Технічні науки

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COMPOSITE MATERIAL WITH A PSEUDO-POROUS STRUCTURE

Innovative Composite Material with a Pseudo-Porous Structure

Summary. *Modern innovative technologies require new materials that combine high thermal conductivity and high electrical conductivity in order to significantly enhance technical performance.*

A new composite material has been invented and developed, which possesses both high thermal conductivity and high electrical conductivity.

The new composite material is capable of absorbing and dissipating significant amounts of energy within very short time intervals.

The material is capable of absorbing and transmitting significant amounts of energy over a distance while maintaining maximum mechanical strength. It demonstrates exceptional reliability in preserving precise geometric shapes 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 featuring an advanced three-dimensional (volumetric) structure composed of numerous identical multi-layered spherical shells encasing spherical cores; the cores with shells (capsules) are bonded together through a series of sequential technological processes and possess an equivalent contact structure form between all capsules.*
- *the composite material possesses properties of ultra-high thermal conductivity and ultra-high electrical conductivity;*

- *the composite material exhibits high mechanical strength, is resistant to the development of internal mechanical and thermal stresses, and consequently, to the occurrence of internal deformations;*
- *the composite material is capable of withstanding high pressures and, under the influence of these pressures, can cause at least some of its components to enter a state of cold-flow behavior. This allows for the calibration of the three-dimensional geometric shape of the structure and ensures very precise geometric dimensions of the structure with a high degree of repeatability.*

Key words: *Composite material, Composite material with a developed three-dimensional (volumetric) structure, Ability to calibrate the three-dimensional geometric form of the structure, Pressure application, Precise geometric dimensions of the structure, Light modular technology, High mechanical strength of the material, Occurrence of internal mechanical and volumetric thermal stresses, Occurrence of internal deformations.*

An outstanding organizer of new directions in the technologies of complex modules containing laser diodes and optical fiber elements, Olena Hrafska, based on her positive experience in the production and operation of light modular equipment containing artificial intelligence and artificial neural network elements in control and monitoring systems, developed the optimal technical specifications for such devices. These specifications were studied with interest and approved by specialists.

Based on these promising developments, a new composite material was invented and developed, which has high thermal conductivity properties and, at the same time, high electrical conductivity properties.

The new composite material is capable of absorbing and dissipating significant amounts of energy in very short periods of time.

The material can absorb and transfer substantial amounts of energy over a distance while maintaining maximum mechanical strength. It also possesses maximum reliability, preserving precise geometric shapes under the influence of high concentrations of temperature, energy, and other types of harmful or extreme impacts.

The formulation of the new composite material as a product:

- A composite material with a developed three-dimensional (volumetric) structure consisting of multiple identical multi-level spherical shells covering spherical cores; the cores with shells (capsules) are bonded together through a series of sequential technological operations and have an equivalent contact structure between all capsules.

- The composite material has properties of super thermal conductivity and super electrical conductivity.

- The composite material has high mechanical strength, is not prone to internal mechanical and thermal stresses, and as a consequence of these phenomena, the occurrence of internal deformations.

- The composite material is capable of withstanding high pressures and, under the influence of these pressures, can cause at least some of its components to enter a cold-flow state, allowing for the calibration of the three-dimensional geometric shape of the structure and ensuring very precise geometric dimensions with a high degree of repeatability.

Variants of the commercial name of the product as a material:

- A composite material that is simultaneously an electrical conductor and an effective heat conductor, with a developed three-dimensional conductive structure, uniformly distributed with nodes (microspheres), points of maximum thermal conductivity, which are not electrical conductors (i.e., made of a material with the highest possible thermal conductivity, such as diamond, which has a thermal conductivity coefficient of 1200 and is not an electrical conductor).

The material has the form of a three-dimensional lattice, with diamond spheres located at the nodes, which are the best known thermal conductors, separated in three-dimensional space by copper shells, which are excellent conductors and thermal conductors.

Thus, for electrical current (most importantly in pulsed mode), the composite structure acts as a kind of pseudo-spongy or pseudo-porous volume, as throughout the entire volume of the conductive material, dielectric spherical spaces are evenly distributed, comparable in size to the conductive spaces.

This fact contributes to relatively fast and uniform current dissipation on one hand and quick, effective, and uniform heat dissipation on the other hand, due to the phenomena occurring in the same volume of the material.

- The material for the shells is selected from the most ductile known materials, such as copper or silver, which also possess the highest electrical conductivity of any known materials. Under the influence of high pressure in a closed volume, these metals can be brought to a cold-flow state.

- Under the condition of applying high pressure in a three-dimensional closed volume, the nature and form of interaction between the capsules in the structure are modified, allowing for the formation of products with the required technical and technological conditions, which cannot be achieved using conventional technologies.

