite size. From the micrographs of the surface and transverse cleavage of the sensed *CdTe* film in the $n-CdS/p-CdTe$ heterostructure presented in (Fig. 2 a, b), obtained at the substrate temperature $T_s = 523\,K$ and $573\,K$, it can be seen that an increase in T_s leads to an increase in the grain size due to other grains, straightening borders and smoothing the corners of the joint. The value of the grain size for *CdTe* films obtained at $T_s = 523K$ is about $1.0-1.5\ \mu m$, and at $T_s 573K - 1.5-2.0\ \mu m$. It is also seen from the figures that the columnar structure extends in some cases to the entire thickness of the film. However, it should be noted that although the transverse structure visually observed from fractograms is monolithic, in fact, the average value of the coherent scattering regions is much smaller, as established by the results of X-ray structural studies.

In the $n-CdS/p-CdTe$ film heterostructure fabricated according to the technology described above, the main working element is the *p-CdTe* photodetector. At room temperature, with frontal stationary illumination with light with a wavelength in the range of $600 \le \lambda \le 800$ nm and an intensity of $L \approx 10^5 \cdot lx$, it generated a photovoltage $V_{AHPV} \approx 200V$. With an additional rear (i.e. from the side of the substrate) illumination in the spectral region of $\lambda \le 500$ nm already at $L_{il} \approx 1 \cdot lx$, the photovoltage V_{APV} drops noticeably, and at $L_{il} \approx 10^5 \cdot lx$, it practically disappears. Notethatanotherisotypic $n-CdS/p-CdTe{:}In$ heterostructure with indium ohmic contacts possessed a similar *APV* property with photoresistive modulation. In this case, the *APV* layer of *CdTe: In* was obtained by additional heat treatment in the vacuum or in the air with the presence of $CdCl_2$ molecules, which leads to an increase in the crystallite size and an increase in the proportion of cubic modification.

In conclusion, it should be noted that the original technology proposed here allows the obtained $n-CdS/p-CdTe$ heterostructure to operate in the transverse photoconductivity mode, which is important for creating a thin-film optical modulator, phototransistor, photoswitch, etc. In a film solar cell, the $n-CdS/p-CdTe$ heterostructure operates in the longitudinal photoconductivity mode, which requires the inclusion of an additional technological process for manufacturing transparent ohmic contacts, which will be dedicated to separate work.

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EFFECT OF GROUP VII ELEMENTS ON STRAIN SENSITIVITY OF POLYCRYSTALLINE FILMS PBTE, PBS

Abstract. The article describes tensoelectric properties of polycrystalline films based on PbTe and Pb S. It was found that the addition of a dopant increased the current carrier concentrations and mobility. It was shown that by changing the amount of lead chloride introduced into lead sulphide and giving an excess of lead, the concentration of current carriers could be changed within a wide range.

Keywords: polycrystalline film, semiconductor, strain sensitivity, strain, resistivity.

Introduction

In recent years in our country and abroad interest in semiconductor strain gauges has increased sharply. The reason of rapid development of semiconductor strain gauges is new wide possibilities of semiconductor strain gauges application in the field of research of material and constructions strength, in super miniature transducers of mechanical quantities (force, pressure, deformation, moment, etc.) in electric signals [1; 2; 3].

At present time intensive researches of semiconductor strain gauges and devices using them as transducers are carried out. Recent investigations have revealed a number of strain-sensitive semiconductor materials such as silicon, germanium, silicon carbide, gallium phosphide, indium and gallium antimonide and others, promising for their use in strain measurement for a range of temperatures [4]. The pilot production of silicon and germanium strain gauges has been successfully mastered [5].

It is known that the strain factor in semiconductor strain gauges is related to the constants of strain sensitivity, the material from which they are made, which are determined from the effect of strain sensitivity.

Strain-sensitivity effects in *n – PbS* monocrystals were investigated in the low temperature region of 77–300 °*K* [6]. In polycrystalline samples, the high strain effect found in [7] is explained by the appearance of micro *p-n* junctions at the grain boundary. However, in all these works there was no comprehensive study of strain response properties of n- and *p – PbS* with different carrier concentrations in the temperature range above room temperature.

The aim of this work is to investigate the strain-sensitivity effect in *PbTe PbS* and to develop a strain-sensitive material for strain gauges based

from it, which has high strain sensitivity and low enough cost.

Experimental methodology

To measure the effect of strain sensitivity in polycrystalline samples we applied the following methodology. Polycrystalline films were obtained under high vacuum, the methodology given in [8].

The samples ready for measurement were installed in the deforming device, the diagram of which is shown in [8]. Although the installation is not complicated, in order to carry out reliable measurements, great attention should be paid to the following circumstances. The friction losses in the set-up must be as low as possible. The force to deform the sample must produce a uniform mechanical stress field throughout the thickness of the sample and, finally, the setup must be suitable for temperature control.

In terms of electrical measurements, more stringent requirements are placed on the quality of the contacts. They must be ohmic and their properties must not be strain dependent. Since very small voltages have to be measured when examining the strain effect, the measuring equipment must be accurate to at least 0.1 +0.3 μV when measuring the voltage. To create optimum concentration of current carriers in *n-PbS* and *PbTe* we investigated impurities of group VII elements.

Experimental results and discussion

Measurement of strain effect in lead sulfide has some interesting features and can give valuable information about its band structure. In [9] it was shown that the change of effective mass (or strain potential constant) makes an essential contribution to the strain effect. In *n-PbS* with carrier concentration 10^{18} cm^3 a noticable temperature dependence of the shear constant π_{44}, is observed which is close to $\frac{1}{T}$: (T – absolute temperature in K degrees), however, in the whole investigated temperature range (73–293 ^0K) the corresponding effect is very small.

Since we are going to study strain gauge parameters of PbTe *PbS* strain gauges as well, it is useful to consider the strain gauge effect and its defining characteristics.

Large values of strain-sensitivity constants of some materials were the basis for the development of strain gauges, widely used to measure strain.

A technique for introducing lead halide impurities into lead telluride was proposed in [10]. They showed that to change the concentration of electrons in telluride lead in a wide range is possible only by the introduction of "double impurity" such as $Pbcl_2$+*Pb*.

We used this technique for the introduction of impurities in lead sulphide obtained by the synthesis of the starting components. Lead chloride was used as an impurity. Experimental data obtained by us on growing crystals showed that lead sulphide with complex addition of lead chloride and lead metal can be obtained in the form of single crystals only in the case, if for each chlorine atom there is one lead atom. If the excess lead is not complexed with added chlorine, the lead is not incorporated into the lattice and interferes with the growth of monocrystals, and fine crystalline ingots are obtained.

Table 1.

Ser.No.	Number of atoms of introduced lead, cm^{-3}	Number of chlorine atoms cm^{-3}	n cm^{-3}	$\alpha \frac{\mu V}{degree}$	σ $см^{-1}$
1.	1 · 1020	1 · 1020	8.5 · 1019	–44	3800
2.	1 · 1020	2 · 1020	8.2 · 1019	–44	3800
3.	2.5 · 1020	2.5 · 1020	1.8 · 1020	–30	4950
4.	3 · 1020	3 · 1020	1.8 · 1020	–30	4950

If, however, more chlorine atoms than lead atoms are introduced with the admixture, the single crystals grow well, but in this case the excess chlorine atoms do not increase the concentration of current carriers.

As can be seen from (Table 1), samples of crystals No. 1 and No. 2 have practically identical carrier concentrations, electric conductivity and coefficient of thermal emf, although with the same amount of lead in the impurity ($1 \cdot 10^{20}$ cm^{-3}) twice as many chlorine atoms are introduced into crystal No. 2.

Increasing the addition of chlorine and lead above $2.5 \cdot 10^{20}$cm^{-3} does not lead to a further increase in current carrier concentration.

The electron concentration, electrical conductivity and thermal EMF in sample No. 3 (Table 1) and No. 4 are the same, although $2.5 \cdot 10^{20}$cm^{-3} of chlorine and lead were added to the former and $3 \cdot 10^{20}$cm^{-3} to the latter.

Lead increases the concentration of electrons to values corresponding to the concentration of chlorine introduced. By varying the amount of lead chloride introduced and giving an excess of lead, the concentration of current carriers can be varied within a wide range (Fig. 1) (curve 3) shows the dependence of the obtained electron concentration on the number of impurity chlorine and lead atoms introduced. The figure shows that increasing the addition of chlorine and lead beyond $2,5 \cdot 10^{20}$ cm^3 does not lead to a further increase in the electron concentration. The maximum electron concentration we were able to achieve by the introduction of the complex addition of $Pbcl_2 + Pb$ is $n = 1,9 \cdot 10^{20}$cm^{-3}.

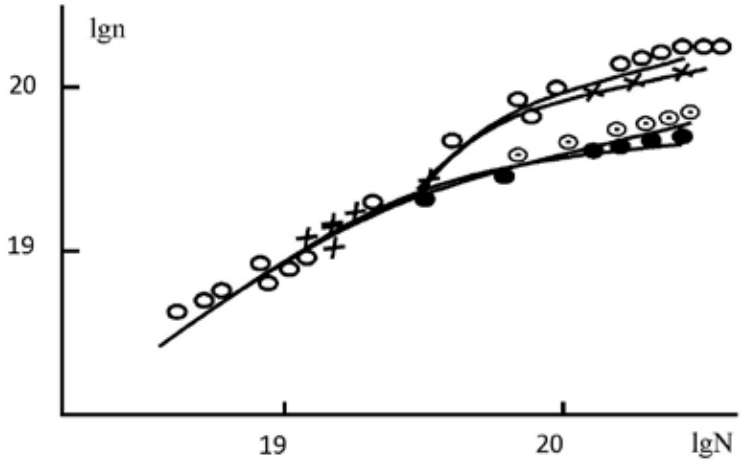

Figure 1. The dependence of Hall effect of conductors in polycrystalline *PbS* and *PbTe* on the amount of injected impurity

The ratio between electron concentration for single crystal samples, calculated from Hall effect measurements and the concentration of introduced impurity chlorine atoms, in average varies in the range 0 : 8 for samples with high concentration of current carriers (above $5 \cdot 10^{19}$cm^{-3}).

The ultimate solubility of lead halides in lead sulphide depends on the mass of the introduced halogen: chlorine has the maximum solubility, iodine has the minimum. It can be assumed that chlorine enters the lattice of lead sulphide more easily than iodine and bromine.

It appears to be that the ionic radii of chlorine and sulfur (1.05 and 1.03) are very close, and bromine and iodine have larger ionic radii than chlorine (1.6 and 1.4 for bromine and iodine, respectively).

Since chlorine allows deeper doping of lead sulfide than other halogens, we studied strain-gauge properties of PbS samples doped with $Pbcl_2$+Pb in a wide concentration range most completely.

Doped ($Pbcl_2$+Pb) amples have higher absolute values of electron mobility compared to samples doped with bromine and iodine. Maximum carrier mobilities from their concentration in polycrystalline *PbS* $PbCl_2$ + Pb, oped samples are obtained for samples with electron concentration in the range of 3.1018 1.2.10^{19}cm^{-3}. With a further increase in carrier concentration the mobility of the samples decreases steeply.

Conclusion

On the basis of the results obtained we can say that with the addition of an alloy of group VII elements we can see a change in the value of the tensivity factor and electron mobility and this is explained by the penetration into the depth of the sample of chlorine and other halogens. Chlorine penetrates the lattice of lead sulphide more easily than iodine and bromine.

