TECHNICAL INSIGHTS

ADVANCED MANUFACTURING

TECHNOLOGY ALERT

16th October 2015

1. METHOD TO MANIPULATE MAGNETIZATION INSPIRED BY BATTERY ELECTROCHEMISTRY

Magnets and Magnetism have influenced the modern electronics a great deal. Over the years, many techniques and processes have been developed to manipulate magnetic properties that have led to an array of applications. Applications ranging from a portable speaker to huge weightlifting electromagnets and magnetic levitation vehicles manipulate magnetic properties to perform astonishing tasks.

However, the creation or manipulation of magnetism has been possible only by physical methods. A new research study by a group of research scientists in Karlsruhe Institute of Technology (KIT) in Germany has succeeded in controlling the magnetic properties in large Ferromagnets using chemical processes inspired by the working principle of lithium-ion batteries.

Earlier, the physical methods used for creating or influencing magnetic fields were to use an electromagnetic coil or to polarize ferromagnets with the desired properties. In the former method, a conducting coil is used to create magnetism. During the process, an electric current is applied through the coil which produces a magnetic field. The strength of magnetic field was modified by varying the voltage across the coils. But, the shortcoming of this method is that the magnetic field exists only when the current flows through the coil. The continuous flow of electric current consumes a large amount of energy and makes this whole process expensive. Meanwhile, the second process - polarization of ferromagnets- does not consume any energy to maintain the magnetic field. But this method induces a permanent magnetism in ferromagnets only in the top monolayer atoms in the crystal lattices of ferromagnets.

In their attempt to influence magnetism chemically, the research team observed the processes in a lithium-Ion battery to reproduce similar processes to influence magnetism. The researchers claim that the idea for reversible magnetism was inspired from the reversible electrochemical processes that take place in a Lithium-ion battery which enables users to charge and discharge these batteries for several cycles during its lifetime.

In the lithium-ion battery, during charging and discharging, the ions move from one electrode to another intercalates (addition of ions into the electrode) into it. Inspired by this electrochemical process, the researchers at KIT created a lithium-ion accumulator in which one of the electrodes was a pure lithium electrode and the other electrode was made from a ferromagnetic iron oxide (Fe_2O_3), maghemite. Later, the lithium-ion accumulator was charged and discharged to observe the outcomes.

It was observed that when lithium ion intercalation on maghemite increased in room temperature, the magnetization of maghemite decreased. After many trials and observations, the scientists concluded that by controlling the flow of lithium ions by charging and discharging the magnetization of maghemite could be controlled. The research team was able to control the magnetization up to 30%.

The research team plans to achieve a complete ON-and-OFF switch magnetic switch. This new chemical method lays the foundation for such an achievement in the long run. When realized, a magnetic switch would work similar to an electrical transistor producing and turning off magnetic field when turned ON and OFF, respectively. The researchers are aiming to create small magnetic actuators using this novel technique in micro robots and microfluidics.

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2. ENHANCEMENTS IN TWO-MICROMETER FIBER OPTIC LASERS

Lasers that operate at two micrometers can provide key benefits compared to lasers that operate at shorter wavelengths. At the two-micrometer wavelength, laser light is readily absorbed by water molecules, and there is a strong absorption peak near 2 micrometers, which reduces the penetration depth of this wavelength in tissue to a few hundred micrometers. The easy absorption of laser light at two micrometers by water molecules renders such lasers quite useful for medical applications such as precision surgery. Water molecules are the primary constituents of human tissue. In surgery, two-micrometer lasers are able to target water molecules during an operation and to make incisions in extremely small areas without deep penetration. Moreover, energy from the laser can prevent bleeding by causing blood to coagulate on the wound.

Two-micrometer lasers are beneficial for other applications, such as industrial materials processing (for example, transparent plastics), detection of lighter atmospheric gases, detection of lighter constituent compounds or markers of explosives, or detection of meteorological data over long distances.

Fiber optic technology allows for creating less bulky and expensive two-micrometer lasers.

Researchers at the Photonic Systems Laboratory (PHOSL) at École polytechnique fédérale de Lausanne (EPFL) in Switzerland, led by Camille Sophie Brès, tenure track assistant professor, Photonic Systems Laboratory, have designed a lower cost fiber optic two-micrometer laser via changing the manner in which the optical fibers are connected to each other.