The new material can acquire its unusual properties through the appropriate technological methods, which, due to their originality, become the basis for the original integrated technological process—the object of the integrative base invention and a series of applicative inventions aimed at the development and enhancement of the properties of these composite materials and their derivatives.

Variants of the name and definition of the production technology of the new composite material:

The method of manufacturing a pseudo-spongy or pseudo-porous composite material, consisting of multiple nano-capsules, bonded together into a three-dimensional structure, subjected to volumetric plastic calibration deformation in a cold-flow state for the material of the plastic shells of the nano-capsules at the final stage of production.

The technologies for producing diamond nanopowder and subsequently coating it with copper or other ductile metals are relatively well-known in terms of technological principles. However, in the later stages of the project, this will require some modification.

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

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

Such a current dissipation or distribution scheme across a relatively large cross-section allows for a sharp reduction in losses and faster current transmission. In cases where heat dissipation is required, the pseudo-porous structure forms the nodes of a specific lattice, with diamond spheres positioned at these nodes. The thermal resistance of these spheres is 4–5 times lower than that of the overall structure, causing heat to flow toward the nodes of the lattice, which ensures very rapid and intense heat removal (dissipation) from the source of its generation.

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As an example of using the composite material, one can consider the packaging and housing of a semiconductor laser (laser diode). For instance, take a laser diode with multimode emission and an output optical power of 1 watt. To operate the diode and achieve 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 electronics, will be at least 2 volts. Thus, the total power consumption amounts to 2 watts, with an actual output power of 1 watt. The power loss coefficient—50%—is currently the best known performance indicator.

That is, even the least loaded laser diode with multimode emission (beam cross-section of 300 microns × 1–3 microns) requires the dissipation of 1 watt of energy.

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

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

The more efficient the material, the more efficient the operation of the laser diode, including its stability, longevity, and output power. The problem becomes even more critical when it comes to dissipating heat from a single-mode diode, as this type of diode has a beam cross-section in the form of a circle with a diameter of no more than 0.6 microns. In this case, the energy concentration is even higher, and the function of heat removal and dissipation becomes even more essential.

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

The majority of laser diodes currently in use have an optical power of approximately 80 milliwatts, operating in the red spectral range and in single-mode. This makes the use of the new efficient composite material especially relevant.

Given that the proposed technical solution affects and can be applied across a wide range of technological fields in various industries, it appears reasonable for the company to file a basic patent application to protect this so-called core technology. This application should be prepared in the most general form possible, using broad definitions.

Such a patent has been developed and published:

United States Patent Application **20120040166**
Kind Code **A1**
February 16, 2012

Composite Material, Method of Manufacturing and Device for Moldable Calibration

Abstract

Composite materials and methods and systems for their manufacture are provided. According to one aspect, a composite material includes a collection of molded together multilayer capsules, each capsule originally formed of a core and shell. The shell, after a plastic deformation process, forms a pseudo-porous structure, with pores locations containing the capsule cores. The cores are made of a material, e.g., synthetic diamond, which is harder than the external shell, which can be formed of, e.g., a ductile metal such as copper. The composite material has high thermal and/or electrical conductivity and/or dissipation.

As the technology applications are developed and the scope of its use expands, the company plans to release additional patent applications (CIP).

The main objective pursued and set in the basic invention is to enhance the material's efficiency in terms of thermal conductivity and heat dissipation; to increase the speed of heat removal from heat sources and the reliability of the heat selection and utilization process over the long-term operation of the object, stabilizing the level of temperature fluctuations.

- To improve the material's efficiency in terms of electrical conductivity and current dissipation; to eliminate current losses as it passes through the structure and ensure the reliability of the current flow and dissipation process over an extended period of operation.

Technical solutions applied to achieve the objective:

- Reducing the diameter of the capsules to the minimum allowed by the production technology (the smaller, the more efficient);

- Calibrating the geometric shape of the structure through plastic deformation of the capsule shells in a cold-flow mode; this reduces the volume of voids between the 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 to be 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 is designated as DMCH — Diamond-Copper Composite (Diamond Metal Composite for Heat Sink). It is produced by the company SUMITOMO ELECTRIC USA, INC. According to the company's data, the thermal resistance and thermal conductivity of this composite are only three times better than those of conventional composites.

Modern electro-optical systems require significantly higher performance — 4 to 5 times better than that of ordinary composites. Such results can be achieved with the proposed nano-composite material.

SUMITOMO ELECTRIC holds a patent for this composite under number 6,270,848, dated August 7, 2001.

