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DESIGN FEATURES OF TECHNICAL SYSTEMS. (Design Features of Technical Systems for Specialized Technological Equipment Using Engineering Software with Elements of Artificial Intelligence and Artificial Neural Networks)

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Abstract

This article examines the increasing requirements for cleanliness in manufacturing processes within modern communication systems, microelectronics, and integrated high-technology production environments. Particular attention is devoted to the role of manufacturing cleanliness as a critical factor influencing process controllability, product reliability, and the overall technological stability of advanced production systems. The purpose of the study is to determine the significance of manufacturing process cleanliness and to identify threshold cleanliness levels below which production quality becomes unstable and effectively uncontrollable. The article further analyzes the relationship between environmental standards, technological cleanliness requirements, and production efficiency. The research is based on a review and synthesis of scientific and technical literature, combined with a conceptual analysis of current industrial approaches to cleanliness management in high-technology manufacturing environments. It is established that maintaining the minimum required level of technological cleanliness is essential for ensuring operational stability, reliability, and consistent product quality in technologically advanced manufacturing systems. The findings demonstrate that insufficient cleanliness directly reduces process controllability and adversely affects final product performance. The article concludes that effective balancing of environmental compliance, production efficiency, and technological cleanliness standards is a necessary condition for the sustainable development of modern high-technology manufacturing.

Keywords: *Modern communication technologies, advanced computer technologies, degree of manufacturing process purity, standard process for developing a new technical solution, interconnection between system elements; higher-order system, modified definitions, unique composite materials*

Introduction

The development of modern communication systems and advanced computer technologies requires increasingly stringent requirements for the cleanliness of manufacturing processes. In scientific and technical literature, these processes often receive more attention than other equally important areas of microelectronics manufacturing processes and integrated production technologies.

To some extent, this can be explained by the desire, not entirely disinterested, to make manufacturing processes comply with established environmental protection standards while simultaneously reducing production costs, since environmental protection measures are often considered to reduce production efficiency and increase the cost of products and services.

However, there exists a minimum level of purification parameters or manufacturing process cleanliness, below which the quality of the technological production process becomes uncontrollable, which immediately affects the quality of manufactured products.

The conventional approach to ensuring the minimum required quality and level of cleaning and rinsing processes is the continuous improvement of the composition and components of chemical reagents, which are increasingly used and, as they are improved, intensify these processes.

This problem is even more significant in the food industry, where the costs of water treatment for use in food production processes and the costs of wastewater regeneration are increasing rapidly, further increasing already high food prices.

These problems can be discussed at length; therefore, the author proposes to proceed directly to the subject of this publication.

Let us consider the process of developing a production module for cleaning semiconductor wafers with a diameter of 300 mm.

Thus, we proceed to the analysis of a real innovation strategy in this technological field and to the question of what is more appropriate in the current situation: to continue improving surfactants and chemical cleaning agents, or to seek an innovative approach to solving these problems. Moreover, it is difficult to determine whether the process of modifying chemical reagents used in cleaning technologies can be considered an innovation process, or whether, according to the criteria of achieving the ideal final result, these modifications solve a problem in one area while simultaneously creating several new problems in others.

The analysis would be incomplete without examining the standard process of developing a new technical solution that is part of a higher-level technical system, and without considering the correspondence between traditional formulations and definitions and the modified formulations and definitions of technical systems at all levels proposed by Mykyta Liakh, a well-known innovation developer whose methodology involves the introduction of unique composite materials, including those based on mineral components, into complex engineering developments.

With the increasing complexity of innovation projects, automated design methods and systems are becoming increasingly important. Their significance increases substantially when elements of artificial intelligence are incorporated, fundamentally changing the automated design methods and systems that specialists are accustomed to.

Only with the use of such systems does it become possible to complete an innovation project within reasonable costs and optimal timeframes, while also taking into account heuristic elements that arise during brainstorming processes.

When reconsidering the main definitions and concepts of TRIZ and ARIZ, taking into account the modification and optimization of definitions and relationships proposed by Mykyta Liakh for practical application in design processes within innovation projects, the following definitions may be used:

1. System approach – the system approach is a reflection and development of the dialectical principles of "universal interconnection" and "development" and is essentially one of the principles of the dialectical method of cognition. The methodology of the system approach involves representing any object as a system and considering it comprehensively. Modern methods and capabilities of computer modeling fundamentally change and significantly expand the concept of the system approach, making it more meaningful and effective.