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COEFFICIENT OF INTERBAND TWO-PHOTON ABSORPTION OF LIGHT AND ITS LINEAR-CIRCULAR DICHROISM

Abstract. Expressions are obtained for the spectral dependence of the coefficient of the interband two-photon absorption of light in narrow-gap semiconductors in the Kane model.

The dependences of the partial coefficient of interband two photon absorption of light are analyzed, which differ from each other by the types of optical transitions, depending on the degree of polarization of the light, and carried out a quantitative analysis of the linear-circular dichroism factor of two photon absorption of light and it is shown that the main contribution to the linear-circular dichroism is made by optical transitions from the subband of light holes to the conduction band.

Keywords: initial state, virtual state, interband two photon absorption of light, Kane's model, optical transitions, semiconductor.

Nonlinear multiphoton absorption of polarized light caused by optical transitions between subband light and heavy holes in the valence band of a semiconductor, and its linear-circular dichroism are considered in [1–8]. However, the question of the linear-circular dichroism of the interband two-photon absorption of light, as well as the spectral and temperature dependences of the absorption coefficient of light in narrow-gap semiconductors, remains open, to which this work is devoted.

Below, we obtain an expression for the spectral dependence of the coefficient of interband two-photon absorption of light in narrow-gap semiconductors in the Kane model. In further calculations, we use the calculation method proposed in [5–8]).

Note that the coefficient of multiphoton absorption of light consists of partial components, which by their nature depend on the zone in which the current carriers are located both in the initial and in the virtual state.

In further (intermediate) calculations, instead of $\sum_{\vec{k}}\left(f_L - f_{cond}\right)\delta\left(E_{cond} - E_L - 2\hbar\omega\right)F(k)$, we use the expression $\frac{1}{\left(2\pi\right)^3}F(k_{c,L})k_{c,L}^2$, where $k_{c,L}$ is the wave vector determined from the energy conservation law: $E_c - E_L - 2\hbar\omega = 0$. In particular, in the spherical approximation in the energy spectrum of current carriers, i.e. in the case of $E_L = E_L^{(0)} + \frac{\hbar^2 k^2}{2m_L}$, the wave vector of current carriers participating in interband

optical transitions is defined as $k_{c,L}^2 = \frac{2\mu_+^{(c,L)}}{\hbar^2}\left(2\hbar\omega - E_g\right)$, where $\mu_+^{(c,lh)} = \frac{m_c m_L}{m_c + m_L}$ is the reduced effective mass, m_L is the effective mass of current carriers in the zone (or subband) with the number L. In particular, for $L = c$ for the conduction band, then $E_L^{(0)} = E_g$, $L = lh(hh)$ for the subband of light (heavy) holes in the valence band $E_L^{(0)} = 0$.

Note that the frequency dependence of the denominators in the matrix elements is determined by the energy conservation law, the type of optical transitions and virtual states under consideration. For example, if the virtual states are in the valence band, and the initial one is in the subband of heavy holes, then the denominator in the matrix element of this transition is determined by the expression $E_{hh} - E_{lh} - \hbar\omega = \frac{m_c}{m_{hh}}\frac{m_{hh} - m_{lh}}{m_c + m_{lh}}\left(2\hbar\omega - E_g\right) + \hbar\omega$, if this transition occurs from the subband of light holes, then the denominator in the matrix element of this transition is determined as $E_{lh} - E_{hh} - \hbar\omega = \frac{m_c}{m_{lh}}\frac{m_{hh} - m_{lh}}{m_{hh} + m_c}\left(2\hbar\omega - E_g\right)$, where the ratios $A - B = \frac{\hbar^2}{2m_{hh}}$, $A + B = \frac{\hbar^2}{2m_{lh}}$ are taken into account.

In what follows, we will calculate the partial two-photon absorption coefficients, which differ from each other from the types of optical transitions, i.e. from the initial, intermediate and virtual states:

a) the initial state is in the heavy-hole subband of the valence band. In this case, the coefficient between the two-photon zone light absorption is determined by the expression

$$K_{C,\pm1/2;V,\pm3/2}^{(2)} = \frac{8\pi^2}{\hbar}\hbar\omega\ \frac{1}{I}\frac{\left(\mu_+^{(c,hh)}\right)^{3/2}}{(2\pi)^3\hbar^3}\sqrt{2}\sqrt{2\hbar\omega - E_g}\,f_{hh}\times \times\left[\frac{m_c}{m_c + m_{hh}}\left(2\hbar\omega - E_g\right)\right]\left[\left(\frac{eA_0}{c\hbar}\right)^2 P_{cV}k\right]^2 \Re_{C,\pm1/2;V,\pm3/2}^{(2)}, \quad (1)$$

here $\Xi_{C,L}^{(2)} = \sum_{\vec{k}}\left(f_L - f_{cond}\right)\delta\left(E_{cond} - E_L - 2\hbar\omega\right)$, P_{cV} is the Kane parameter [9], $e'_{\pm} = e'_x \pm ie'_y$ and here (and further) it was assumed that $Oz \| \vec{k}$, symbol $\langle ... \rangle$ means averaging over the solid angles of the wave vector of current carriers,

$$\Re_{C,\pm1/2;V,\pm3/2}^{(2)} = \frac{1}{4\pi}\left\langle\left|\frac{2(A-B)e'_+e_{z'}}{\left(-\hbar\omega\right)} + \frac{e'^2_-B}{\left(E_{lh} - E_{hh} - \hbar\omega\right)}\right|^2\right\rangle + \left\langle\left|\sqrt{2}B\frac{e'_ze'_-}{\left(E_{lh} - E_{hh} - \hbar\omega\right)}\right|^2\right\rangle = = \frac{B^2}{15\left(\hbar\omega\right)^2}\left[\left(2\frac{A-B}{B}\right)^2 a_{C,\pm1/2;V,\pm3/2}^{(2)} + \left(\frac{\hbar\omega}{E_{lh} - E_{hh} - \hbar\omega}\right)^2 b_{C,\pm1/2;V,\pm3/2}^{(2)}\right], \quad (2)$$

which in the spherical approximation in the energy spectrum of current carriers takes the form

$$\Re_{C,\pm1/2;V,\pm3/2}^{(2,sfer)} = \frac{B^2}{15\left(\hbar\omega\right)^2}\left[\frac{16m_{lh}^2}{\left(m_{hh} - m_{lh}\right)^2}a_{C,\pm1/2;V,\pm3/2}^{(2)} + \left(\frac{\hbar\omega\left(m_{hh} + m_c\right)m_{lh}}{m_c\left(m_{hh} - m_{lh}\right)\left(2\hbar\omega - E_g\right) - \hbar\omega}\right)^2 b_{C,\pm1/2;V,\pm3/2}^{(2)}\right] \quad (3)$$

where for linearly (circularly) – polarized light $a_{C,\pm1/2;V,\pm3/2}^{(2)} = 2$ ($a_{C,\pm1/2;V,\pm3/2}^{(2)} = 9$), $a_{C,\pm1/2;V,\pm3/2}^{(2)} = 3$ ($b_{C,\pm1/2;V,\pm3/2}^{(2)} = 13$), $b_{C,\pm1/2;V,\pm3/2}^{(2)} = 3$ ($b_{C,\pm1/2;V,\pm3/2}^{(2)} = 13$). In this case, the coefficient of linear-circular dichroism for these optical transitions depends on the frequency of light and band parameters;

b) if the initial state is in the subband of light holes, then we get

$$K_{C,\pm1/2;V,\pm1/2}^{(2)} = \frac{32\pi^2}{\hbar}\hbar\omega\frac{1}{I}\Xi_{c,lh}\left(\frac{eA_0}{c\hbar}\right)^2\frac{P_{cV}^2k^2}{3}\Re_{C,\pm1/2;V,\pm1/2}^{(2)} \quad (4)$$

here

$$\Re_{C,\pm1/2;V,\pm1/2}^{(2)} = \frac{1}{4\pi}\left(\left\langle\left|\frac{3Be'^2_+}{\left(E_{hh} - E_{lh} - \hbar\omega\right)} + 2\frac{(A+B)e'_-e_{z'}}{\left(-\hbar\omega\right)}\right|^2\right\rangle + \left\langle\left|2\sqrt{2}(A+B)\frac{e'^2_z}{\left(-\hbar\omega\right)}\right|^2\right\rangle\right) =$$

$$= \frac{B^2}{15(\hbar\omega)^2}\left[4\left(\frac{A+B}{B}\right)^2+\left(\frac{3\hbar\omega}{E_{hh}-E_{lh}-\hbar\omega}\right)^2\right]a^{(2)}_{C,\pm1/2;V,\pm1/2}, \quad (5)$$

which in the spherical approximation in the energy spectrum of current carriers takes the form

$$\Re^{(2,sfer)}_{C,\pm1/2;V,\pm1/2} = \frac{\hbar^4(m_{hh}-m_{lh})^2}{15(4\hbar\omega m_{hh}m_{lh})^2}\left[4\left(\frac{2m_{hh}}{m_{hh}-m_{lh}}\right)^2+\left(\frac{3\hbar\omega}{\frac{m_c}{m_{hh}}\frac{m_{hh}-m_{lh}}{m_c+m_{lh}}(2\hbar\omega-E_g)+\hbar\omega}\right)^2\right]a^{(2)}_{C,\pm1/2;V,\pm1/2}, \quad (6)$$

where for linearly (circularly) – polarized light $a^{(2)}_{C,\pm1/2;V,\pm1/2}=8$ ($a^{(2)}_{C,\pm1/2;V,\pm1/2}=7$), the linear-circular dichroism coefficient for these optical transitions does not depend on the light frequency and is equal to 8/7.

Now let the virtual states of the current carriers be in the conduction band. Then:

$$K^{(2)}_{C,\pm1/2;V,\pm3/2} = \frac{2\pi}{\hbar}2\hbar\omega\frac{1}{I}\Xi_{c,hh}\left(\frac{eA_0}{c\hbar}\right)^4\left(\frac{P_{cV}k}{\hbar\omega}\frac{\hbar^2}{m_c}\right)^2\frac{1}{15}a^{(2)}_{C,\pm1/2;V,\pm3/2}, \quad (7)$$

where for linearly (circularly) – polarized light $a^{(2)}_{C,\pm1/2;V,\pm3/2}=2$ ($a^{(2)}_{C,\pm1/2;V,\pm3/2}=3$), the coefficient of linear-circular dichroism for these optical transitions is constant and equal to 2/3;

a) if the initial state is in the subband of heavy holes of the valence band, then, without taking into account the contribution of the effect of coherent saturation in $K^{(2)}_{C,\pm1/2;V,\pm3/2}$, we have

b) if the initial state is in the subband of light holes of the valence band, then

$$K^{(2)}_{C,\pm1/2;V,\pm1/2} = \frac{2\pi}{\hbar}2\hbar\omega\frac{1}{I}\Xi_{c,lh}\left(\frac{eA_0}{c\hbar}\right)^4\left(\frac{P_{cV}k}{\hbar\omega}\frac{\hbar^2}{m_c}\right)^2\Im^{(2)}_{C,\pm1/2;V,\pm1/2}, \quad (8)$$

$$\Im^{(2)}_{C,\pm1/2;V,\pm1/2} = \left\langle\frac{\left|e'_z e'_+\right|^2}{\sqrt{1+4\frac{\alpha_\omega}{\hbar^2\omega^2}\left[\frac{1}{\sqrt{3}}\left(\frac{eA_0}{c\hbar}\right)^2\frac{1}{\hbar\omega}\frac{\hbar^2}{m_c}P_{cV}k\right]^2\left|e'_z e'_+\right|^2}}\right\rangle + \left\langle\frac{\left|\sqrt{2}e'^2_z\right|^2}{\sqrt{1+4\frac{\alpha_\omega}{\hbar^2\omega^2}\left[\frac{1}{\sqrt{3}}\left(\frac{eA_0}{c\hbar}\right)^2\frac{1}{\hbar\omega}\frac{\hbar^2}{m_c}P_{cV}k\right]^2\left|\sqrt{2}e'^2_z\right|^2}}\right\rangle, \quad (9)$$

from which, without taking into account the contribution of the effect of coherent saturation in $K^{(2)}_{C,\pm1/2;V,\pm1/2}$, we obtain that for light with linear (circular) polarization $\Im^{(2)}_{C,\pm1/2;V,\pm1/2}=8/15$ $\left(\Im^{(2)}_{C,\pm1/2;V,\pm1/2}=7/15\right)$, and the coefficient of linear-circular dichroism is 7/8.