The technical solution proposed by the developing company in collaboration with Olena Grafska and her working group has the following advantages over this patent:

- The invented composite contains only two components — diamond spheres (grains) and copper shells around them
- The invented composite features a heat-dissipating effect
- The invented composite features a current-dissipating effect
- The electrical resistance of the invented composite is equivalent to that of copper
- The invented composite is formed and calibrated using the cold-flow (cold metallicity) effect of copper (or any other ductile metal)
- The invented composite has high mechanical strength due to calibration by inducing a cold-flow state
- The invented composite has a high level of electrical conductivity due to calibration by inducing a cold-flow state
- The invented composite has more precise dimensions thanks to calibration through the cold-flow (cold drawn of metal or cold metallicity liquid state) process
- The invented composite achieves a higher level of thermal conductivity due to the extremely small size of the capsules (nanometers) and calibration through the cold-flow method

Based on the demonstrated positive effect of using the composite material, potential directions for development and application in various fields can be proposed as follows:

The capsule core is made of ceramic; the capsule shell is made of copper, silver, aluminum, or nickel.

- tungsten
- iron
- beryllium
- magnesium
- silicon
- zirconium
- diamond
- sitall
- hard alloy

- copper; silver; nickel; aluminum
- aluminum; copper
- aluminum
- aluminum
- copper; silver; gold
- aluminum
- copper; silver; gold
- copper; silver; gold
- copper; aluminum; cobalt; molybdenum

Example of composite material application with the following compositions:

Beryllium–aluminum

Magnesium–aluminum

These composites can be used to manufacture the bases of hard magnetic disks for computer memory storage devices. Thanks to their technical characteristics, such disks are capable of operating at rotational speeds exceeding 20,000 RPM.

These materials open up new possibilities in:

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

The proposed composite material has the potential to fundamentally change the operating conditions and performance characteristics of high-energy-density electronic devices. It enables the development of a new generation of electronic components that are significantly less dependent on thermal characteristics. This is especially critical for high-power pulse technology, where the peak pulse power exceeds the nominal power of the device.

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

The heterostructure of the mentioned semiconductor laser (laser diode) was mounted on a substrate made from the proposed composite material, which was created in the form of a pseudo-porous structure.

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

- Manufacture of device housings from the same material with a homogeneous monotonic structure;

- Creation of housings and supporting components for electronic devices in the form of a conductive sponge system, capable of quickly dissipating or accumulating the excess part of a sudden energy load caused by peak current pulses or temperature fluctuations;

- The ability to combine both current-conducting and heat-conducting functions within the same structural element.

The composition of the invention created by the developing company based on the initial integrative technical requirements and characteristics presented by Olena Grafska in her developments includes the following integrally linked specific technical solutions:

- structure of the multilayer (multi-level) capsule;

- geometric shape of the multilayer (multi-level) capsule - sphere;
- order of alternating layers (levels) in the spherical capsule;
- arrangement and geometry of spherical capsules in the three-dimensional structure of the product;
- technological principle of the product manufacturing;
- introduction of calibration operations into the manufacturing process after the first pressing stage.
- performing the calibration operation in a three-dimensional coordinate system;
- performing the calibration operation when the material of the outer layer (shell) of the capsule is in a state close to or equivalent to the cold fluidity state of the metal constituting this shell;
- removing all unfilled cavities from the three-dimensional space of the product during calibration that are not filled with conductive material;
- forming a pseudo-porous structure in the three-dimensional space of the product, where less plastic materials, used in the composite of the capsule, serve as separating points in this structure;
- using the porous structure of the product for dissipating heat and current throughout the volume;
- using the pseudo-porous structure of the product to absorb (store) excess energy that occurs during peak moments of the pulse-mode operation of the product;

- using the cold fluidity state to relieve internal stresses in the material and to calibrate dimensions in three coordinates simultaneously.
- combining materials in the hierarchy of the spherical capsule's shells such that each subsequent layer is made of a softer and more ductile material;
- combining materials in the hierarchy of the core and shells of the spherical capsule such that the core is always made of the hardest material among all the materials used in the capsule construction;
- applying the principle of calibration where the solid core of the sphere remains undistorted, and the maximum plastic deformation occurs in the ductile materials of the peripheral layers of the capsule's sphere;
- applying high specific pressure for calibration in a closed three-dimensional space;
- applying the principle of uniform pressure distribution across all coordinates (axes) of the closed three-dimensional space;
- selecting the thickness of the plastic deformable layers so that the minimum layer thickness is greater than or equal to the core's diameter.

