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INNOVATIVE COMPOSITE MATERIAL WITH A PSEUDO-POROUS STRUCTURE. (A composite material having a developed three-dimensional (volumetric) structure consisting of a multitude of identical multi-level spherical shells covering spherical cores)

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Abstract

An outstanding expert and inventor, Mykyta Liakh, has developed a fundamentally new innovative composite material based on artificial diamond microspheres. The material is characterized by a pseudo-porous internal structure and is intended for use in advanced smart and high-technology systems.

The composite created by Mykyta Liakh combines high thermal conductivity with high electrical conductivity. Owing to its unique internal architecture, the material is capable of rapidly absorbing, distributing, and dissipating significant amounts of energy within very short time intervals.

At the same time, the material maintains high mechanical strength and reliability while preserving precise geometric stability under conditions of elevated temperatures, high energy concentrations, and other extreme or harmful external influences.

Structurally, the composite material has a developed three-dimensional (volumetric) architecture consisting of a large number of identical multi-level spherical shells surrounding spherical cores. These cores with shells (capsules) are interconnected through sequential technological operations, forming a stable structure with equivalent contact geometry between the capsules. The material demonstrates high resistance to internal mechanical and thermal stresses and is capable of withstanding high pressures. Under pressure, part of the material's components can enter a cold-flow regime, enabling calibration of the three-dimensional structure and ensuring highly precise and repeatable geometric parameters.

Keywords: *Innovative composite material; Composite material with a developed three-dimensional (volumetric) structure; A multitude of identical multi-level spherical shells; Spherical cores; Artificial diamond microspheres; Composite material possessing high thermal conductivity while simultaneously having high electrical conductivity; Three-dimensional geometric structure ensuring, with a high degree of repeatability, very precise geometric dimensions of the structure*

Innovative composite material based on artificial diamond microspheres

An outstanding expert and talented inventor, Mykyta Liakh, has created a fundamentally new type of innovative composite material whose base consists of artificial diamond microspheres. The internal structure of this material is pseudo-porous and is of significant importance for advanced smart and innovative technologies.

Mykyta Liakh has successfully invented and developed a new composite material possessing high thermal conductivity while simultaneously demonstrating high electrical conductivity.

The new composite material invented by Mykyta Liakh is capable, within very short periods of time, of absorbing and dissipating significant amounts of energy.

The material is capable of absorbing and transmitting substantial amounts of energy over distance while maintaining maximum mechanical strength and reliability, preserving precise geometric forms under the influence of high concentrations of temperature, energy, and other harmful or extreme impacts.

Formulation of the new composite material as a product:

- a composite material having a developed three-dimensional (volumetric) structure consisting of a multitude of identical multi-level spherical shells covering spherical cores; the cores with shells (capsules) are interconnected through a series of sequential technological operations and have an equivalent contact form between each other for all capsules of the structure;
- the composite material possesses properties of super-thermal conductivity and super-electrical conductivity;
- the composite material has high mechanical strength, is not prone to the formation of internal mechanical and temperature stresses and, as a consequence of these phenomena, to the occurrence of internal deformations;
- the composite material is capable of being subjected to high pressures and, under the influence of these pressures, at least for part of its components entering a regime of cold flow, which allows the calibration of the three-dimensional geometric form of the structure and ensures, with a high degree of repeatability, very precise geometric dimensions of the structure.

Possible variants of the commercial name of the product as a material:

- a composite material that simultaneously acts as a conductor of electric current and as an effective thermal conductor, having a developed three-dimensional current-conducting structure with uniformly distributed nodes (microspheres) that represent points of maximum thermal conductivity and are not conductors of electric current (that is, made of a material with the maximum possible thermal conductivity, for example diamond, whose heat transfer coefficient is 1200 and which is not a conductor of electric current);

The material has the form of a three-dimensional lattice in the nodes of which diamond spheres are located, which are among the best known thermal conductors, separated from each other in the three-dimensional structure by copper shells that are excellent electrical and thermal conductors.

Thus, for electric current (which is particularly important for current operating in pulse mode) the composite structure represents a pseudo-spongy or pseudo-porous volume, since throughout the entire volume of the current-conducting material dielectric spherical spaces are uniformly distributed, comparable in size to the conductive space.

This fact contributes, on the one hand, to a sufficiently rapid and uniform dissipation of electric current and, on the other hand, to the rapid, efficient, and uniform dissipation of heat due to the processes occurring within the same material volume.