Now let the virtual states of charge carriers be in the extended spin-orbital zone:

a) if the initial state is in the subband of heavy holes of the valence band, then we get that

$$K^{(2)}_{C,\pm1/2;V,\pm3/2} = \frac{2\pi}{\hbar}2\hbar\omega\frac{1}{I}\Xi_{c,hh}\left[\left(\frac{eA_0}{c\hbar}\right)^2\frac{1}{\sqrt{2}}\frac{\mathrm{B}kP_{cV}}{(E_\Delta-E_{hh}-\hbar\omega)}\right]^2\Phi^{(2)}_{C,\pm1/2;V,\pm3/2}, \quad (10)$$

here

$$\Phi^{(2)}_{C,\pm1/2;V,\pm3/2}=\left\langle\frac{\left|e'_z e'_-\right|^2}{\sqrt{1+4\frac{\alpha_\omega}{\hbar^2\omega^2}\left[\left(\frac{eA_0}{c\hbar}\right)^2\frac{1}{\sqrt{2}}\frac{\mathrm{B}kP_{cV}}{\left(E_\Delta-E_{hh}-\hbar\omega\right)}\right]^2\left|e'_z e'_-\right|^2}}\right\rangle+$$
$$+\left\langle\frac{\left|e'^{\,2}_\perp\right|^2}{\sqrt{1+4\frac{\alpha_\omega}{\hbar^2\omega^2}\left[\left(\frac{eA_0}{c\hbar}\right)^2\frac{1}{\sqrt{2}}\frac{\mathrm{B}kP_{cV}}{\left(E_\Delta-E_{hh}-\hbar\omega\right)}\right]^2\left|e'^{\,2}_\perp\right|^2}}\right\rangle, \quad (11)$$

from which, without taking into account the contribution of the effect of coherent saturation in $K^{(2)}_{C,\pm1/2;V,\pm3/2}$, we obtain that for light with linear (circular) polarization, the coefficient of linear-circular dichroism is 2/3;

b) if the initial state is in the subband of light holes of the valence band, then the coefficient of two photon absorption of polarized light is determined as

$$K^{(2)}_{C,\pm1/2;V,\pm1/2}=\frac{2\pi}{\hbar}2\hbar\omega\frac{1}{I}\Xi_{c,lh}\times\left[\left(\frac{eA_0}{c\hbar}\right)^2\frac{1}{\sqrt{6}}\frac{BkP_{cV}}{\left(E_\Delta-E_{hh}-\hbar\omega\right)}\right]^2\Phi^{(2)}_{C,\pm1/2;V,\pm1/2}, \quad (12)$$

$$\Phi^{(2)}_{C,\pm1/2;V,\pm1/2}=\left\langle\frac{\left|3e'^{\,2}_\pm+4e^2_{z'}\right|^2}{\sqrt{1+4\frac{\alpha_\omega}{\hbar^2\omega^2}\left[\left(\frac{eA_0}{c\hbar}\right)^2\frac{1}{\sqrt{6}}\frac{BkP_{cV}}{\left(E_\Delta-E_{hh}-\hbar\omega\right)}\right]^2\left|3e'^{\,2}_\pm+4e^2_{z'}\right|^2}}\right\rangle+ \quad (13)$$
$$+\left\langle\frac{\left|e'_z e'_+\right|^2}{\sqrt{1+4\frac{\alpha_\omega}{\hbar^2\omega^2}\left[\frac{1}{\sqrt{3}}\left(\frac{eA_0}{c\hbar}\right)^2\frac{1}{\hbar\omega}\frac{\hbar^2}{m_c}P_{cV}k\right]^2\left|e'_z e'_+\right|^2}}\right\rangle,$$

from which, without taking into account the contribution of the effect of coherent saturation in $K^{(2)}_{C,\pm1/2;V,\pm3/2}$, we obtain that for light with linear (circular) polarization, the coefficient of linear-circular dichroism is 3/2.

Note that the total coefficient of two-photon light absorption is determined by the sum of the above-mentioned partial coefficients of two-photon light absorption.

Thus, the main contribution to the linear-circular dichroism of two-photon absorption of light comes from optical transitions proceeding from the subband of light holes to the conduction band.

Next, we calculate the spectral dependence of the total coefficient of two-photon absorption of light in the Kane model and use the following expressions for the energy spectra of current carriers in the parabolic approximation

$$E_c\left(\vec{k}\right)=E_g+\frac{\hbar^2k^2}{2m_0}+\frac{k^2P^2_{cV}\left(E_g+\frac{2}{3}\Delta\right)}{E_g\left(E_g+\Delta\right)},$$
$$E_{hh}\left(\vec{k}\right)=\frac{\hbar^2k^2}{2m_0},\ E_{lh}\left(\vec{k}\right)=\frac{\hbar^2k^2}{2m_0}-\frac{2k^2P^2_{cV}}{3E_g},$$
$$E_{so}\left(\vec{k}\right)=-\Delta+\frac{\hbar^2k^2}{2m_0}-\frac{k^2P^2_{cV}}{3\left(\Delta+E_g\right)}, \quad (14)$$

$E_g\left(\Delta\right)$ is the width of the forbidden (spin-orbital) band, P_{cV} is the Kane parameter [9]. Then the spectral dependence of the coefficient of two-photon absorption of linearly polarized light in the region of small values of the wave vector of current carriers will be written as

$$K_{c,\mathrm{V}}^{(2)}(\omega) = K_{c,\mathrm{V}}^{(0)} \Im_{c,\mathrm{V}}^{(2,l)}\left(\frac{2\hbar\omega}{E_g}\right), \qquad (15)$$

here $K_{c,\mathrm{V}}^{(0)} = \dfrac{4\pi e^2 P_{cV}}{\hbar c^2 n_\omega^2 E_g^3}$, $E_g \ll E_{so}$ for the case $l = 1$, $E_g \gg E_{so}$ for the case $l = 2$,

$$\Im_{c,\mathrm{V}}^{(2,1)}(\xi) == \frac{4\xi^{3/2}}{15\sqrt{6}(\xi+1)^3}\left[480\frac{(\xi+1)^{1/2}}{(3\xi+1)^2} + \frac{(\xi+2)^{3/2}}{(\xi+1)^5}\left(9(\xi+1)^4 + 40(\xi+1)^2 + 96\right)\right], \qquad (16)$$

$$\Im_{c,\mathrm{V}}^{(2,2)}(\xi) == \frac{32\xi^{3/2}}{15(\xi+1)^3}\left\{36\frac{(\xi+1)^{1/2}}{(3\xi+1)^2} + \frac{(\xi+2)^{3/2}}{(\xi+1)^5}\left((\xi+1)^4 + 2(\xi+1)^2 + 6\right)\right\}, \qquad (17)$$

where $\xi = \left(2\cdot\hbar\omega - E_g\right)/E_g$. Calculations show that under illumination of InSb with linearly polarized light, both in the case of $E_g \ll E_{SO}$ and $E_g \gg E_{SO}$, the spectral dependence of $K_{c,\mathrm{V}}^{(2)}(\omega)$ increases with increasing frequency, reaches a maximum, and then decreases. This is due to the complexity of the band structure of the semiconductor in the Kane model, which is reflected in the matrix elements and in the energy spectra. This gives rise to complex dependences of the density of states and energies of both the final and initial states of photoexcited current carriers on the frequency of light. If we restrict ourselves to the spherical approximation in the energy spectrum, then $K_{c,\mathrm{V}}^{(2)}(\omega)$ will increase with increasing frequency under the condition $E_g \ll E_{SO}$.

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SINGLE-PHOTON LINEAR-CIRCULAR DICHROISM IN NARROW-GAP CRYSTALS. TAKING INTO ACCOUNT THE EFFECT OF COHERENT SATURATION

Abstract. In the paper, from a microscopic point of view, the linear-circular dichroism of one-photon between band absorption of light in the Kane approximation in narrow-gap crystals is investigated.

The linear-circular dichroism of one-photon absorption of polarized light is calculated taking into account the effect of coherent saturation in photoexcited charge carriers.

Keywords:

The matrix elements of one-photon interband optical transitions and the corresponding linear-circular dichroism and the spectral dependence of the light absorption coefficient are calculated.

Currently, in practice, nonlinear optical phenomena occurring in crystals are widely used [1–3]. In this context, the research of nonlinear absorption of polarized light is actual both from the physical point of view and from the point of view of application.

Note that in the case of one-photon absorption of light, optical transitions do not occur through virtual states at all. Therefore, linear-circular dichroism is not observed in single-photon optical transitions in crystals with cubic and tetrahedral symmetry.

One- and multiphoton absorption of polarized light in crystals, caused by optical transitions between the subbands of the valence band, was researched in [4–11], where the contribution to the interband one-photon absorption of light from the effect of coherent saturation [6; 7], caused by the finite lifetime of photoexcited carriers current in the final state, to which this work is devoted.

If we take into account the contribution to the absorption of the effect of coherent saturation, then the coefficient of two-photon absorption of light will be written in the form

$$K^{(1)}(\omega,T)=\frac{4\pi}{\hbar}\hbar\omega\frac{1}{I}\sum_{k;s=\pm1/2,m=\pm1/2,\pm3/2}(f_{hh}-f_c)\delta(E_{hh}-E_c+\hbar\omega)\left\langle\frac{\left|M^{(1)}_{C,s;V,m}(\vec{k})\right|^2}{\sqrt{1+4\frac{\alpha_\omega}{\hbar^2\omega^2}\left|M^{(1)}_{C,s;V,m}(\vec{k})\right|^2}}\right\rangle, \quad (1)$$

where $f_{hh}(f_c)$ and $E_{hh}(E_c)$ – distribution functions and energy spectra of holes (electrons), respectively, sign $\langle ... \rangle$ means averaging over the solid angles of the wave vectors of current carriers, the rest are generally known values.