The advantages of the invented composite material:

- The heat-conducting and electrically-conducting pseudo-porous three-dimensional structure that the invented composite material consists of ensures:
- Maximum heat dissipation;
- Maximum current absorption;
- Low electrical resistance;

- Low thermal resistance;
- Low current loss when passing through the three-dimensional structure;
- Maximum speed of impulse signal transmission with minimal energy loss;
- Maximum absorption of energy pulses with high frequency and short duration, comparable to the pulse frequency, with the peak energy saturation reaching at least twice the nominal value.

Among the indirect advantages of the invention developed at the company based on Olena Grafska's preliminary work on the technical characteristics and properties of the composite material, the following should be noted:

- Materials and nanosized spheres for use as the core of the capsule are mass-produced based on several identical technological processes.

- Technological processes for applying or building the subsequent layers (shells) after the core are well-known and tested.

- Volumetric calibration processes are used in cold extrusion technology, in the production of molds, matrices, etc.

The method of producing the composite material, taking into account the experience and developments of Olena Grafska, has additional advantages resulting from the unique features of the invented material:

As a result of achieving the final geometric shape, an exceptionally high surface quality of the structure can be obtained without additional mechanical processing. If necessary, a conductive coating made of synthetic diamond can be applied to this surface, onto which electronic components can be attached or soldered. This capability is new.

Thus, structurally, the proposed invention can be represented as an integrative hierarchy consisting of interconnected distinctive physical, structural, and technological characteristics, based on which the final properties of the object of the invention—the composite material—are formed.

The invented material has both heat-conducting and electrical-conducting properties simultaneously. The material has a buffering ability to dissipate thermal pulses and the associated electrical current fluctuations within its volume.

The goal set in the described invention is defined by the properties of the invented material and allows achieving the following when applied:

- Increasing the power of electronic devices that are intended to use the proposed materials;
- Reducing the size of electronic devices that are intended to use the proposed materials;
- Enhancing the reliability of electronic devices that are intended to use the proposed materials.
- Extending the lifespan of electronic devices that are intended to use the proposed materials;
- Improving the overall efficiency of electronic devices that are intended to use the proposed materials.

List of references used, patent and licensing information:

United States Patent **8,694,091**
Birk , et al. **April 8, 2014**

In vivo determination of acidity levels

Abstract

A bolus for use in a ruminant animal's reticulum includes a cavity (100) configured to receive ruminal fluids present in the stomach. The cavity has walls (110) of a dielectric material and is encircled by a coil member (120), which is configured to subject the ruminal fluids to an electro-magnetic field. A Sensor element (310) measures the electromag-netic field's influence on the ruminal fluids and thus register an electromagnetic property representative of an acidity level of said fluids. A transmitter (410) transmits a wireless output signal (SD) reflecting the acidity

United States Patent	**9,316,605**
Birk , et al.	**April 19, 2016**

Determination of attributes of liquid substances

Abstract

A monitoring unit (100) that determines parameters (p1, p2) of an attribute (P) of a liquid substance flowing (F) through a dielectric conduit (110) includes plural coil members (121, 122) encircling the dielectric conduit (110) that subjects a flow of the liquid substance to plural different electromagnetic fields (B(f)), and under influence thereof measuring circuitry registers corresponding impedance measures (z(f)) of the liquid substance. A processor (130) derives the parameters (p1, p2) of the attribute (P) based on the registered impedance measures (z(f)).

United States Patent Application	**20130178721**
Kind Code	**A1**
Bird; Uzi ; et al.	**July 11, 2013**

VIVO DETERMINATION OF ACIDITY LEVELS

Abstract

A bolus for use in a ruminant animal's reticulum includes a cavity (100) configured to receive ruminal fluids present in the stomach. The cavity has walls (110) of a dielectric material and is encircled by a coil member (120), which is configured to subject the ruminal fluids to an electro-magnetic field. A Sensor element (310) measures the electromag-netic field's influence on the ruminal fluids and thus register an electromagnetic property representative of an

acidity level of said fluids. A transmitter (410) transmits a wireless output signal (SD) reflecting the acidity measure.

United States Patent Application	**20130173180**
Kind Code	**A1**
Birk; Uzi ; et al.	**July 4, 2013**

DETERMINATION OF ATTRIBUTES OF LIQUID SUBSTANCES

Abstract

A monitoring unit (100) that determines parameters (p1, p2) of an attribute (P) of a liquid substance flowing (F) through a dielectric conduit (110) includes plural coil members (121, 122) encircling the dielectric conduit (110) that subjects a flow of the liquid substance to plural different electromagnetic fields (B(f)), and under influence thereof measuring circuitry registers corresponding impedance measures (z(f)) of the liquid substance. A processor (130) derives the parameters (p1, p2) of the attribute (P) based on the registered impedance measures (z(f)).