In the design of a two-micrometer fiber optic laser, light is typically injected into an optical-fiber ring that contains a gain region which amplifies the two-micrometer light. The light circulates in the ring, and as it passes through the gain region many times, the light increasingly gains power until it becomes a laser. For optimal operation, the systems can include an isolator, a costly component that forces the light to circulate in a single direction.

In contrast, the PHOSL, researchers built a thulium-doped fiber laser that operates without requiring an isolator. The concept involves connecting the fibers differently, to steer light instead of stopping it. Instead of using an isolator to stop light from moving in the wrong direction, the researchers created a deviation or detour that redirects the light heading in the wrong direction.

The system also can be capable of generating higher quality laser light. Due to the amplifying fiber's composition and dimensions and the high power circulating in the unusual laser architecture, the laser's output becomes purified since the light interacts with itself in a special way. Owing to the specialized architecture, the association of the amplifying fibers and high power improves, rather than weakens, the laser's performance.

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3. COST-EFFECTIVE METHOD TO MANUFACTURE SOLAR CELL SILICON WAFERS

The growing need to reduce global warming is increasing the adoption of clean energy all over the world. The most popular form of clean energy that is available in abundance is solar energy. Solar energy is harvested through solar cells. Solar cells and solar modules are used in variety of applications from lighting systems in homes and streets to huge solar power stations.

However, the cost of the solar cells is rather high, making its affordability restricted to a few people. Solar cells are typically made of silicon wafers. In fact, silicon wafers are the heart of most solar cells. However, silicon wafers are the expensive part of a solar cell. This high cost of silicon wafers can be attributed to the manufacturing costs associated with silicon wafers.

A group of researchers from Fraunhofer Institute for Solar Energy Systems ISE in Freiburg, Germany, has developed a new manufacturing technique that has opportunities to cut the costs of solar cell silicon wafers drastically. The novel manufacturing method saves raw materials by up to 50%. Similarly, this new method uses only 20% of the energy required compared to the existing wafer making processes.

Conventional manufacturing processes for making solar cell silicon wafers start with an impure form of silicon. The silicon is then melted. Chlorine is added into molten silicon to purify it. This result in the formation of a compound called chlorosilicane. For obtaining high-quality polysilicon, hydrogen gas is passed through chlorosilicane. However, for making solar cell wafers, the crystal structure of polysilicon is not suitable. Therefore, the chlorosilicane is melted at

1450 degrees C. This molten chlorosilicane is then grown using various methods to form silicon crystal blocks weighing from 200 kilograms to 1000 kilograms. Later, smaller square crystal blocks are cut from the large blocks, and these blocks are sawed to form small wafers that are placed inside solar cells. Nearly 50% silicon is wasted from the time chlorosilicane is melted and is finally sawed into wafers.

The new method developed by the Fraunhofer researchers takes an alternative approach. In this approach, after obtaining chlorosilicane, it is melted at 1000 degrees C and mixed with hydrogen gas. Soon after this, instead of letting the molten chlorosilicane form crystals randomly, the researchers make the molten silicon to grow in a desired form.

The desired crystal form from molten chlorosilicane is achieved with the help of a chemical vapor deposition (CVD) process. Basically, by using the CVD process, the gaseous silicon is made to deposit layer over layer with the required crystal structure on a substrate. Interestingly, the substrate here is another silicon wafer itself.

As the gaseous silicon passes over the silicon wafer substrate, it settles on the wafer surface and coats it in a crystalline form. Further, the wafers settle layer over layer with a thickness equal to the atomic size of a silicon atom. In this way, multiple layers of crystalline silicon wafers are formed. In order to remove each layer off the substrate, a mechanical breakpoint in the form of porous silicon is introduced on the substrate.

Another striking advantage of using the silicon wafer of the substrate is that it provides the necessary information for the required crystal structure for every new layer of wafer formed over it. This is a very important feature for solar silicon wafers because a specific crystal structure is required for silicon wafers to convert the incident sunlight into electricity.

This new approach to making solar silicon wafers eliminates the messy sawing process. This means that nearly 50% of the high-quality silicon used in the wafer making process is saved. Another advantage of the new process is that the wafer formed is very thin compared to the wafers formed using conventional methods. The thinner the wafer, the less it costs, which will further bring down the cost of solar cells.

In summary, all the advantages rendered by the new process are estimated to bring down the cost of a solar cell by half. The reduction in the cost of solar cells is expected to reduce the cost of solar modules by around 20%.