2. System – a system is a set of elements regularly organized in space and time, interconnected and forming an integral unity. A system is characterized by its elements, structure, and function. Computer-based control and monitoring systems, as well as various combinations of their monitoring functions, significantly expand the concept of a system, making it more complete and providing it with additional analytical capabilities and characteristics.

3. Elements – relatively indivisible parts of a whole; objects that together form a system. An element is considered indivisible within the limits of preserving a given system quality. For elements, the most typical process is innovative modification and optimization, the result of which may be a technical solution corresponding to the four criteria of an invention.

4. Structure – a regular and stable relationship between system elements that reflects the form, arrangement of elements, and the nature of interaction between their properties and characteristics. Structure makes the system a qualitatively defined whole, distinct from the sum of the qualities of its individual elements, since it implies interaction between elements in specific ways and through specific properties rather than as a whole.

5. Function – the external manifestation of the properties of an object (element) within a given system of relations; a specific way an object interacts with its environment; the "ability" of an object. Systems possess multiple functions.

6. Subsystems (local independent systems) – parts of a system representing certain arbitrarily or naturally identified groups of elements. Subsystems are identified according to functional characteristics. One element may sometimes coincide with a subsystem or belong to several different subsystems simultaneously. The relationships between elements within subsystems and within the overall system differ from the relationships between the subsystems themselves. Elements and subsystems are combined under the concept of system components.

7. Supersystem (meta-system) – a higher-level system relative to the given system, in which the given system is embedded and functions as a subsystem. In such a structure, functions are controlled and monitored by automated control and monitoring systems implemented through programmable controllers or processors, significantly expanding functional capabilities.

8. Technical system (TS) – an artificially created material unity of elements organized in space and time and interconnected, whose purpose is to satisfy a specific social need. Elements of a technical system may be both artificial and natural. Any technical system exists within two systems of relations: on the one hand, it is an object of the material world subject to the laws of nature (primarily the laws of physics), and on the other hand, it functions as an element of social relations, since technology serves as a means of achieving social goals.

The concept of a Technical System (TS) makes it possible to formulate the main feature of a Technical Solution (TS): a Technical Solution identifies a specific Technical System whose functioning makes it possible to achieve a defined objective, i.e., it establishes the relationship between the Technical System and the target objective. The concept of a technical system makes it possible to formulate the main feature of a technical solution: a technical solution identifies a specific technical system whose functioning makes it possible to achieve the stated objective, that is, it defines the relationship between the technical system and a particular goal.

The working centrifuge of a unit for preparing semiconductor wafers with a diameter of 300 millimeters for photolithography processes is shown in Figure 1.

The numbers in the figure indicate:

1 – semiconductor wafer with a diameter of 300 mm

2 – aerodynamic gripper

3 – non-contact aerodynamic gripping system

4 – pipeline for supplying purified compressed air

5 – cone for uniform distribution of foam over the surface of the semiconductor wafer

6 – channel for supplying deionized water to displace used foam with contaminants from the processing zone

7 – working chamber – centrifuge bath

8 – openings for draining used foam with contaminants removed from the processing zone

9 – collector for used foam with waste and contaminants

10 – outlet pipe in the bottom of the centrifuge for waste discharge

11 – gap between the processed side of the semiconductor wafer and the centrifuge table