- the material for the shells is intended to be among the most ductile known materials, for example copper or silver, which also possess the highest electrical conductivity among known materials; when exposed to high pressure in a closed volume, these metals can be brought into a state of cold flow;
- when high pressure is applied in a closed three-dimensional volume,

the nature and form of interaction between the capsules in the structure are modified, which makes it possible to form products with the required technical and technological characteristics that cannot be obtained using conventional technologies.

The new material can acquire its unusual properties due to appropriate technological techniques which, because of their originality, become the basis for an original complex technological process – the object of an integrative base invention and a series of applicative inventions aimed at the development and improvement of the properties of the specified composite materials and their derivatives.

Variants of the name and definition of the technology for producing the new composite material, described by Mykyta Liakh in his original developments:

Method for producing a pseudo-spongy or pseudo-porous composite material consisting of a multitude of nano-capsules interconnected into a three-dimensional structure that, at the final stage of production, is subjected to volumetric plastic calibrating deformation in a cold-flow regime for the material of the plastic shells of the nano-capsules.

Technologies for producing nano-powder from diamonds and subsequently coating it with copper or other ductile metals are relatively well known from the point of view of technological principles; however, at the subsequent stages of the project they will require certain modifications.

The proposed composite material, after the completion of all manufacturing operations, acquires the form of a finished geometric structure, for example a prism, which should be considered as an electrically conductive object within the volume of which dielectric spheres made of synthetic diamonds are uniformly distributed.

The cross-section of such a conductor is sufficiently large, and due to the developed volumetric structure the electrical resistance of such a conductor is relatively low. Since inclusions of diamond grains (spheres), which are not electrical conductors, are present in the volume of the conductive structure, the electric current bypasses these zones within the body of the structure and passes only through the conductive volume.

Such a scheme of current dissipation or distribution over a relatively large cross-section makes it possible to sharply reduce losses and accelerate the passage of current. In cases where it is necessary to dissipate heat, the pseudo-porous structure represents nodes of a specific lattice in which diamond spheres are located; their thermal resistance is 4–5 times lower than the average value for the entire structure. Therefore heat tends to move toward the nodes of this lattice, which ensures a very rapid and intensive outflow (dissipation) of heat from its source.

Thus, in both cases a phenomenon of spot-like three-dimensional distribution of zones with different specific coefficients of thermal conductivity and electrical conductivity is created.

In addition, the nanoscale dimensions of the capsules and the final plastic deformation in the cold-flow regime make it possible to significantly reduce the gaps between the capsules, which increases the efficiency of removing and dissipating heat and current impulses.

The calculated and expected effect in heat dissipation exceeds the best existing technical solutions by approximately 4–5 times.

As an example of the application of the composite material, one can consider the packaging and housing of a semiconductor laser (laser diode). For example, a laser diode with multimode emission and an output optical power of 1 watt may be considered. In order to control the operation of such a diode and obtain an output power of 1 watt, it is necessary to supply at least 1 ampere of current. The voltage, taking into account the internal resistance of the laser diode itself and the control electronic system, will be at least 2 volts. Thus, the total power consumption will amount to 2 watts with a real output power of 1 watt. The power loss coefficient is therefore 50%, which is the best value known today.

In other words, even the least loaded multimode laser diode (with a beam cross-section of approximately 300 microns by 1–3 microns) requires the dissipation of about 1 watt of energy.

The standard housing for this type of diode is designated SOT-148, and the diameter of its mounting flange is 9 mm. In order to dissipate such a large specific amount of heat, a composite material is required that is capable of removing the heat generated by the conversion of approximately 1 watt of energy from the heterostructure of the laser diode, whose dimensions do not exceed those of a standard semiconductor crystal of an integrated circuit.

The nominal operating temperature in the region of the heterostructure must not exceed 25–27 °C. In order to transfer such an amount of heat, the heterostructure is soldered to a composite carrier, which dissipates heat into the diode housing, which in turn transfers the generated heat to the cooling system (a thermoelectric cooler).

The more efficient the material, the more efficient the operation of the laser diode, including its stability, durability, and output power. The problem becomes even more acute when heat must be removed from a single-mode diode, since in such diodes the beam cross-section is a circle with a diameter not exceeding 0.6 microns. In this case the energy concentration is even higher, and the function of heat removal and dissipation becomes even more critical.

Considering the fact that laser light sources are required for various video systems, optical memory systems, optical storage devices for personal computers, and similar products across different spectral ranges, the number of laser diodes produced annually only for these purposes exceeds 100 million units, with the price of a 1-watt laser diode exceeding $1000.

At present, the optical power of most laser diodes in use is approximately 80 milliwatts; however, these diodes operate in the red spectral range and in single-mode operation, therefore the application of a new efficient composite material is extremely relevant.