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4. 3D GLASS PRINTING TECHNOLOGY

The development of 3D printing and its growing ability to use various materials for printing is increasingly making the technology more robust and mature. In fact, technology development and increased market adoption have led to the introduction of substantially lower-priced 3D printers based on such technologies as fused deposition modeling/fused filament fabrication, digital light processing, stereolithography, and selective laser sintering.

Massachusetts Institute of Technology (MIT), USA, has developed three-dimensional (3D) printing technology that uses a powder bed and is similar to inkjet printing. Such technology has been licensed to other companies, including ExOne, founded as a spin-off of Extrude Hone Corp. (which licensed such technology in 1996).

Now, MIT has come up with another 3D printer and process that will open new possibilities with 3D printing technology.

The team of researchers from MIT has produced a 3D printer that can print structures and objects using transparent glass. In describing the feat of being able to use glass in 3D printing, the researchers explained that they were able to overcome the obstacles faced by several other teams attempting to 3D print objects using glass.

The biggest obstacle of all is to maintain an extremely high temperature required to melt glass. Many have attempted to overcome this obstacle by breaking the glass into tiny pieces and melting them using a technique called sintering at relatively low temperatures. However, the drawback of using sintering is that it weakens the structural integrity of glass and compromises other prominent attributes of glass such as strength and transparency. In order to overcome this limitation, the MIT researchers have developed a high-temperature system that is capable of melting glass, yet keeping its properties intact.

The entire 3D glass printing consists of an upper chamber, where the high temperature system is placed. This chamber serves as a kiln, where glass is melted and supplied for printing processes. The second component is the nozzle made up of an alumina-zircon-silicon compound through which the molten glass flows to form a glass object. The third component is the lower chamber, which is insulated and houses the platform on which the object is built.

The process of creating a glass object through 3D printing starts with melting the glass in the upper chamber. The high temperature system in the upper chamber heats to nearly 2000 degree C and melts the glass. The molten glass then flows through the nozzle. The nozzle is maintained at a temperature of 1900 degrees C. As the molten glass flows through the nozzle, it settles on the build platform in the lower chamber. The lower chamber is maintained at an optimum temperature. The temperature should be maintained in the lower chamber in such a way that the chamber is not as hot as the upper chamber, in which case the glass will lose its shape and becomes a lump. At the same time, the temperature should not be so low that glass starts solidifying quickly, which will break the lower layers which are relatively colder and hard as hotter molten glass settles over it.

The new 3D glass printing process opens up the possibility of not only creating complex designs and patterns on the outer surface of glass objects, but also producing intricate designs inside glass objects.

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5. PATENT ANALYSIS OF CHEMICAL VAPOR DEPOSITION PROCESS

Chemical vapor deposition (CVD) is a technique used to coat or deposit materials in the form of a thin film on wafers and other substrates. This technique is very commonly used in the semiconductor industry, where silicon wafers are coated with thin films of materials.

The process of CVD involves a reaction chamber, where the coating material is mixed with a suitable gas and introduced. Then heat is applied along with high voltage or other techniques to decompose the gas and the coating material. After decomposition, chemical reactions occur in the chamber and the coating material deposits on the substrate placed inside the chamber. The CVD technique is used to produce thin film coatings with high purity. The thickness of thin films deposited by CVD can range anywhere from a fraction of a nanometer (atomic thickness) to a few micrometers.

The evolution of 3D printing technologies has expanded the use of CVD in 3D printing nanostructures and in 3D bioprinting.

Exhibit 1 highlights some patents for chemical vapor deposition techniques filed in 2015 (to date). Patents filed this year indicate that a fair amount of research in the chemical vapor deposition technique is taking place all over the world.