12 – gap between the centrifuge table and the centrifuge housing

13 – conical cavity for forming and supplying foam into gap 11

14 – aerodynamic foam generator

15 – deionized water supply pipe

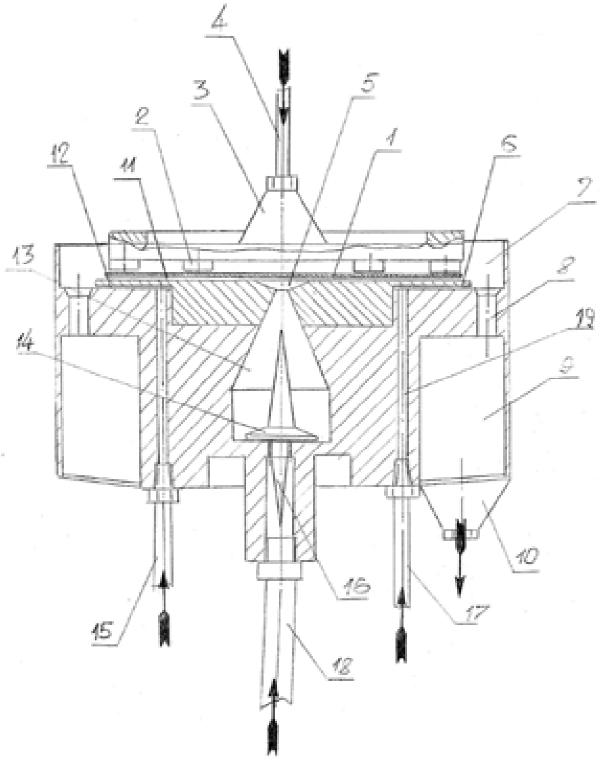
16 – inlet conical reflector of the foam generator

17 – deionized water supply pipe

18 – purified compressed air supply pipe

19 – pipelines for supplying deionized water

Figure 1. *Working centrifuge of a semiconductor wafer preparation unit (300 mm wafers) for photolithography processes*



Technical Systems Structure

In the working centrifuge shown in the figure, there are at least four autonomous technical systems, each of which represents an independent technical solution having the status of a recognized invention.

Such systems include:

- aerodynamic gripping devices;
- aerodynamic and hydrodynamic devices forming a uniform flow of deionized water distributed along the bottom of the centrifuge;
- aerodynamic foam-generating unit;
- aerodynamic and hydrodynamic washing foam generator.

These autonomous technical systems can each be classified individually as subsystems and collectively as one integrated supersystem.

Taking into account the requirement to meet the four criteria of an invention, and especially the criterion of non-obviousness of the technical solution, each of the specified solutions at the subsystem level can be classified as completely non-obvious (based on the recognition of each solution as an invention). Most importantly, the supersystem represents a completely non-obvious combination of subsystems, in which the new and non-obvious feature is the coaxial arrangement of foam generators and their equivalents in combination with typical and obvious solutions for gripping and feeding semiconductor wafers into the processing zone.

Since each of the specified technical systems includes a processor that regulates pressure, flow rate, temperature, motion speed, and other direct and indirect parameters, and since this regulation is flexible and can be performed remotely, the classification of both the subsystems and the integrated supersystem can be presented as follows:

Classification of Technical Systems

Technical system – according to the classical methodology of definition, each subsystem can be considered a Technical System, and the system into which these subsystems are integrated can be considered a supersystem.

Local technical system – each subsystem within the integrated supersystem can simultaneously be considered a Local Technical System, since its functions and operations occur within the limited working space of the integrated supersystem, and each individual system and the entire set of systems possess the property of non-obviousness.

Developed technical system – all local technical systems mutually complement each other's functions, and the integration of local functions within the supersystem makes it possible to form complex functional capabilities and possibilities, that is, it develops and forms an integrated technical characteristic of the supersystem, with complete non-obviousness for an average specialist in this field. Thus, these integration principles make it possible to classify the system as a developed system, at least due to the non-obvious integrative combination of subsystem output parameters.

Global technical system – the presence of a processor-based programmable structure for control, regulation, and active monitoring, and the possibility of transmitting all exchange information via the Internet, with a clearly traceable possibility of remote operation, makes it possible to classify such a complex integrated solution as a Global Technical System.

Smart technical system – finally, the presence of a hierarchy of programmable controllers and processors that perform control, adjustment, and regulation of parameters in real time, with the possibility of programming and reprogramming remotely, collectively forms the conditions under which this technical system can be classified as a Smart Technical System.

It must be acknowledged that the first person to classify modern types, parameters, distinguishing features, and characteristics of complex innovative technical systems, both structurally innovative and technologically innovative, in a practical format was Mykyta Liakh in his publications.

Engineering Concept

Let us now proceed to the topic of development and consider a system working position for effective cleaning of semiconductor wafers with a diameter of 300 mm and minimal thickness.