It can be seen from (10) that the coefficient of interband one-photon absorption of light $K^{(1)}(\omega,T)$ consists of partial components that differ from each other in the type of optical transitions. In particular, for an optical transition of the type $|V,\pm 3/2\rangle \to |C,\pm 1/2\rangle$ it is expressed as

$$K^{(1)}(\omega,T)=\frac{16e^2}{3c\omega\ \hbar^2 n_\omega}\mu_{c,L}^{(+)}\cdot k_{c,L}^{(\omega)}\cdot P^2\cdot F(\beta,1,\omega)\cdot \Im(\omega)\cdot\left[f_{hh}(E_{hh}k_{c,L}^{(\omega)})-f_c\left(E_c k_{c,L}^{(\omega)}\right)\right] \quad (2)$$

here

$$F(\beta,1,\omega)=\left[1-\exp(\beta\hbar\omega)\right]\exp\left[\beta\left(\mu-E_{hh}(k_{c,L=hh}^{(\omega)})\right)\right],$$

$$\zeta_\omega=4\frac{\alpha_\omega}{\hbar^2\omega^2}\left(\frac{eA_0}{c\hbar}\right)^2 P_{CV}^2,$$

$$k_{c,L}^2=\frac{2\mu_{c,L}^{(\omega)}}{\hbar^2}\left(\hbar\omega-E_g\right),\qquad \frac{1}{\mu_{c,L}^{(+)}}=\left(\frac{1}{m_c}+\frac{1}{m_L}\right),$$

$$\beta^{-1}=k_BT,\ \Im(\omega)=\left\langle\frac{|e'_\pm|^2}{\sqrt{1+\zeta_\omega|e'_\pm|^2}}\right\rangle.$$

Also, it can be seen from (13) that the linear-circular dichroism of one-photon absorption of light is determined by the quantity $\Im(\omega)$, which depends on the frequency and degree of polarization of light, the band parameters of the sample, which arises due to the complexity of the band structure of the crystal.

Note that if we disregard the effect of coherent saturation ($\zeta_\omega=0$), then $K^{(1)}(\omega,T)$ does not depend on the quantities mentioned above, in particular on the degree of polarization of light, i.e. is a constant number: $\Im(\zeta_\omega=0)=\frac{4}{3}$, i.e. in this case, one-photon linear-circular dichroism is not observed. However, if we take into account the effect of coherent saturation, then $\zeta_\omega\neq 0$, which means that in this case one-photon linear-circular dichroism arises. This is due to the fact that for linearly polarized light

$$\Im_{lin}=\int_{-1}^{+1}d\mu\frac{1-\mu^2}{\sqrt{1+\zeta_\omega\left(1-\mu^2\right)}}; \quad (3)$$

for circularly polarized light

$$\Im_{circ}=\int_{-1}^{+1}d\mu'\frac{\frac{1}{2}\left(1+\mu'^2\right)\mp P_{circ}\mu'}{\sqrt{1+\zeta_\omega\left[\frac{1}{2}\left(1+\mu'^2\right)\mp P_{circ}\mu'\right]}}, \quad (4)$$

where P_{circ} – degree of circular polarization of light, sign "±" refers to $\sigma_\pm$ of the polarized light $\phi(\phi')$ – angle between vectors $\vec{e}$ and $\vec{q}$, $\mu'=\cos\phi'$, $\mu=\cos\phi$, $\vec{q}$ is the wave vector of a photon.

For example, in the case $P_{circ}=1$ for linearly polarized light

$$\Im_{lin}=\zeta_\omega^{-5/2}\left\{\zeta_\omega^{3/2}+\zeta_\omega^2\cdot\arcsin\left(\frac{\zeta_\omega}{1+\zeta_\omega}\right)^{1/2}-\zeta_\omega\cdot\arcsin\left(\frac{\zeta_\omega}{1+\zeta_\omega}\right)^{1/2}\right\}, \quad (5)$$

for circularly polarized light

$$\Im_{circ}=\frac{2\left(\zeta_\omega^{3/2}\sqrt{\zeta_\omega+1}-\zeta_\omega\arcsin\sqrt{\zeta_\omega}\right)}{\zeta_\omega^{5/2}}. \quad (6)$$

Figure 1 shows the graphs of the functions $\Im_{lin}(\zeta_\omega)$ and $\Im_{circ}(\zeta_\omega)$ depending on the value $\zeta_\omega\propto\left(\frac{eA_0}{c\hbar}\right)^2\propto I$. As can be seen from (Fig. 1), with increasing light intensity coefficient of interband single-photon linear-circular dichroism $\eta=\Im_{lin}(\zeta_\omega)/\Im_{circ}(\zeta_\omega)$ increases and tends to saturation, i.e. at very high intensity values ($\zeta_\omega>>1$) does not depend on the intensity and $\eta\approx 1.1$. For quantitative calculations, we used the data from [14].

Thus, one-photon linear-circular dichroism due to interband optical transitions in a narrow-gap crystal arises when the effect of coherent saturation is taken into account. However, in the case of interband multiphoton absorption of polarized light, linear-circular dichroism is observed regardless of whether the effect of coherent saturation is taken into account or not. This issue requires separate consideration.

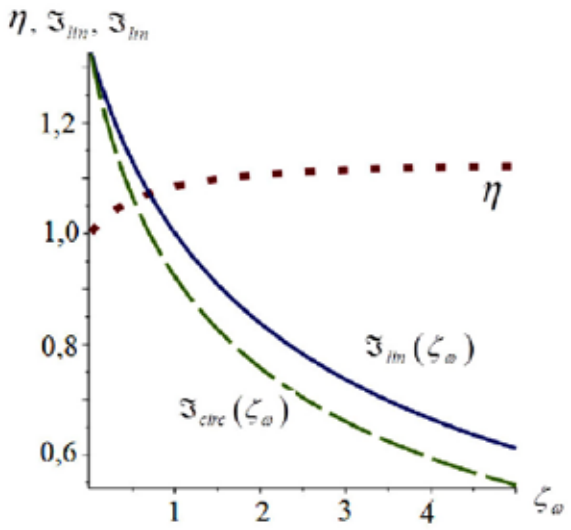

Figure 1. Function graphs $\Im_{lin}$, $\Im_{circ}$ and η factor of linear-circular dichroism depending on $\zeta_\omega \propto I$ (on light intensity) in Kane approximation in a narrow-gap crystal

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According to [12; 13], the effective carrier Hamiltonian for the three-band Kane model is expressed as follows:

$$H^{eff}(k_z) = \begin{pmatrix} E_c & -i\sqrt{2/3}Pk_z & -iPk_z/\sqrt{3} \\ i\sqrt{2/3}Pk_z & E_v & 0 \\ iPk_z/\sqrt{3} & 0 & E_v - \Delta \end{pmatrix}, \text{(Ap.1)}$$

whose eigenvalue is determined by the equation:

$$(E_c - E)(E_v - E)(E_v - \Delta - E) - \\ -P^2k^2(E_v - E - 2\Delta/3) = 0, \quad \text{(Ap.2)}$$

where $k_z = k = |\vec{k}|$. This equation has three solutions: $E_{el}(k), E_{lh}(k), E_{so}(k)$. From (Ap. 2) we have $k^2(E) = \frac{1}{P^2}\frac{(E_c - E)(E_v - E)(E_v - E + \Delta)}{(E - E_v + 2\Delta/3)}$ and with the help of the last dependence the graph of $k^2(E)$ is built in (Fig. 2) shows that all energy bands are nonparabolic, and the quadratic dependence of the energy on $k = |\vec{k}|$ observed in the region of small values of the wave vector.

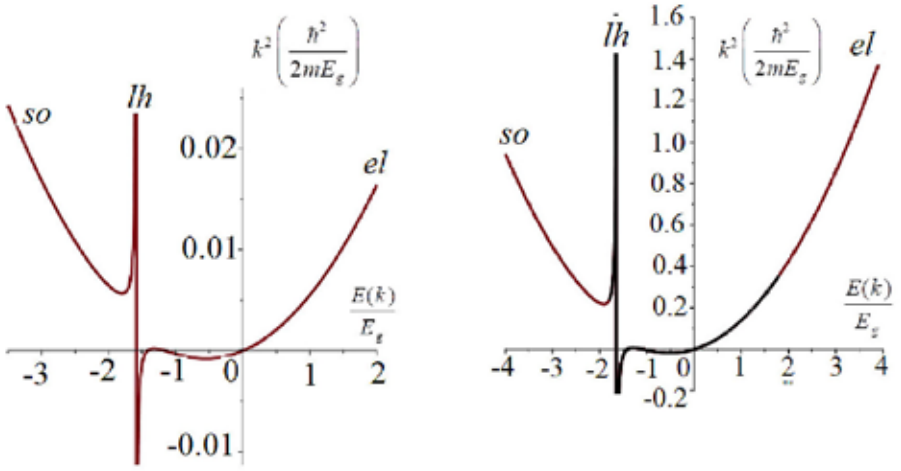

Figure 2. Energy spectra of charge carriers in GaAs ($\Delta/E_g = 2{,}4$ $E_g = 1{,}42\ eV$, $m_{el} = 0{,}067 \cdot m_0$) and InSb ($\Delta/E_g = 3{,}4$ $E_g = 0{,}18\ eV$, $m_{el} = 0{,}013 \cdot m_0$) in the three-zone isotropic Kane model, where the range of negative values of the quantity $k^2(E)$ correspond to the band gap and the spin-orbit splitting band

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Section 6. Philology and linguistics

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EXTRA-TERRESTRIAL INSPIRATION OF THE BAYTAJIES THROUGH THE ARABIC-OTTOMAN LETTERS

Abstract. Poetry is considered momentum, which comes out of the soul and grips the whole body, and then, begins to come out of the soul to the outside world through magical words and beautiful verses, which please both body and soul.

The Baytajies wrote in a stylistic and beautiful Arabic-Ottoman poetic language but explanations were in Albanian, and considered their verses to be something extra-abstract and divine because beautiful words can only come from one who is beautiful.

They used the Arabic-Ottoman language but claimed that beautiful poetry was woven authentically, without having to imitate anyone else in their pleasant verses.

Their poetic inspiration was divine and, therefore, their words also emanated from the depths of a pure, transcendental world.

Keywords: Baytajies, Poetry, Inspiration, Soul, Influence.

Beytajies, under the influence of their beliefs from various literary and philosophical fields, considered the principle of divine inspiration as the basis for the inspiration of their thoughts, ie the principle of divine influence in the creativity of their ideas that they expressed in poetry.

Divine inspiration is clearly seen in their statements and words woven into various poems, even not only in the poetic content but also in the titles of the poems.

In this context, Jalaludin Guta titles his poem "God inspires me", and in it, he clearly proves that God is the One who inspired the creativity of his pedagogical-philosophical ideas, where he says:

"God inspires me,
He informed me as I wished,
For the good I enjoy,
He informed me as I wished,
And I sang these lines!" [5, P. 83]

Based on these words we clearly understand that the inspiration of the creativity of his ideas is God and that He, in addition to creative poetic abilities, has also given him the knowledge he had preferred in life.

Since God is the inspiration of the poetical ideas and thoughts, then it means that all this creativity should be used for the sake of God and not for the sake of other benefits and benefits in this world. According to Nezim Frakulla, every time a person re-

ceives a book, he must remember God during the reading and during the phase of isolation from society because such knowledge requires sacrificing life and living in solitude.