One of the interesting patents, filed by Schunk Kohlenstofftechnik GMB (EP 2885443), pertains to a CVD apparatus to coat surfaces of substrates via chemical hot-filament vapor deposition using coated carbon fiber filaments. Another interesting patent is filed by inventor Hongxing Wang (WO/2015/074544) for a microwave plasma CVD process that includes a waveguide for introducing microwaves.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Method of coating substrate by chemical vapour deposition	July10, 2015/ US 0002555273	NA	Saiu	FIELD: chemistry. SUBSTANCE: present invention relates to a method of coating a substrate (2), having on its surface a material different from silicone rubber, or consisting of such material, by chemical vapour deposition using a flame. The method includes exposing the substrate to a burner flame (1), to which a stream of precursor elements which enable to obtain coating material is added. Without external cooling, the substrate is moved relative to said flame with a relative speed greater than 30 m/min while allowing the flame to stretch along the reaction zone (3) located behind the burner. EFFECT: obtaining a coating of good quality, particularly on heat-sensitive materials. 26 cl, 6 dwg
Method for preparation of a nanocomposite material by vapour phase chemical deposition	July 02, 2015/ US 20150188147	Commissariat a l'energie atomique et aux energies alternatives	Sophie Mailley	The invention relates to a method for preparing a nanocomposite material by simultaneous vapour phase chemical deposition and vacuum injection of nanoparticles and to the materials and nanopartides obtained thus and the application thereof.
Apparatus for chemical vapour deposition having carbon fibre filaments	June 24, 2015/ EP 2885443	Schunk Kohlenstofftechnik GmbH	Schneweis Stefan	The invention relates to an apparatus for coating surfaces of a substrate by the method of chemical hot-filament vapour deposition, wherein the filaments for thermal excitation of the reaction gases consist of carbon fibres which have a coating and the coating of the carbon fibre filaments can consist of one or more layers. Forming the filaments according to the invention of coated carbon fibres makes it possible to produce and use particularly thin wires. The coating enables, firstly, the chemical behaviour of the filaments to be influenced while, secondly, the coating can also serve to meet particular physical requirements, for example to influence the mechanical, electrical or thermal properties of the filament in a targeted manner. Furthermore, the invention relates to a process for producing coated carbon fibre filaments.
Microwave plasma chemical vapour deposition apparatus	May 28, 2015/ WO/2015/074544	Wang, Hongxing	Wang, Hongxing	The present invention provides a microwave plasma chemical vapour deposition apparatus, comprising: a waveguide apparatus (1) used for introducing a microwave, the waveguide apparatus (1) being connected to a reaction chamber (2) arranged thereunder, equally spaced reaction gas inlets (9) being arranged on the top of the reaction chamber (2); an isolation window (7) is arranged at the level of the connection between the waveguide apparatus (1) and the reaction chamber (2), said isolation window (7) being used for separating the waveguide apparatus (1) and the reaction chamber (2) such that the reaction chamber (2) maintains a pre-set degree of vacuum; and a sample platform (4) used for supporting a substrate holder (3) is arranged coaxially inside the reaction chamber (2), gas channels enabling reaction gas to flow into the reaction chamber (2) being provided around the periphery of the substrate holder (3). Using the present microwave plasma chemical vapour deposition apparatus, gas flow distribution can be changed, increasing the concentration of dopant element in the vicinity of the substrate holder surface such that the level of utilisation of dopant gas in the plasma is increased and film-forming effects are strengthened.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Thick polycrystalline synthetic diamond wafers for heat spreading applications and microwave plasma chemical vapour deposition synthesis techniques	June 17, 2015/ EP 2882890	Element Six Technologies Ltd.	Williams Gruffudd Trefor	A method of fabricating a polycrystalline CVD synthetic diamond material having an average thermal conductivity at room temperature through a thickness of the polycrystalline CVD synthetic diamond material of at least 2000 Wm-1K-1, the method comprising: loading a refractory metal substrate into a CVD reactor; locating a refractory metal guard ring around a peripheral region of the refractory metal substrate, the refractory metal guard ring defining a gap between an edge of the refractory metal substrate and the refractory metal guard ring having a width 1.5 mm to 5.0 mm; introducing microwaves into the CVD reactor at a power such that the power density in terms of power per unit area of the refractory metal substrate is in a range 2.5 to 4.5 W mm-2; introducing process gas into the CVD reactor wherein the process gas within the CVD reactor comprises a nitrogen concentration in a range 600 ppb to 1500 ppb calculated as molecular nitrogen N2, a carbon containing gas concentration in a range.5% to 3.0% by volume, and a hydrogen concentration in a range 92% to 98.5% by volume; controlling an average temperature of the refractory metal substrate to lie in a range 750oC to 950oC and to maintain a temperature difference between an edge and a centre point on the refractory metal substrate