Since the proposed technical solution affects and can be applied in a wide range of technological directions in various fields, for the protection of the said technical solution – the so-called base technology – the company considers it advisable to prepare a basic patent application, which should be drafted in the most general form possible, using general definitions.

As the technology applications are further developed and the scope of its use expands, the author provides for the filing of additional patent applications (CIP – Continuation in Part).

The main objectives pursued and established in the base invention are:

- increasing the efficiency of the material in terms of thermal conductivity and heat dissipation; increasing the rate of heat removal from heat sources and ensuring the reliability of heat extraction and dissipation during long-term operation of the device in which the level of temperature pulsations is stabilized;
- increasing the efficiency of the material in terms of electrical conductivity and current dissipation; eliminating current losses during passage through the structure and ensuring the reliability of current transmission and dissipation during long-term operation.

Technical solutions used to achieve the objective:

- reducing the diameter of the capsules to the minimum permitted by the technology of their production (the smaller the diameter, the higher the efficiency);
- calibration of the geometric form of the structure through plastic deformation of the capsule shells in the cold-flow regime; this reduces the volume of voids between capsules, decreases electrical and thermal resistance, improves the mechanical characteristics of the structure, and eliminates internal stresses in the three-dimensional hierarchy of the structure.

As of today, the following composite materials are known and used for similar purposes:

- copper–tungsten;
- copper–molybdenum;
- aluminum–silicon carbide;
- aluminum–silicon;
- aluminum nitride;
- synthetic single-crystal diamond;
- chemical diamond;
- diamond–copper composite.

This composite material is designated DMCH – Diamond–Copper Composite (Diamond Metal Composite for Heat Sink). It is manufactured by SUMITOMO ELECTRIC USA, INC. According to information from this company, the thermal resistance and thermal conductivity of this composite are only three times better than those of ordinary composites.

Modern electro-optical systems require significantly higher performance – 4–5 times better than that of ordinary composites. Such results can be achieved by the proposed nano-scale composite material developed by Mykyta Liakh.

The company SUMITOMO ELECTRIC holds a patent for this composite under Patent No. 6,270,848, dated August 7, 2001.

The original integrative technological solution proposed by Mykyta Liakh has the following advantages compared with this patent:

- the invented composite contains only two components – diamond spheres (grains) and copper shells surrounding them;
- the invented composite exhibits a heat-dissipation effect;
- the invented composite exhibits a current-dissipation effect;
- the electrical resistance of the invented composite is equivalent to the electrical resistance of copper;
- the invented composite is formed and calibrated using the cold-flow effect of copper (or any other ductile metal);
- the invented composite possesses **high mechanical strength** due to calibration using the cold-flow state;
- the invented composite possesses a high level of electrical conductivity due to calibration using the cold-flow state;
- the invented composite has more precise geometric dimensions due to calibration using the cold-flow state of the metal (cold drawn metal or cold metallic liquid state);
- the invented composite has a higher level of thermal conductivity due to the extremely small size of the capsules (nanometers) and due to calibration using the cold-flow state.

Based on the existence of a positive effect from the use of the composite material, it is possible to assume directions for the development of the following applications in various fields:

Capsule core – ceramic; capsule shell – copper; silver; aluminum; nickel;

- tungsten – copper; silver; nickel; aluminum;
- iron – aluminum; copper;
- beryllium – aluminum;
- magnesium – aluminum;
- silicon – copper; silver; gold;
- zirconium – aluminum;
- diamond – copper; silver; gold;
- glass-ceramic – copper; silver; gold;
- hard alloy – copper; aluminum; cobalt; molybdenum.

Examples of composite material combinations:

- beryllium–aluminum;
- magnesium–aluminum.

From such composites it is possible to manufacture bases for hard magnetic disks for computer memory storage devices. Such disks, due to their technical characteristics, may operate at rotational speeds exceeding 20,000 RPM.

These materials also open new possibilities in:

- the creation of hybrid disks;
- coating technologies in microelectronics;
- the creation of fuel activating additives;
- the manufacture of critical components.

The proposed composite material can fundamentally change the operating conditions and performance characteristics of high-energy electronic devices. It makes it possible to create a new generation of electronic devices that are much less dependent on thermal characteristics. This is especially important for high-power pulse equipment, where the peak pulse power exceeds the nominal power of the device.

As an example, a single-mode semiconductor laser with a nominal optical output power of 300 milliwatts and a wavelength of 780 nanometerss can be considered. When connected to a control electronic module operating in the radio-frequency range (100 MHz), at a pulse peak with a duration of 10 nanoseconds, repeating every 10 nanoseconds, the device demonstrated an optical output power of 3.1 watts for 72 hours.