In the poem "Ashik Sadik", he says:
Ever since I started singing,
To separation I made myself a seed,
Whenever I get the books, I look at them,
Just as I see your greatness! [1, P. 183]

In some other verses, Nezimi confirms the purpose of his pedagogical-philosophical thoughts, saying that the whole corpus of his thoughts and ideas acquired in this world is made for the sake of God and not for other purposes. So, in this way he proves that ideological creativity, not only stems from divine inspiration, but also is practiced in life to gain the divine reward:

Given the fact that the thoughts of the bejtejs are the product of divine inspiration and that their ultimate goal is God, I can emphasize that their literature or literary activity firstly shows their Islamic religious nature, secondly the intensity of appropriation and conversion of thoughts on spiritual property and thirdly the opportunities created for the preparation of intellectuals in Islamic formation [2, P. 146].

Baytajies also had a great influence through religious sermons in mosques and sermons, because the direct word can have a greater influence than poetry. They were not only poets but also agile preachers who knew well the mentality of the masses. There are predispositions and desire for the acquisition of supplementary subjects required by the preacher such as: knowledge of Eastern languages in the first place, but also other languages, knowledge of rhetoric, oratory, knowledge of religious pedagogy, psychic predisposition of memory, knowledge of methodology scientific structure of the subject without reproduction, defining the topics, their composition away from the tautology so that the lectures (sermons) are interesting, attractive, argued with quotations and fragments that leave the listener not only emotional but also rational in the formation of a sound, consistent and principled religious awareness.

According to Mahmud Hysa, their sermons were thematic with an organized structure, argued by Islamic history, intertwined with contemporary history or events, with a pure vocabulary, above all in the mother tongue. They have aroused tremendous interest in the listeners so much that the mosques have been filled and overflowing with shrines [4, P. 171].

Muhamed Kyçyk Çami has a wide knowledge and culture and for this reason he becomes for his time and place an example of education and culture, religion, knowledge and human humanity. He enjoyed great respect and he developed his educational activity mainly between feelings, assemblies, various gatherings in chambers, through sermons in the mosque but in particular, through the teaching he held in the Madrasa of Konispol, where he worked as a teacher [7, P. 257].

Hafiz Ali Ulqinaku is also considered a preacher with great influence in the masses. In these combinations he combined the content of the topics with the methodology of its presentation. It always started with an Islamic greeting in the presentation of the topic, then continued with Qur'anic quotations, hadiths, events from history or life, listing them in a few points, and finally ended with the assignment of tasks, with the distinction between good and evil, of the halal from the haram, of the right from the perverse, of the useful from the harmful, of the beautiful from the ugly, of the moral from the immoral [3, P. 37].

During the sermons, the Baytajean poets used the words with great care and, as usual, influenced the masses by marking holidays, marked events, popular concerns and even educational problems. They did not repeat the words because they did not want to create an overload and thus aroused interest, attention and benefit.

In the following, we will mention some other preachers, who were preachers with great influence in the masses:

Hafiz Halim Haydari from Shkodra served for many years as a priest and teacher in the mejtepes of Shkodra, with a distinguished name and very rich pedagogical experience as a master educator of lessons for children and adults [6, P. 344].

Hajji Hasan Alia (Sheikh Shamia) was distinguished at his high level in lectures that filled the mosques full of congregations.

Hafiz Halil Puka excelled in the methods of lectures, explanations and interpretations of the congregation that conveyed it through the rites.

Hafiz Ymer Bahalli was known as a prominent performer and outstanding lecturer of the sermon.

Hajji Hafiz Muhamed Bekteshi was distinguished by his interesting lectures, his oratorical skills, his thematic sermons.

Hafiz Shefqet Boriçi was also distinguished by his style, oratorical ability and thematic sermons [4, P. 172].

Thus, the Baytajies were considered masters of mass influence because they were good and prominent pedagogues. They were not boring to the ear of the masses because they convey their words either through pleasant poetry or through sermons at various parties.

Such thoughts of theirs are proof because they form a creative divine originality, and thus, can not be the product of human influence and inspiration. The Baytajean writers do not accept the claims that creativity was made under the influence of the Easterners and in this context, Yahya Bey Dukagjini, when defended by epigonism (imitation of Persian sofas) and about the poem "Yusuf and Zulihaja" in his work: "Book of Principles", says: "I do not translate other people's words. I have not translated foreign words in my poem. My language is not Persian translation". "I do not eat the food of the dead Persians" [4, P. 254].

As a conclusion, Divinely inspired thoughts cannot be compared to man-inspired thoughts, because what comes out of God is used for His sake and to meet Him, and inspiration from men is considered inspiration that has a limited period because people die and God does not, and thus, such thoughts become eternal rather than temporary.

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Section 7. Economics and management

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IMPACT OF THE COVID-19 PANDEMIC ON THE ACTIVITIES OF GEORGIAN BANKS

Abstract. Based on the newest references and factual materials, the article explores and analyzes the current situation and future prospects of banks in light of the constraints caused by the Covid-19 pandemic.

The current situation is a clear indication that the resilience of the country's economy to shocks is crucial. As a result of the reforms carried out in previous years, the National Bank of Georgia has effective monetary and macroprudential policy instruments. Georgia's financial sector is resilient and has accumulated buffers, which will help it overcome the crisis with fewer losses in the future.

Keywords: Pandemic, Financial stability, Banking system, National Bank of Georgia, Crisis.

Introduction. Georgia, as a small open economy, is highly sensitive to the global economic and financial situation. Against the backdrop of the pandemic, the risks of financial stability have increased.

This article is based on the data we have collected. The purpose of the study is to assess the impact of the pandemic's restrictions on the operations of banks operating in Georgia and make predictions for the future. The purpose of the study is to assess the impact of restrictions on decisions made during a pandemic, the effectiveness of remote work of employees, changes in the channels of relationships with customers, etc., and also to identify the main directions and accents of banks' activities after the restrictions are lifted.

The necessary data were obtained from 22 heads of corporate lending, retail lending, risk management, information technology and operating subdivisions of eight banks operating in Georgia. The information was obtained through a survey (telephone interview). The questionnaire consists of 15 questions. Both qualitative and quantitative studies were used. The survey was conducted from November 2020 to February 2021 inclusive. Of these eight banks, three banks are of systemic importance.

Results. When asked how the restrictions imposed due to the pandemic affected their bank, 45% of the respondents believe the restrictions had a positive or more positive than negative effect, 23% answered they had a negative or more negative than positive effect, while 32% felt the pandemic did not have a significant impact on their activities.

The survey showed that 36% of bank employees found it difficult to switch to remote work; 45% found it easy to work remotely, and 19% of employees, however, find it difficult to get used to working remotely.

After imposing restrictions and transferring employees to remote work, the majority of respondents consider the lack of remote work space at home as the key problem (41%), staff performance monitoring (23%), staff performance management (23%), lack of teamwork (9%).

The respondents detailed which services switched to remote work relatively smoothly: HR (23%), IT (23%), Corporate Customer Service (23%), Financial Services and Accounting (18%), Risk Management Service (8%), other back office services (5%).

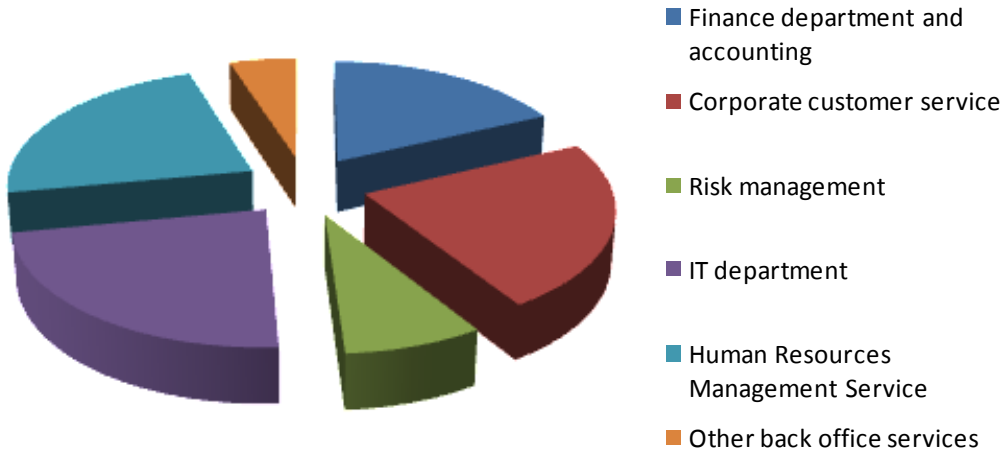

Figure 1.

According to the survey, 55% of respondents reported their bank had never remote work practice before the pandemic, 41% said they used it in certain cases, and only 4% confirmed they utilized this practice extensively.

Regarding the active use of remote channels after the pandemic, 14% of selected respondents indicated they would promptly return to their normal work schedule, 68% said that some employees would be transferred to remote work, and only 18% answered they would steadfastly maintain their current remote work style.

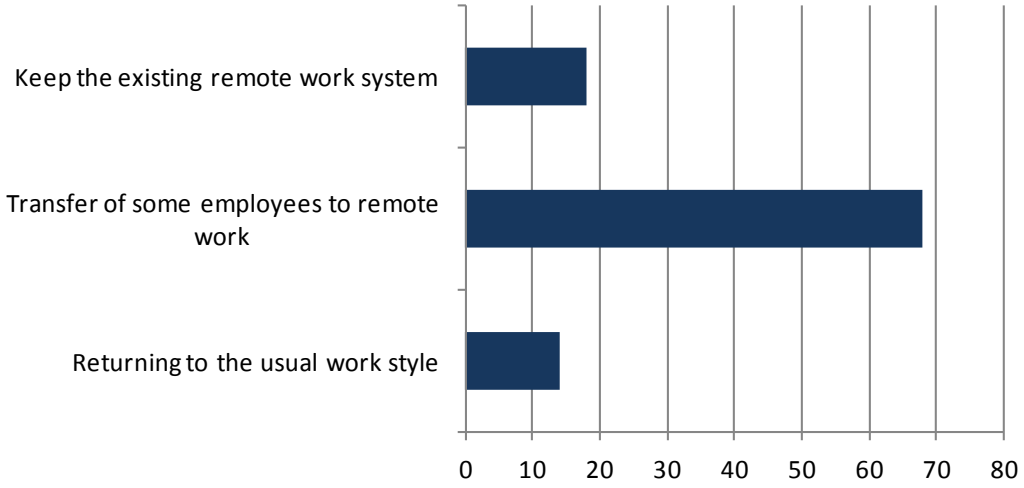

Figure 2.

According to the bank representatives, the main efforts to adapt to unstable conditions were focused on changes in banking services and products (32%), development of remote channels (23%), efficient

implementation of digital services (18%), risk management (9%) cost reduction (9%), payment optimization (5%), others (4%).

As the research shows, issues such as reducing the number of employees and optimizing wages were not an utmost priority for bank executives in the condition of restrictions.

Regarding the activities of physical branches/service centers, 50% of the respondents do not expect any cardinal changes in the near future, 23% believe consulting services and remote sales will be more active, 13% think the number of branches/service centers will decrease, and 14% think branches will switch to the latest customer service technologies.