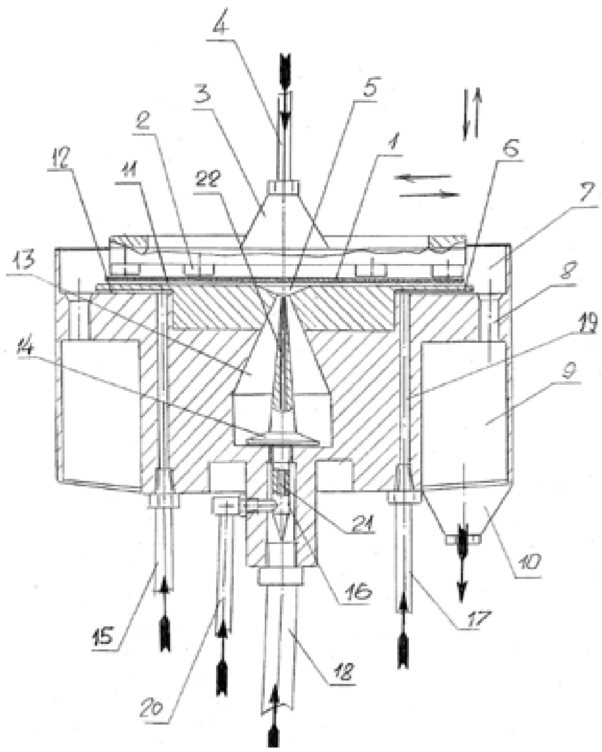
Taking into account the fact that, by all characteristics and parameters, the example working centrifuge, its component elements, and the significant flexibility of adjustment options, together with the possibility of real-time control and monitoring, including remote control, make it possible to classify these integrated capabilities as elements of artificial intelligence, which form the characteristics of a Smart Technical System, the initial developments and definitions proposed by Mykyta Liakh opened the way for developers in creating industrial and experimental solutions with such parameters and characteristics.

Of particular importance and value for the design process are the options for introducing innovative elements at the subsystem level into technical systems in the form of specific technical solutions that transform a subsystem into a supersystem. It should be noted that under current conditions, all of the above must be considered in close functional connection with control and monitoring additional functions delegated to the technical system by programmable controllers or processors. At the same time, for a complete analysis and analytical evaluation, it is also necessary to take into account the level of development of software systems and their adaptability to the overall structure of the technical system.

At the same time, it is also impossible to completely ignore the heuristic capabilities developed and formulated at levels determined by the qualification and talent of the lead specialist of the project.

Since there are different design schools, and their design methods and techniques do not always coincide, they can also have a real influence on the final result.

Figure 2. *Working centrifuge of a semiconductor wafer preparation unit (300 mm wafers) for photolithography processes with additional detailed explanation*



The working centrifuge of a unit for preparing semiconductor wafers with a diameter of 300 millimeters for photolithography processes with additional detailed explanation is shown in Figure 2.

The numbers in the figure indicate:

1 – semiconductor wafer with a diameter of 300 mm

2 – aerodynamic gripper

3 – non-contact aerodynamic gripping system

4 – pipeline for supplying purified compressed air

5 – cone for uniform distribution of foam over the surface of the semiconductor wafer

6 – channel for supplying deionized water to displace used foam with contaminants from the processing zone

7 – working chamber – centrifuge bath

8 – openings for draining used foam with contaminants removed from the processing zone

9 – collector for used foam with waste and contaminants

10 – outlet pipe in the bottom of the centrifuge for waste discharge

11 – gap between the processed side of the semiconductor wafer and the centrifuge table

12 – gap between the centrifuge table and the centrifuge housing

13 – conical cavity for forming and supplying foam into gap 11

14 – aerodynamic foam generator

15 – deionized water supply pipe

16 – inlet conical reflector of the foam generator

17 – deionized water supply pipe

18 – purified compressed air supply pipe

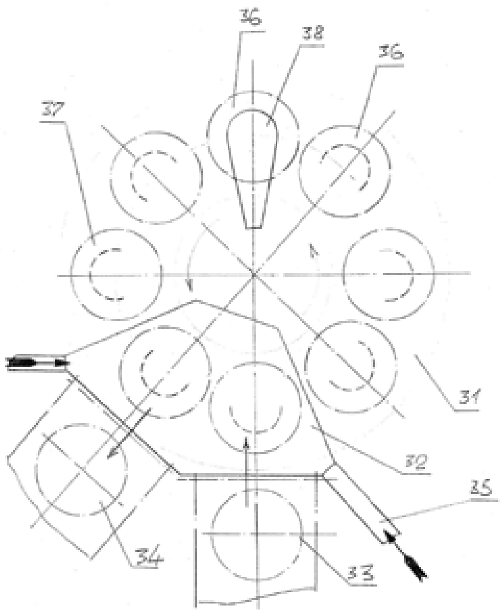
19 – pipelines for supplying deionized water