The heterostructure of the specified semiconductor laser (laser diode) was mounted on a substrate made of the proposed composite material, formed as a pseudo-spongy structure.

Additional possibilities provided by the use of the proposed material include:

- manufacturing instrument housings from the same material with a homogeneous monotonic structure;
- producing housings and load-bearing components of electronic devices in the form of a conductive sponge-like system capable, in the event of sudden peak pulsations of current or sudden temperature spikes, of rapidly dissipating or accumulating the excess portion of the suddenly generated energy load;
- the possibility of combining current-conducting and heat-conducting functions in the same structural element.

The invention created by Mykyta Liakh includes the following integratively interconnected technical solutions:

- the structure of a multi-layer (multi-level) capsule;
- the geometric form of the multi-layer capsule – a sphere;
- the sequence of alternation of layers (levels) in the spherical capsule;
- the arrangement and geometry of placement of spherical capsules in the three-dimensional structure of the product;
- the technological principle of manufacturing the product;
- the introduction into the manufacturing process of an operation for calibrating the geometric shape of the product after the first stage of pressing;
- performing the calibration operation in a three-dimensional coordinate system;
- performing the calibration operation when the material of the outer capsule layer (shell) is in a state close or equivalent to the cold-flow state of the metal forming the shell;
- removal during calibration of all cavities not filled with conductive material from the three-dimensional space of the product;
- formation within the three-dimensional space of the product of a pseudo-spongy structure, where the role of separating points in this structure is performed by less ductile materials used in the capsule composite;
- use of the sponge-like structure of the product for dissipation of heat and current throughout the entire volume;
- use of the pseudo-spongy structure for absorption of excess energy arising during peak moments of the pulsed operating mode of the device;
- use of the cold-flow state to relieve internal stresses in the material and perform dimensional calibration simultaneously in three coordinates;
- combination of materials in the hierarchy of spherical capsule shells in such a way that each subsequent layer is made of a less hard and more ductile material.
- the combination of materials in the hierarchy of the core and shells of the spherical capsule is arranged in such a way that the core is always made from the hardest material among all materials used in the capsule;
- the application of the main calibration principle – preservation of the solid sphere core without deformation and the maximum level of plastic deformation of the ductile materials forming the peripheral layers of the spherical capsule;
- the application of high specific pressure for calibration in a closed three-dimensional space;
- the application of the principle of uniform pressure distribution along all coordinates (axes) of the closed three-dimensional space;
- selection of the thickness of plastically deformable layers in such a way that the minimum thickness of the layer is greater than or equal to the diameter of the capsule core.

Advantages of the composite material invented by Mykyta Liakh:

The heat-conducting and electrically conducting pseudo-spongy three-dimensional composite structure from which the invented composite material is formed provides:

- maximum heat dissipation;
- maximum current absorption;
- low electrical resistance;
- low thermal resistance;
- a low level of current losses during its passage through the three-dimensional structure;
- maximum speed of transmission of pulse signals with minimal energy losses;
- a maximum level of absorption of energy impulses occurring with high frequency and having short duration comparable with the pulse frequency, while at the pulse peak the energy density reaches a maximum value at least twice exceeding the nominal value.

Among the indirect advantages of the composite material invented by Mykyta Liakh are the following:

- materials and nano-spheres intended for use as the capsule core are manufactured in series on the basis of several identical technological processes;
- technological processes for applying or forming the layers (shells) following the core are known and have been tested;
- technological processes of volumetric calibration are used in cold extrusion technology in the production of molds, dies, and similar components.

The method of producing the composite material has additional advantages arising from the characteristics of the invented material.

As a result of forming the final geometric shape, it is possible to obtain an exceptionally high surface quality of the structure without additional mechanical processing and, if necessary, to apply on this surface a conductive film of artificial diamond to which an electronic component can be mounted or soldered. This possibility is new.

Thus, structurally the proposed invention can be represented as an integrative hierarchy consisting of interconnected distinctive physical, structural, and technological features on the basis of which the final properties of the subject of the invention – the composite material – are formed.

The invented material simultaneously possesses thermal conductivity and electrical conductivity. The material has a buffering capability to dissipate within its volume thermal impulses and the associated pulsations of electric current.

The objective established in the invention is determined by the properties of the invented material and allows, when applied, the achievement of:

- increased power of electronic devices in which the proposed materials are intended to be used;
- reduction of the dimensions of electronic devices in which the proposed materials are intended to be used;
- increased reliability of electronic devices in which the proposed materials are intended to be used;
- extension of the service life of electronic devices in which the proposed materials are intended to be used;
- improvement of the overall efficiency of electronic devices in which the proposed materials are intended to be used.

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