When inquired what the most important steps need to be taken to entice customers and improve their services in the post-pandemic period, 32% of respondents mentioned the development of remote and digital channels. Yet 23% indicated the widespread introduction of voice messages, chat bots, virtual assistants, touch screens, and other innovations; 18% reported that in common was the successful introduction of innovative products/services and personal offers; 14% pointed to the reorganization of branches and 9% indicated improvement of the call center and consultants' work.

We also asked the respondents to what extent, in their opinion, the Georgian banking system was prepared for the pandemic, to which we received the following answers:

- Properly prepared-59%
- More or less prepared-27%
- Not properly prepared-14%

The measures taken by the National Bank in the context of a pandemic are assessed as follows:

- Successful-50%
- Good-32%
- More or less successful-18%

45% of respondents believe that in the post-pandemic period it is expected to intensify the merger / acquisition processes of banks; 23% consider the gradual replacement of traditional banks by electronic banks (neobanks) inevitable; a whopping 82% of respondents agrees that globalization and related processes pose a threat to the financial system of a sovereign country;72% of them believe that the banking system of Georgia is successfully coping with the Covid-19 pandemic.

When asked whether banks, like other risk management instruments, need to take responsibility for reducing climate change risk, 36% of respondents stated that it was necessary, 55% declared that it was not relevant, and 9% did not return the question.

Conclusions. The data obtained from the survey are significant for summarizing some preliminary results and setting guidelines.

The results show that in order to adapt to work in unstable conditions, the main efforts of banks are aimed at making changes in the provision of banking services and products and the development of remote channels. Issues such as downsizing and salary optimization were not absolute priorities for bank executives, which is absolutely welcome.

Only a small proportion of respondents believes that the restrictions imposed because of the pandemic have affected their bank negatively or more negatively than positively, which in common is a better result than expected.

As the pandemic has made it difficult for traditional banks to attract potential customers and provide services, they have turned to developing digital channels and delivering products and services through remote channels. Banks also pay great attention to introducing various types of innovations and providing customers with personalized offers.

There is also a tendency that despite the temporary closure of branches/service centers and the active switch to digital services, banks are not ready to cancel branches in the next few years. Simultaneously, part of the respondents confirmed that it is urgent to optimize the number of branches and introduce modern forms of services and technological innovations.

The study showed that the introduction of remote banking services is definitely not the closest reality for banks. Partial transfer of employees to remote work is possible, but still considerable importance is attached to face-to-face communication with customers and activation of consulting services.

After the transfer of employees to remote work, about 1/3 of them found it difficult to get used to remote work, and the biggest difficulty was to provide teamwork, control work and efficiency, as well as lack of work space at home, which is largely due to the lack of remote work experience and existing unsustainable environmental conditions.

Most of the structural units of the back office have moved to remote channels without much effort, especially IT service, corporate clients, financial service and accounting, which suggests that it is recommended transferring these services to part-time remote work.

Most do not adequately understand the risk posed by climate change and its management and believe that this risk is not relevant for banks today. We believe that banks in Georgia are not sufficiently informed and not motivated in this regard. Therefore, additional work is required in this direction.

It is noteworthy that the National Bank of Georgia and its activities in the conditions of a pandemic are trusted by the vast majority of respondents, which is undoubtedly the result of the enormous authority of the Bank and its timely and planned measures. Based on the above, respondents believe that the banking system withstood the first wave of the pandemic with relatively few losses and was prepared to meet external shocks. On top of that, according to the majority of respondents, the Georgian banking system is currently adequately addressing the challenges associated with the pandemic.

Globalization and its related threats are of immense importance to the part of the respondents; however, they do not consider the fact that the process of replacing traditional banks by electronic banks is relevant and real.

An absolute majority of respondents consider the banking system to be one of the chief factors for the stability of the country's economy. It should be emphasized that an important aspect emerges from the answers received – the management of the banks has a great responsibility in this regard.

Finally, there are certain expectations in the banking system of Georgia regarding the merger of banks, which is in line with the global trend.

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RESULTS OF EMPLOYEE PSYCHOLOGICAL TESTING BY MYER-BRIGGS METHOD IN GEORGIAN COMPANIES

Abstract. The article presents the results of a study conducted by the authors in 12 Georgian companies, which examined the psychological relevance of the position of employees in senior positions. According to the authors, the staff of the surveyed companies is recruited only as a result of checking their professional level and, in general, Georgian companies do not pay attention to the psychological characteristics of the applicants. According to the authors, there should be centers in Georgia that determine the psychological types of able-bodied population, the assessment, and recommendations of which should be taken into account by the employer when hiring staff.

Keywords: hiring, psychological characteristics, introverts, extroverts.

Introduction. From the beginning of the twentieth century, the factors of production were brought to the fore by the human factor of Shroy. It has been named as the main source of competitiveness and the main asset of the company. The human factor refers to human capital or human knowledge, skills, experience, and competence. Their summary determines the level of human professionalism. The staffing of Georgian companies is done on a professional basis.

At such times, in addition to this approach, when recruiting staff abroad, they also use their psychological characteristics. It is determined by r. Jatela, Lucher, b. Dark, Meyer-Briggs, and other tests. In this article, we will talk about the results of a Myer-Briggs test.

1. Determining the psychological types of people by the Myer-Briggs test

One of the most successful models for defining human personality traits is the Myer-Briggs model. It originated in 1940 with the scientist K. Based on Jung's ideas and found great use in the US and Europe.

In the Myer-Briggs model, people are grouped into two groups – introverts and extroverts. Each group includes 8 psychological types. Abbreviations are the initial letters of 8 English words:

– **ESTJ**: extraversion (E), sensing (S), thinking (T), judgment (J)

– **INFP**: introversion (I), intuition (N), feeling (F), perception (P)

Let us consider them in detail:

ISTJ types are people of duty. They are calm, locked in, restrained, and somewhat unemotional and locked-in people. They like subordination and instance system.

ISFJ types are cautious, calm, restrained. Satisfied with explanatory activities. Try to live in an orderly and moderately responsive manner.

INFJ types are service-oriented. Are prone to an orderly and planned lifestyle. Are caring towards others.

INTJ types are stable, confident, competent, and possessive of a keen mind. Independence is their main task. Can think strategically.

ISTP types are operated independently. They perform the task with high readiness. They do the job on time. You are attracted to practical behaviors – analysis, information retrieval, and processing.

The ISFP types are Khatrian, meek, quiet, and accommodating. They were invisible. Their natural talent is service to those around them.

INFP types are characterized by flexibility and adaptability. Are competent tours and have far-sighted abilities.

INTP types are idea generators. They love abstract understandings and questions. There are thinking types. Carefully weigh cause and effect.

ESTP types are open-minded, realistically matched people. They act on inspiration and like that it is known to everyone. They take life openly. They are oriented towards the present day.

ESFP types love surprises. They are delightful, life-loving, and cheerful people. They overcome difficulties lightly. Their work style is characterized by high energy and humorous relationships.

ENFP types have the enthusiasm and quick energy. They have a large reserve of trust. They love to participate in several projects. Has good communication skills with people.

ENTP types are characterized by incomparable energy and optimism. Constantly looking for something new and making changes in the situation. Their dignity is the thirst for an active life.

ESTJ types are straightforward. They look at the world through the prism of the applied situation. Have a high sense of responsibility and duty.

ESFJ types have the ability to achieve appropriateness and benevolence in any situation. They are mobile and sociable. They are extremely attentive to those around them.

ENFJ types are persuasion masters. Are endowed with the ability to teach others. Characterized by listening to others.

ENTJ types are born leaders. Their qualities are orderliness, completeness, method, responsibility, objectivity. For them, whole life is learning.

2. To study the psychological compatibility of employees with the position held

We conducted research in 12 Georgian companies. 92 people employed in the management apparatus were interviewed. 12 of the respondents were – General Manager of the company, 12 – Accountant, 10 – Marketing Specialist, 6 – Logistics Manager, 9 – Sales Manager, 7 – Lawyer, 12 – Personnel Manager, and 3 – Innovation and Research Manager. The questionnaire included 15 questions, only one of which explained whether they worked in the profession. All other questions related to their psychological state and position in the company.

It turned out that only lawyers and marketers work in the profession. The range of employment by profession in other positions is 35–91%. Sales managers (35%), production managers (80%), and personnel managers (90%) have less love for work and are loyal to the company. Marketers (25%) and sales managers (40%) are stressed at work. They do not enjoy coming to work – 20% of accountants, 10% of production managers, 4% of sales managers, 5% of logistics managers, and 20% of personnel managers. 60% of logistics managers, 40% of sales managers, and 50% of personnel managers – are looking for a new job. In the psychologically closed nature (introverts) are 50% of general managers, 60% of production managers, 30% of marketing, 90% of sales managers, and 50% of logistics managers.

In addition, it was found that companies do not have psychologists in the state and as a result, employees do not even know their psychological type. It is difficult for us to prove how sincere the respondents' responses to the survey were. Since the survey was anonymous, we think the respondents were sincere.

The answers obtained allow us to conclude that Georgian companies do not take into account their psychological characteristics when hiring staff – character, objectivity, responsibility, flexibility, risk-taking, impartiality, sociability, inspiration, observation, and many more.

We will take into account the neglect of their psychological characteristics in the staffing of Georgian companies, which leads to the incomplete realization of their capabilities, staff turnover, and confrontation of employees with management, using the Mayer-Briggs methodological apparatus (table 1).

As can be seen from the table, taking into account the psychological characteristics of people, we have designed 12 jobs for the administrative apparatus of a hypothetical company. Consider the features that introverts and extroverts have according to the Mayer-Briggs model. These qualities had 100% psychological compatibility with the workplace for general managers, accountants, purchasing and sales managers, lawyers, personnel managers and innovation managers, and 95% compatibility for all others.

Due to psychological characteristics, we preferred men in seven jobs and women in five jobs. These positions are: Accountant, Financial Manager, Office Manager, Psychologist and Personnel Manager.

Table 1.– Staffing of the management apparatus of a hypothetical company by the Myer-Briggs method

Workplace	**Required psych. type**	**Characteristics of the required psychological type**	**Psychological type compatibility with the workplace**	**Preference in employment**	
				Man	**Woman**
1	***2***	***3***	***4***	***5***	***6***
1.General Manager	**ENTJ**	Strategic vision; Responsibility; Orderliness; Methodical.	100%	+	
2. Production Manager	**ENTJ**	Strategic vision; High responsibility; Order.	95%	+	
3. Financial Manager	**ESFJ**	Punctuality; Accuracy; Responsibility.	95%		+
4. Accountant	**ISFJ**	Calmness; Restraint; Caution; High responsibility.	100%		+
5. Marketing Manager	**INTP**	Purposefulness; Impartiality; Thinking; Realistic.	90%	+	
6. Procurement Manager	**ENFJ**	Ability to persuade and negotiate	100%	+	

1	*2*	*3*	*4*	*5*	*6*
7. Sales Manager	**ENFJ**	Ability to persuade and negotiate	100%	+	
8. Lawyer	**ISTP**	Impartiality; Fairness; Cold mind.	100%	+	
9. Personnel Manager	**INFJ**	Attention and care for others; Contact; The ability to compromise.	100%		+
10. Innovation and Research Manager	**INTJ**	Discerning mind; Competence; Self-confidence; Independence; Conceptual thinking.	100%	+	
11. Office Manager	**ESFP**	Free and cheerful behavior; Lover of communication.	95%		+
12. Psychologist	**ESFJ**	Loving people; Observant	95%		+

Conclusion. A survey conducted in Georgian companies found that they do not take into account their psychological characteristics when hiring staff. Personnel are selected only on the basis of professionalism. In order for companies to receive more returns from employees, it is necessary to take into account their psychological type when hiring, that employees worked not only for a salary, but also for the realization of their own skills. And in this way they met the need that psychologist Abram Maslow called the fifth level need [3].

