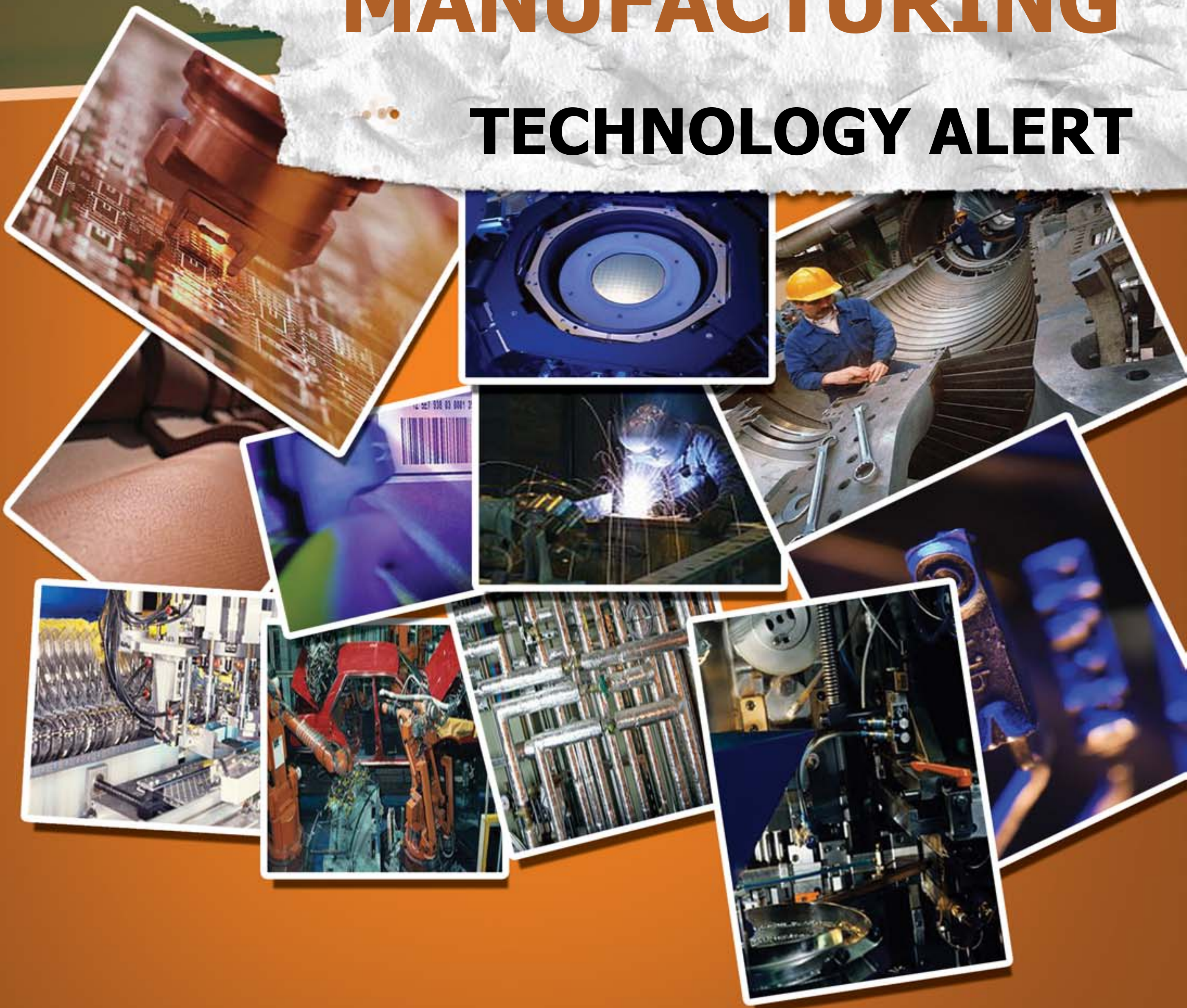
TECHNICAL INSIGHTS

ADVANCED MANUFACTURING

TECHNOLOGY ALERT



03 July 2015

1. ANALYSIS TOOL FOR TESTING OF MICRO- AND MACRO-STRESS LEVELS OF MATERIALS

Materials that are used for various applications by different industrial sectors are subjected to failure mode analysis to determine the point at which the materials undergo breakage. Until now, it has been difficult or impossible in some cases to study the stress levels of the materials at both micro- and macro scales simultaneously.