of no more than 80o C growing polycrystalline CVD synthetic diamond material to a thickness of at least 1.3 mm on the refractory metal substrate; and cooling the polycrystalline CVD synthetic diamond material to yield a polycrystalline CVD synthetic diamond material having a thickness of at least 1.3 mm, an average thermal conductivity at room temperature through the thickness of the polycrystalline CVD synthetic diamond material of at least 2000 Wm-1K-1 over at least a central area of the polycrystalline CVD synthetic diamond material, wherein the central area is at least 70% of a total area of the polycrystalline CVD synthetic diamond material, a single substitutional nitrogen concentration no more than 0.80 ppm over at least the central area of the polycrystalline CVD synthetic diamond material, and wherein the polycrystalline CVD synthetic diamond material is substantially crack free over at least the central area thereof such that the central area has no cracks which intersect both external major faces of the polycrystalline CVD synthetic diamond material and extend greater than 2 mm in lengt
Methods of fabricating synthetic diamond materials using microwave plasma actived chemical vapour deposition techniques and products obtained using said methods	May 21, 2015/ WO/2015/071484	Element Six Technologies Limited	Khan, Rizwan	A method of fabricating synthetic diamond material using a microwave plasma activated chemical vapour deposition technique is provided which utilizes high and uniform microwave power densities applied over large areas and for extended periods of time. Products fabricated using such a synthesis technique are described including a single crystal CVD diamond layer which has a large area and a low nitrogen concentration, and a high purity, fast growth rate single crystal CVD diamond material.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Method of obtaining epitaxial layer of binary semiconductor material on monocrystalline substrate by organometallic chemical vapour deposition	April 20, 2015/ RU 0002548578	NA	Burobin Valery A.	FIELD: chemistry. SUBSTANCE: invention relatesto microelectronics and can be used in producing epitaxial structures of semiconductor compounds A3B5 and A2B6 by chemical vapour deposition of organometallic compounds and hydrides. A method of producing an epitaxial layer of a binary semiconductor material on a monocrystalline substrate through organometallic chemical vapour deposition employs a reactor with a vertical reaction chamber which is circular relative to a central vertical axis, a horizontally mounted substrate holder, mounted in the reaction chamber to allow rotation about said axis, a circular shield mounted in said reaction chamber at a distance of about 15-40 mm over said substrate holder and having a larger diameter than said substrate holder, wherein a predetermined temperature of the uniformly rotating substrate holder is maintained, at least two reaction gases are separately fed into different radial sectors of the reaction chamber, wherein the reaction gases and a carrier gas are fed in a manner that allows flow thereof in a radial direction within the reaction chamber at the same rate at the same diameter in all sectors. EFFECT: improved quality of heteroepitaxial structures. 7 cl, 4 dwg
Chemical vapour deposition of thin films using metal amidinate precursors	April 08, 2015/ EP 2857549	Harvard College	Gordon Roy Gerald	The application discloses CVD of thin films employing amidinate complexes of the metals lithium, sodium, potassium, beryllium, calcium, strontium, barium, scandium, yttrium, lanthanum and the other lanthanide metals, titanium, zirconium, hafnium, vanadium, niobium, tantalum, molybdenum, tungsten, manganese, rhenium, iron, ruthenium, cobalt, rhodium, nickel, palladium, silver, Zinc, cadmium, tin, lead, antimony and bismuth as precursor. A novel cobalt precursor is also disclosed.
Apparatus for growing diamonds by microwave plasma chemical vapour deposition process and substrate stage used therein	March 05, 2015/ US 20150059647	IIa Technologies Pte. Ltd.	Devi Shanker Misra	An apparatus for growing diamonds, the apparatus comprising: one or more chambers, each chamber is in fluid connection with one or more other chambers, each chamber comprising one or more substrate stage assembly within the chamber to support a substrate stage having a plurality of diamond seeds disposed thereon.
Depositing doped ZnO films on polymer substrates by chemical vapour deposition under UV action	February 27, 2015/ RU 0002542977	NA	Xu Chen	FIELD: chemistry. SUBSTANCE: invention relatesto a method of forming a transparent doped layer containing zinc oxide on a polymer substrate for optoelectronic devices and a transparent doped layer. The method includes contacting a polymer substrate with at least one precursor containing a dopant and zinc, and exposing to ultraviolet light during chemical vapour deposition to decompose at least one precursor and deposit a layer on the polymer substrate. The polymer substrate is selected from a group consisting of fluoropolymer resins, polyesters, polyacrylates, polyamides, polyimides and polycarbonates. The contacting step is carried out at pressure approximately equal to atmospheric pressure. EFFECT: providing a chemical vapour deposition method for depositing doped zinc oxide films on polymer substrates for use in optoelectronics. 12 cl, 1 tbl, 8 dwg, 2 ex

Exhibit 1 lists patents for the chemical vapor deposition process.

Picture Credit: WIPO

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