We propose that Georgian companies be required to work as a psychologist in the state. In addition, it is desirable to have centers for determining the psychological characteristics of people in all major cities of Georgia.

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SCIENTIFIC CONCEPT OF ECONOMIC AND ENVIRONMENTAL DEVELOPMENT OF INDUSTRIAL SECTORS IN ENSURING THE SAFETY OF PRODUCTS

Abstract. The article covers the formation of the economic and environmental development pathways of industrial sectors, first of all, the description of the economic and environmental safety of products through the concept of "economic and environmental interaction", based on the methodological point of view that the problem of economic and environmental development is of vital importance in the growth of the level of industrialization. It is proved that the economic and financial results of the implementation of the environmental protection measures specified in the article should be assessed on the basis of the impact of resource-saving, environmental and social factors on the efficiency of the extraction and use of fuel-mineral raw materials.

Keywords: industrial sectors, economic development, environmental impact, economic-environmental development, economic-environmental interaction, ecology, fuel-mineral resources, modernization of the economy.

I. Introduction

Industrial sectors, which are the main link of the development of our economy, have an important place in the economic and social life of our country, and during the reforms carried out in recent years in 2015–2019, due to the consistent continuation of the processes of radical structural changes in our economy, modernization and diversification, special attention is paid to ensure high growth rates with the third priority direction of the strategy of action on the five priority areas of development of the Republic of Uzbekistan in 2017–2021, ensuring the proportionality and stability of the national economy, increasing the share of industry, services, small business and private entrepreneurship in its structure is defined as a special task [1].

II. Literature review

The economic development of industrial sectors in the conditions of modernization of the economy is characterized by an increase in the processes of environmental influences. The problem of economic and environmental development is of paramount importance especially in the growth of industrialization. The formation of the ways of economic and environmental development of industrial sectors requires, first of all, to understand the essence of the concepts of "development" and "economic-environmental interaction". In general, having understood the problem of development of modern economy, it should be noted that this problem has not been fully studied. The first attempts to solve this problem are recorded in the works, as is known, Confucius, Ksenofont, Plato, Aristotle, as well as T. Moore, A. Saint-Simon, Charles Fourier, R. Owen and a number of other scientists. The modern interpretation of the essence of economic and environmental impact is contained in

the materials of the United Nations conference on the environment (Stockholm, 1972 y.). The concerted basis of economic and environmental impact was also reflected in the reports of the Roman club in the 70–80-ies. The concept of sustainable development is used in the "Global strategy for the protection of the environment" put forward by the international union for the protection of nature and natural resources, which has been described as a development aimed not only at improving the quality of life of the present-day humanity, but also the quality of life of the future generation, preserving nature [2]. In the interpretation of the concept of "development" we will dwell on the following aspects. The application of the concept of "long-term" in sustainable development takes into account the main parameters S. N. Bobilev, A. Sh. Khodjaev was represented by as follows [3]:

$$F_t(L, C, N, I) \le F_{t+1}(L, C, N, I)$$

Here:

$F_t(L, K, N, I)$ – sustainable development function,

L – labor resources,

C – artificially generated capital, means of production,

N – natural resources,

I – institutional factor,

$t = 0 \ldots n$ – time.

The global description of the concept of environmental development of the economy is due to the fact that this concept combines with complex environmental, economic, social and institutional problems for a long time. Without refuting the above points, in our opinion, economic and environmental development occurs as a result of an economic-environmental interaction, which is determined by the ecological aspect, the economic element is the leader. Economic-ecological interaction – the dynamics of interaction of economic objects with each other is a process of interaction, based on environmental improvement, which determines the characterization of the existence and organizational structure of economic-ecological systems.

III. Analysis and results

Since 1970, representatives of large-scale business have noted significant achievements in the field of economic and environmental impact on the basis of the introduction of various economic and environmental effective projects. At the price of the International Monetary Fund, natural resources spent on the unit of finished products are reduced by 1,23% per annum. The sphere of use of secondary raw materials has significantly expanded. For example, 90% of agricultural waste in Germany, 98% of machine housings, 90% of used oils are ironed [4]. Recent reviews show that on the basis of the introduction of modern technologies, the effectiveness of the use of natural resources has increased by 4 times. Increasing the efficiency of the use of resources is certainly not easy, but it is being used in practice. In the middle of 1970's, it was about the fact that the polemics in the field of American engineering economics could make up 10 or 30% of the total used energy without cost savings. In the middle of 1980's, this figure was considered to be around 50–– 80%, while in the middle of 1990's, experts gave an opinion that this figure could approach 90–99% and make the economy by 10–100 times more energy [5]. Economic and environmental development of activities on an industrial scale requires knowledge of the theoretical foundations of ecologization. The theoretical basis for the ecologization of the economy reflects the main methodological aspects of this problem, on the basis of which further scientific principles are formed.

If we pay attention to the above points, then ecology is a process that characterized a type of economic growth, aimed at the constant gradual implementation of production and technical, organizational and economic, environmental and legal decisions, increasing the efficiency of costs incurred on natural resources, reducing the negative impact on the environment, achieving the results of the best recent economic activity, as a result of which the economy is developing.

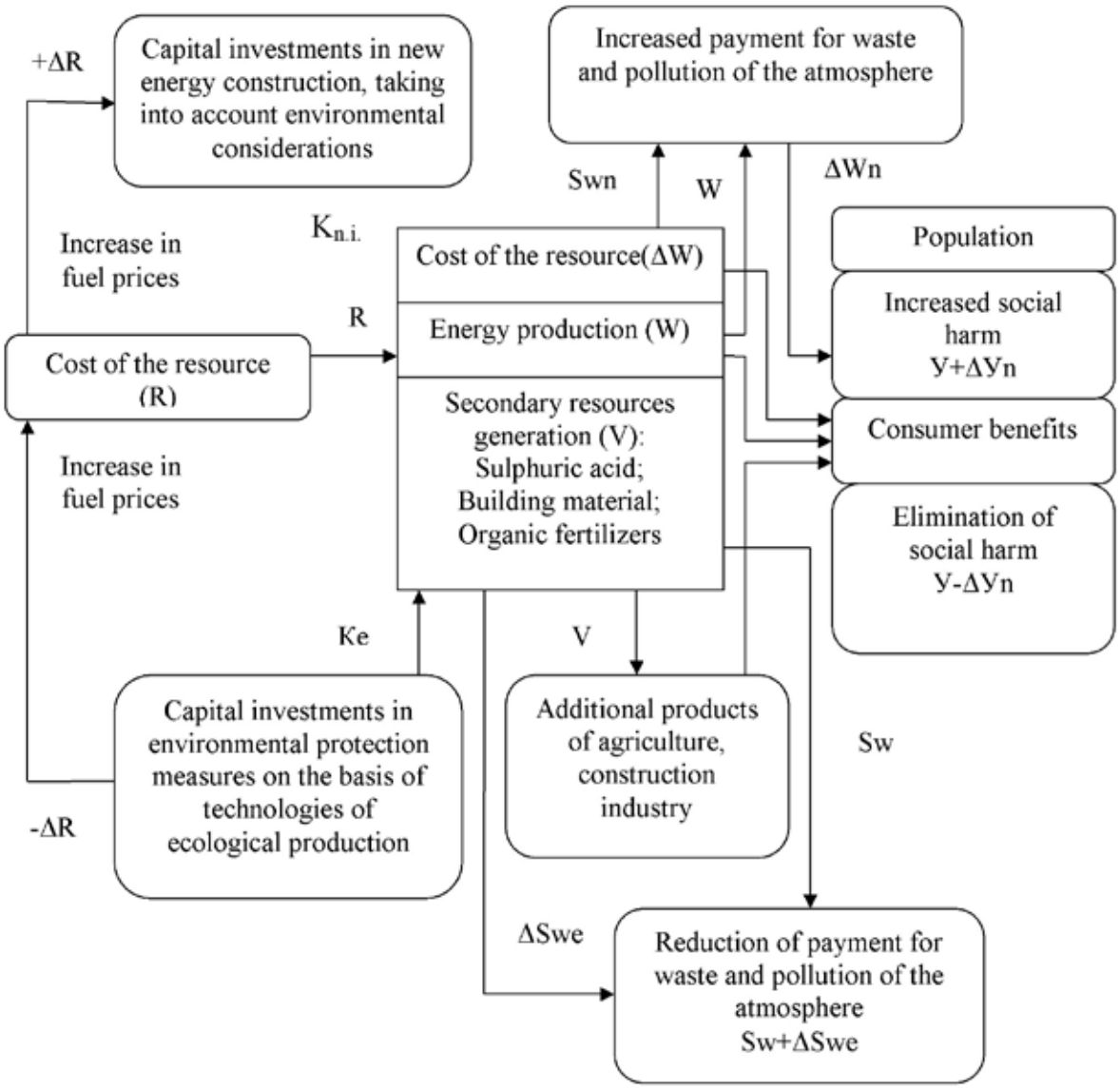

Figure 1. Structural scheme of the impact of resource-saving, environmental and social factors on the efficiency of the extraction and use of fuel-mineral raw material resources

R – fuel prices;

$K_{n.i.}$ – investments in new energy capacities;

K_e – investments in environmental protection and resource-saving technologies;

S_w – payment for emissions into the atmosphere under the base option (without the implementation of new capacities and environmental protection measures);

ΔS_{wn} – additional payment for the emissions into the environment as a result of the introduction of new energy capacities;

ΔS_{we} – eliminated payment for environmental strikes as a result of environmental protection measures;

$У$ – damage to the health of the population from pollution of the atmosphere by the base option;

ΔV_n – additional damage to the health of the population as a result of the introduction of new energy capacities;

V – secondary resources.

Fuel-mineral raw material resources into an ecologically developed type of production of mining

and their use requires a long period of time, considerable material and labor costs, which is observed with the resolution of a number of problems in real life. First, despite the fact that the economy, which is being done to reduce or eliminate waste disposal, placement and disposal, partially covers the costs, not all existing enterprises also have sufficient resources to carry out environmental innovation. Secondly, in most cases, the effect of introducing low-output technology is felt only after a long period of time, which raises the question of whether it is worthwhile to add capital to the novelty. Thirdly, the object of assessing all types of damage caused by pollution of the environment with the waste of extraction and use of mineral raw materials resources is complicated, in turn, it is reliable to assess the limits of the economically expedient application of the technology of full processing of fuel. At the same time, at the modern stage of development of our society, an important condition for the application of such technologies is their adaptability to the requirements of the conditions of the market economy, commercial efficiency. The solution of environmental protection problems is important in the extraction and use of mineral resources. The economic and financial results of the implementation of the mentioned environmental protection measures should be assessed on the basis of the impact of resource-saving, environmental and social factors on the efficiency of extraction and use of mineral raw materials (Figure 1).