Researchers from the department of mechanical engineering and applied mechanics at the Penn's School of Engineering and Applied Science, University of Pennsylvania, USA, have developed a novel method, which enables the study of stress of materials at both micro and macro scales at the same time. This has been achieved by using a model system in which the microscopic particles are made to stand in for molecules. With this method, the researchers have been able to demonstrate a unique hybrid behavior in the model material which is a reversible rearrangement of its particles having the characteristics of a plastic deformation on the nanoscale.

The research that has been carried out could pave way for designing the above mentioned unique hybrid behavior into newer materials. The deformation of plastic materials usually dissipates the energy rather than transferring it, hence a material capable of deforming itself repeatedly in this way could be used for dampening of vibrations, thereby protecting it against impacts. The simultaneous investigation of macroscopic and microscopic behavior of a material that is under stress is a challenge especially for bulk materials since they are generally opaque. This opaque characteristic seen in bulk materials makes it difficult to see the inside of the material while maintaining the bulk properties. In order to make this possible, researchers have built a model material sacrificing the complexity for access.

The researchers have sacrificed the complexity in the third-dimension (3D), thereby developing a two-dimensional (2D) material in the lab consisting of microscopic particles placed on an oil-water interface. These particles consists of small electric charge that constantly keeps them pushing away from each other. This new material model also helped the researchers in studying a behavior model known as the yielding transition in which it was found how the particles of a disordered solid are jammed against each other and do not rearrange until there is an outside energy that is applied. The researchers used a needle that was also placed on the materials oil-water interface in the plane along with the other particles. By employing an electromagnetic field, the needle was made to swing back and forth against the particles thereby calculating the resistance that was provided by the particles. From the various experiments conducted using this model 2D material, it was found that by moving the needle repeatedly back and forth the particles arranged themselves in such a way that they came to the original state after the completing each cycle of deformation. This behavior has only been achieved in the material that has been developed by the researchers in the lab and they are currently working on understanding the conditions in which it arises, thereby incorporating it to materials that are used outside the lab. The researchers believe that it could be achieved and used on a large scale by 2016. This research has been funded and supported by the National Science Foundation through Penn's Material Science Research and Engineering Center.

The advantage of this novel model is that is that it can be used for incorporating the hybrid behavioral properties into newer materials that could be used for different applications. For instance, it can be used for materials that are employed for manufacturing the body of a car. When a car is subjected to a crash, the body car would be able to absorb the impact thereby deforming its shape without transferring the impact to the inside of the car. With the above advantages, this model can have potential to be used for a wide range of materials in the future.

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2. SMALL, LOW-POWER CARBON DIOXIDE SENSOR

Sensors for detecting carbon dioxide (CO_2) are typically used to monitor indoor air quality, particularly for demand control ventilation (DCV) in buildings. DCV allows for adjusting the outside ventilation air based on the number of occupants in a space and the ventilation demands of such occupants. This capability safeguards against using more energy than necessary by over-ventilating during periods of low occupancy.

Carbon dioxide is often detected using non dispersive infrared (NDIR) sensor technology. Such technology detects CO_2 based on the intensity of the wavelength of light absorbed by CO_2.

Such infrared carbon dioxide detectors can be relatively expensive, due to the components involved, which include an IR light source, sensing chamber, wavelength filter, and infrared detector. Infrared CO_2 sensors also can be susceptible to changes in barometric pressure variations and to aging.

Non-infrared carbon dioxide sensors, which are not as widely used as their infrared counterparts, can provide lower cost, smaller size, and less-power consumption. However, such non-infrared carbon dioxide sensors may be subject to drift or have a relatively limited lifetime.

Poly(ionic liquid)s (PILs), a sub-class of polyelectrolytes, have attracted keen interest due to their unusual physical properties compared to conventional polyelelctrolytes. PILs combine the physical-chemical features of ionic liquids with the flexibility, mechanical stability, and processability of polymers. However, it has been challenging to establish a method for easy synthesis of PILs.