20 – pipe for supplying cleaning solution

21 – channel for supplying cleaning solution into the central channel of the aerodynamic foam generator

22 – channel for supplying cleaning solution into cone 5

Figure 3. *General block diagram of a carousel-type unit for preparing semiconductor wafers for photolithography processes*



The general block diagram of a carousel-type unit for preparing semiconductor wafers for photolithography processes is shown in Figure 3.

The numbers in the figure indicate:

31 – carousel with 8 working positions

32 – loading and unloading module, as well as installation and removal of semiconductor wafers from the aerodynamic holders of the working centrifuges

33 – semiconductor wafer loading system

34 – processed semiconductor wafer unloading system

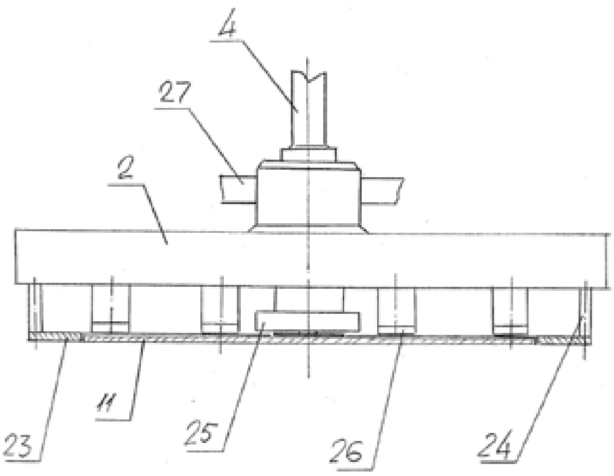
35 – system for supplying laminar flow of purified air to the loading and unloading systems

36 – centrifuges before the working position

37 – centrifuges after the working position

38 – non-contact aerodynamic gripping system

Figure 4. *A fundamentally new type of gripper for a semiconductor wafer with a diameter of 300 mm*



A fundamentally new type of gripper for a semiconductor wafer with a diameter of 300 mm is shown in Figure 4.

The numbers in the figure indicate:

2 – support plate (gripper disk)

4 – pipe for supplying purified compressed air (which does not disturb the laminar downward airflow of the entire

cleanroom where the equipment is installed)

11 – semiconductor wafer with a diameter of 300 mm

23 – annular protector preventing the occurrence of edge effects along the contour of the semiconductor wafer

24 – pins supporting and positioning the annular protector

25 – central aerodynamic gripper using the Bernoulli principle

26 – peripheral aerodynamic grippers using the Bernoulli principle

27 – structural element of the robot arm carrying and operating the gripper in a system whose operating cycle represents the Ideal Final Result of implementing a combination of inventions for orientation, gripping, transportation, and fixation of the semiconductor wafer both during transportation and during processing, combined with protection against edge effects and micro-deformations of the semiconductor wafer

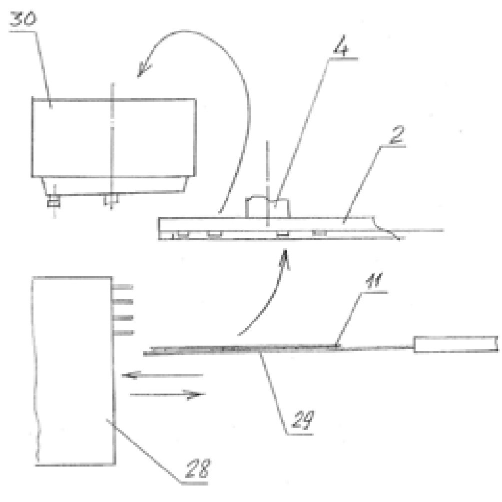
Engineering and Technological Considerations

In addition to purely design-related issues, it is also necessary to consider technological materials, methods, and techniques, since all of them together may introduce significant complexity into the processes of integration and implementation of the new development. First of all, it is advisable to analyze the possibility of using so-called temporary composites in the developed system as components within the chemical complex used to activate the cleaning process.