IV. Conclusion and discussions

The above-mentioned analysis of the theoretical principles of economic and environmental development in the conditions of modernization of the economy, as well as national and foreign studies of the ecological use of nature made it possible to draw the following conclusions at the modern stage of economic reforms carried out in the Republic:

1. In the search for economic growth or the development of industrial development of society, the violation of economic and environmental balance is the primary cause of the occurrence of an ecological crisis. Today, the provision of economic growth is carried out without taking into account the boundaries of the natural environment. In fact, economic growth based on environmental sustainable development as the main link between community development is essential.

2. The fact that there is no possibility to increase the productivity of the potential of the natural environment creates the need to create more end products from waste, resulting in an increase in the efficiency of the use of natural resources on account of their lack of quantity. Such an acceleration of economic development will not be able to completely eliminate the main obstacles that harm nature, but will make it possible to directly solve many environmental tasks through the ecologization of production.

3. It is relevant to carry out research on the development of the quantitative measuring instrument of investment and environmental efficiency of measures that protect and restore the natural environment in an economic-mathematical format. The reason is that, firstly, the research and design developments carried out for the purpose of ecological restoration of environmental objects require the investment of innovations in the conservation and restoration of nature and the creation and further use of a uniform framework that unifies the procedures for the selection of economically and environmentally friendly options, and secondly, there is no agreed and recognized, and the concerted-methodical principles of its creation are not sufficiently developed.

4. The relevance of the development of an analytical method of calculation of investment and environmental efficiency of decisions that protect and restore nature is that on its basis it is possible to work with economic loss, to examine whether the participants of production activities directly affected by nature are not economically interested in the ecology of their activities. Such methodologies, based on environmental and socio-economic priorities,

contribute to the formation of economic production, stimulating the recognition of environmental dominance in the activities of economic entities in the conditions of modernization and industrialization of the economy.

Therefore, the expediency of carrying out the above-mentioned functions of ecology should be determined on the basis of a complex analysis of the effectiveness of long-term investments that protect nature.

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REVOLUTION AS THE CAUSE OF THE RUPTURE OF SUCCESSIVE TIES IN LAW

Abstract. The article is devoted to such a phenomenon in succession as discretion, which can occur as a result of external influence of other states, excessive borrowing of foreign law, and as a result of internal reasons (revolution), an objective process of development of the legal system. The author believes that the balance of the legal system corresponding to a certain stage in the development of the national legal system is ensured by the unity of its essence, structure, functions, and principles. At the same time, according to the author, the law is constantly changing; accordingly, the process of appearance of changes in the law, its transition from one state of equilibrium to another should be taken into account.

Keywords: Borrowing of foreign law, revolution, objective process of state development, legal system.

Discretion in the development of the legal system can take place both as a result of the external influence of other states, excessive borrowing of foreign law, and as a result of internal reasons, the objective process of development of the legal system.

The balance of the system of law, corresponding to a certain stage of the national legal system, is ensured by the unity of its essence, structure, functions, and principles. However, history shows that law is constantly changing, respectively, one should consider the process of the appearance of changes in the law, its transition from one equilibrium state to another, the presence or absence of successive connections between them.

In sociology, when studying social systems, the concept of "dysfunction" is used. If the functions "contribute to the ordering of the system", then dysfunction is a negative consequence of the impact of one part of the system on another". Dysfunctions reduce the ordering of the system, so the latter is never perfect, fully integrated. Accordingly, the equilibrium of the system is never static, it is always dynamic and is the result of the balance of functions.

With regard to the law, the situation looks as follows: the factors-challenges that arise in front of a particular subsystem of society cause changes in it, and then in the entire system, through which society again seeks to come to a stable state. Changes in subsystems are the basis for changes in the law. On their basis, new and important for society regularities are formed, requiring their transformation into a legal form – norms, and the principles underlying them. At the same time, the changes require guiding activities from the legislator to adapt society to them. He faces a number of tasks, the solution of which is possible only through the creation and implementation of legal norms, built, including taking into account changes in the cultural subsystem of society, changes in its value basis.

Thus, the norms of law can also play a dysfunctional role if the relations regulated by them in some way contradict those prevailing in a given historical type of society. Accordingly, within the framework of the system. The latter, corresponding to a certain stage in the development of the national legal system, will exist as long as the norms that implement

the functions and are based on the principles corresponding to the dominant laws of the given society will form the basis of the legal system. In parallel with them, in the legal system, there are norms that reflect alternative patterns in law that perform a dysfunctional role that corresponds to other principles. So, during the Middle Ages, the manorial economy was the dominant form of economy, and in the sphere of regulating economic relations, the leading role belonged to manorial and fief law. However, as a result of the "agricultural revolution of the XI–XII centuries." the number of cities is growing, trade and the corresponding trade law are developing. It begins an independent growth, which over time will lead the trade right to a dominant place in the regulation of economic relations.

As a result of the impact of external factors in the legal system, there is an accumulation of innovations, therefore, the accumulation of dysfunctions and alternative principles. And if in society they cause an increase in contradictions and social conflicts, then in the legal system and increase in functional imbalance, contradictions of principles corresponding to various laws, leads to its instability and inefficiency.

The growth of contradictions in the legal system is also associated with the growth of value imbalance. Changes in the cultural subsystem of society entail a modification of the system of cultural values, society's views on justice. New goals and values cause the appearance of functions uncharacteristic for the law of a given society, introducing a value contradiction in the content of the law. The consolidation of opposing values is characteristic not only of the norms governing economic relations, although there they are most contrasting, but also for other branches of law.

The legislator constantly ensures the dynamic equilibrium of the legal system by adopting compromise norms. As a result, the development of law is a combination of variability and continuity in each case. The institution of the loan in the history of European law has come a long way from a complete ban on usury through the system of exceptions to this ban to its modern understanding as a compensated contract.

If the law at any time is a combination of continuity and innovation, then the question arises about the nature of the change in the stages of the national legal system, about its gradualness or abruptness. The existence of a close connection between the development of society and the development of its subsystems makes it possible to use the models of society development proposed by the theory of social changes when answering the question posed. In accordance with one of the modernization models, the model of T. Parsons, society, due to the processes of differentiation of subsystems and their functions, gradually evolves and goes through a number of stages. T. Parsons' model was rightly criticized for excluding deviant deviations and conflicts from the problem field, the absence of a satisfactory explanation of the social change.

In accordance with the Marxist model, the process of evolution, i.e. gradual maturation in the depths of the old social system of the elements of the new, ends with a social revolution, the main component of which is a political revolution. Karl Marx's model, in turn, was rightly criticized for the contradiction "between economic determinism and the collective voluntarism of the revolution".

It seems that the history of law consists of both evolution and revolutions. In this case, the position of G. J. Berman is interesting, who singles out six revolutions in the history of Western society and law:

a) Papal revolution 1075–1122;

b) Reformation;

c) 17th-century English revolution;

d) French and American revolutions of the late 18th century;

e) Russian revolution of 1917.

Berman connects them neither with the doctrine of the change of formations nor with the Marxist understanding of the class struggle. Most of them were initially local in nature, but after a short period of hostility towards the country that was its carrier, they

found a response on the scale of the entire West. All these revolutions were "total" in the sense that they created not only new forms of government but also new structures of social and economic relations, new structures of relations between church and state and new structures of law, as well as new views on society, new views on history and new systems of universal values and beliefs".

Thus, there is no doubt about the existence of events in history that reflect the rapid transition of society and law, as the most important regulatory regulator of social relations, to a new qualitative state. The only controversial issue is the number of such leaps in the history of law.

The revolutionary leap is due to the presence of a value-functional imbalance in the legal system. The imbalance can be minimized in an evolutionary way – through gradual changes realized by the state authorities. The national legal systems of states that perceived the ideas of revolution in a softened form have similar development. The issue of the "threshold" of transition from one state to another should be resolved in its essence but fits into the framework of a global revolutionary change caused by one of the above revolutions.

The overthrow of the old law is caused by the reluctance of the ruling elites, due to ideological reasons, social inertia, to give up power, compromise with opponents, reform the legal system and the entire social system as a whole. In addition to the subjective will of the legislator, the situation of the crisis is aggravated by the objective focus of the right to stabilize social relations. General social justice inherent in law is constantly changing in accordance with the change in the subsystems of society. Consequently, the adequacy of ideas about it in society and its reflection in the content of legal norms must be constantly ensured by changing the latter. At the same time, the variability of law contradicts one of its main goals – to ensure stability in regulation and order. As a result, any legislator is constantly forced to seek a compromise between the views of society on justice, which should be reflected in law, and the stability of public life and legislation.

The stability of the legal system is also influenced by the legislator's awareness of the functions and principles of law, which from this moment acquire significance for him, in accordance with them he seeks to formulate legal norms. Their invariability for him is identified with the stability of the rule of law. Abuse of the latter can lead to the overthrow of the law.

On the eve of the social revolution, despite conflicts in social life and value-functional imbalance in legislation, norms, and institutions that consolidate outdated principles and perform functions harmful to the new society are supported by the coercive power of the state, and norms and institutions that correspond to social realities are suppressed. As a result, a conflict is growing in the public consciousness – justice, enshrined by the authorities in the law, is not perceived by such people. "The rejection of the existing law as an order has always been justified by the restoration of a more fundamental law – justice." In his research, G. J. Berman convincingly shows that all revolutions represented a radical rejection of the old law, but none of them succeeded in abolishing the pre-revolutionary legal system and immediately creating an absolutely new one instead. Each of the revolutions experienced an intermediate period, when new laws, decrees, orders were rapidly born and just as rapidly amended, canceled, or replaced. In the end, each of these revolutions reconciled with pre-revolutionary law and restored many of its elements by incorporating them into a new system built on new principles and performing new functions.

The revolution immediately sweeps away the norms and institutions that are fundamentally contrary to the new legal order, and qualitative successive ties in the development of the legal system are broken. Only quantitative continuity remains with those norms and institutions that at the previous stage played a destabilizing alternative role, and at the new stage took dominant positions. In addition, as in the life of society, many outdated social rela-

tions continue to exist due to social inertia, gradually fading away, so the legal norms regulating them continue to operate, gradually losing their effectiveness. However, apart from them, there is a block of norms that retains its significance. There are norms and institutions that contain neutral values and perform neutral functions in relation to the new social order and the new legal system. These include the norms and institutions that govern technical processes.

Thus, it is obvious that changes in the law occur both evolutionary and revolutionary: "elements of continuity, evolution is combined with elements of discreteness, qualitative leaps, and bounds and, in this sense, revolutionary". The revolution in law causes a break in the qualitative continuity in its development. At the same time, revolutionary changes are always accompanied by quantitative continuity.

Based on the study, we can conclude:

1. Discreteness in the development of law is the reverse of continuity characteristic of the development of the national legal system, consisting in the absence of qualitative successive links between the stages of development of the national legal system. Discontinuity in the development of law is a period caused by a certain historical event in the development of the national legal system, during which its qualitative change took place, accompanied by the interruption of qualitative successive ties between the stages of its development;

2. In the development of the national legal system, discreteness takes place in the event of the conquest of the state, in the event of a revolution in law, and may occur in the event of a voluntary large-scale reception of foreign law. Quantitative continuity in the development of law is always preserved, except in cases of complete assimilation of the people, or its destruction;

3. To prevent the freedom of perception of foreign law in the development of national law, it is necessary that borrowing meets a number of requirements:

a) Society should be aware of the need for changes requiring the adoption of the new law;

b) The transferred right must come from a society, the main features of which are not very different from those of the perceiver.

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