Researchers at at ETZ Zurich (Switzerland) and the Max Planck Institute of Colloids ad Interfaces (Germany) have leveraged the benefits of PILs to develop a chemiresistive sensor to measure carbon dioxide concentration at room temperature. Such sensors, which consist of the polymers mixed with nanoparticles, can provide advantages such as smaller size, streamlined construction, and reduced power consumption. The sensor is made from a composite material (Poly[(*p*-vinylbenzyl)trimethylammonium hexafluorophosphate] and $La_2O_2CO_3$ (lanthanum oxycarbonate) nanoparticles, which are insulating materials and showed increased conductivity in the presence of CO_2 at concentrations between 150 ppm (parts per million) and 2400 ppm. The sensor undergoes a change in conductivity and electrical resistance based on CO_2 concentration.

It is significant that the chemiresistive sensor is able to achieve such conductivity at room temperature. Traditionally, sensors made of chemiresistive materials have shown such behavior only after being heated to a high operating temperature (around several hundred degrees celsius. The change in conductivity achieved in the newly developed sensor is likely due to a phenomenon in which a chemical change in the presence of CO_2 takes place mainly at the interface between the nanoparticles and the polymers at the nanometer level. The presence of CO_2 in the environment influences the mobility of the charged particles within the material.

The sensors can measure concentrations of CO_2 from 0.04 volume percent to 0.25 volume percent. The new material technology could enable new or expanding applications, such as portable air monitoring instruments for scuba diving, mountain climbing, or healthcare.

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3. ULTRASENSITIVE NANOPHOTONIC NEMS BIOSENSOR

Biosensors, which combine a biological component and a chemical detector, have key opportunities to detect a wide range of analytes. Nano-electromechanical systems (NEMS) technology has opportunities to enable smaller, lighter, lower power, and smarter biosensors. However, certain transduction techniques (such as electrostatic, thermal, piezoelectric, and so on) can limit the biosensor's capability in real-world conditions. Moreover, optical transduction techniques can be relatively complicated or expensive.

Researchers at the Moscow Institute of Physics and Technology (MIPT)'s Laboratory of Nanooptics and Plasmonics, Dmitry Fedyanin and Yury Stebunov, have developed a very compact, sensitive, monolithically integrated NEMS biosensor for analysis of the chemical composition of substances and detection of biological objects, which provides all-nanophotonic transduction and actuation. The device includes a nanophotonic waveguide with a nanobeam cantilever above the waveguide. Both the waveguide and the cantilever can be cost-effectively fabricated using the same complementary metal oxide semiconductor (CMOS)-compatible process. The cantilever can be very efficiently actuated. Its response, directly read out using the same waveguide, provides very high sensitivity along with single-molecule detection capability.

The nanomechanical biosensor can be beneficial for detecting biological substances such as viral disease markers, which occur when the immune system responds to serious diseases, such as HIV, hepatitis, herpes, and so on. The sensor has potential to help pinpoint markers present in the body. The markets can indicate the emergence and growth of cancerous tumors.

The optical sensor could enable earlier detection and diagnosis diseases, since it can track changes of just a few kilodaltons in the mass of a cantilever in real time. One dalton approximately equals the mass of a proton or neutron, and several thousand daltons correspond to the mass of individual proteins and DNA molecules.

The sensor does not have any complex junctions and can be fabricated via a standard CMOS process. The sensor has a simple design and does not use a single circuit. It is comprised of a photonic (plasmonic) nanowave guide for controlling the optical signal, and a micro-cantilever over the waveguide. The cantilever undergoes a few million oscillations per second.

Molecules adsorbed on the surface of the cantilever change the resonant frequency of mechanical oscillations or create a surface tension, resulting in the cantilever's bending. The magnitude of the transmitted optical signal and the frequency of modulation can be measured with a photodetector and indicate the mass of adsorbed molecules and the adsorption rate to provide an efficient, accurate transduction arrangement.

The cantilever's oscillations allow for determining the chemical composition of the environment. The frequency of mechanical vibrations depends on the materials' dimensions and properties and on the mass of the oscillatory system, which changes during the chemical reaction between the cantilever and the environment.