Since the cleaning process in the developed working position is carried out using a special type of foam produced by an aerodynamic foam generator with the capability of extremely precise regulation of the air bubble diameter in the foam and with the capability of stabilizing foam parameters without the use of any chemical activating or stabilizing materials, these factors must be systematically taken into account when analyzing design and engineering solutions and when forming the future technical characteristics of the working position as a technical system. These factors must also be taken into account when building computer models of devices that together form the specified working position and when modeling cyclic changes in its functions and current values of the main operating parameters.

The indicated real possibility of obtaining an understanding of the expected parameters and operating characteristics of the working position without the need to manufacture and test a prototype is the most important distinguishing feature characterizing the modern design process. It introduces computer modeling stages as the most important part of the design process and of the complete end-to-end process of creating a new innovative technical system.

Figure 5. *Diagram of the loading–unloading system for semiconductor wafers to the working position using a fundamentally new type of gripper shown in Figure 14*



The diagram of the loading and unloading system for semiconductor wafers to the working position using a fundamentally new type of gripper shown in Figure 14 is presented in Figure 5.

The numbers in the figure indicate:

2 – support plate (gripper disk)

4 – pipe for supplying purified compressed air (which does not disturb the laminar downward airflow of the cleanroom where the equipment is installed)

11 – semiconductor wafer with a diameter of 300 mm

28 – wafer cassette

29 – fragment of the loading–unloading robot arm

30 – working position of the photolithography production line

System Description

The complex presented in the figure includes several functionally interconnected technical systems:

- the semiconductor wafer gripper as a supersystem, including subsystems consisting of sensors, peripheral aerodynamic grippers, a central aerodynamic gripper, and an air supply, monitoring, and control system;
- a wafer cassette with a loading–unloading system;
- a loading–unloading robot including all assemblies, electronics, and computer control;
- the working position complex including all integrated subsystems.

The presented system complies with the laws of technical system evolution, taking into account their optimization according to the principles proposed by Mykyta Liakh, which made it possible to classify this object as a whole as a subject of an original technical solution – the subject matter of an invention corresponding to the four criteria in accordance with United States patent law.

List of Used Literature and Patent Materials

Jorda Sanuy, X., et al. (2011). *Self-aligned metal mask assembly for selectively depositing thin films on microelectronic substrates and devices, and method of use*. United States Patent Application No. 20110033726, Kind Code A1, February 10, 2011.

Dimeo, F., et al. (2010). *Cleaning of semiconductor processing systems*. United States Patent Application No. 20100154835, Kind Code A1, June 24, 2010.

Ivanov, I. C. (2006). *Systems and methods affecting profiles of solutions dispensed across microelectronic topographies during electroless plating processes*. United States Patent Application No. 20060029727, Kind Code A1, February 9, 2006.

Peulevey, N., et al. (2007). *Circuit board with microelectronic elements assembled thereon and method for producing such circuit board*. United States Patent Application No. 20070120618, Kind Code A1, May 31, 2007.

Curtis, G. L., et al. (2001). *Reactor for processing a microelectronic workpiece*. United States Patent Application No. 20010015176, Kind Code A1, August 23, 2001.

Harris, R., et al. (2003). *Apparatus with processing stations for manually and automatically processing microelectronic workpieces*. United States Patent Application No. 20030159921, Kind Code A1, August 28, 2003.

Di Stefano, T. H., et al. (2015). *Transport apparatus for moving carriers of test parts*. United States Patent Application No. 20150177318, Kind Code A1, June 25, 2015.

Peace, S. L. (2003). *Apparatus and method for regulating fluid flows, such as flows of electrochemical processing fluids*. United States Patent Application No. 20030217929, Kind Code A1, November 27, 2003.

Alvarez, D., Jr., et al. (2017). *Methods and systems for delivering process gases to critical process applications*. United States Patent Application No. 20170072081, Kind Code A1, March 16, 2017.

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