Suitable applications for the mew biosensor can include smart phones or wearable electronics. A single chip of several millimeters could contain several thousand sensors.

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4. PATENT ANALYSIS OF ULTRASONIC ADDITIVE MANUFACTURING PROCESS

Ultrasonic additive manufacturing, or ultrasonic consolidation, is a process based on employing a delicate welding process for joining strips of metal parts together thereby manufacturing a part containing one sheet of a metal. Ultrasonic additive manufacturing bonds the metal strips together using the ultrasonic welding process, which is a solid state welding technique where a bond is created without the metal being melted. The low temperature used in the ultrasonic welding process eliminates the brittleness that occurs in the layers of metals that are caused with other welding processes. This method also allows the metallic bonds to be formed between different metals.

One of the latest patent in ultrasonic additive manufacturing process, US 8581472 B2, is assigned to Nihon Dempa Kogyo Co. Ltd. The patent pertains to a method of manufacturing an ultrasonic probe that contains a signal foil made of copper foil patterned via an additive method. Nihon Dempa Kogyo Co. Ltd., has filed a number of patents for the ultrasonic additive manufacturing process.

Some of the other key innovators for this manufacturing process include Telsonic Holding AG (US 20130075454 A1), which pertains to a torsion sonotrode ultrasonic welding device and method; and Edison Welding Institute Inc. (EP 2544880 A1), which pertains to an ultrasonic welding assembly system for enhancing sonotrode performance in ultrasonic additive manufacturing.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Ultrasonic probe and manufacturing method thereof	November 12, 2013/ US 8581472 B2	Nihon Dempa Kogyo Co., Ltd.	Yasunobu Hasegawa	A manufacturing method of an ultrasonic probe that has a signal foil made of a copper foil patterned by an additive method is provided. The manufacturing method includes preparing a base material and forming an insulating layer on a surface of the material, patterning the insulating layer by exposure, development, and peeling according to a lithographic technique, forming a cavity reaching an upper surface of the base material in the insulating layer along the patterning, forming a signal foil by performing plating in the cavity in the order of copper plating and solder plating, and demolding the formed signal foil from the cavity.

Extrusion-based additive manufacturing system for 3D structural electronic, electromagnetic and electromechanical components/devices	July 11, 2013/ WO 2013103600 A1	Board Of Regents, The University Of Texas System	Ryan B. Wicker, Eric Macdonald, Francisco Medina, David ESPALIN, Danny W. MUSE	The present invention provides a system and method for making a three-dimensional electronic, electromagnetic or electromechanical component/device by: (1) creating one or more layers of a three-dimensional substrate by depositing a substrate material in a layer-by- layer fashion, wherein the substrate includes a plurality of interconnection cavities and component cavities; (2) filling the interconnection cavities with a conductive material; and (3) placing one or more components in the component cavities.
Torsion sonotrode, ultrasonic welding device and method for producing a welded connection by means of ultrasonic sound	March 28, 2013/ US 20130075454 A1	Telsonic Holding Ag	Albert Buettiker	The invention relates to a torsion sonotrode, comprising two mutually opposing end faces (S**1**, S**2**) and a circumferential surface (U) which surrounds a torsion axis (T) and on which at least one working surface (A**1**, A**2**, A**3**, A**4**) is provided at a radial distance from the torsion axis (T).
System for enhancing sonotrode performance in ultrasonic additive manufacturing applications	January 16, 2013/ EP 2544880 A1	Edison Welding Institute, INC.	Matthew A. Short	An ultrasonic welding assembly, comprising: a sonotrode having a single welding region and two nodal regions formed on either side of the welding region; a mounting plate for supporting the sonotrode having a force application region on the upper surface thereof; at least one ultrasonic transducer connected to the sonotrode; at least one diaphragm spring disposed between the ultrasonic transducer and the sonotrode; at least one roller bearing connected to the diaphragm spring; at least two linear guides connected to the roller bearing, wherein the at least two linear guides are connected to the mounting plate and support the roller bearing and the sonotrode in a flexible manner; and first and second low-friction linear bearings in contact with nodal regions for the application of downward force to the sonotrode, wherein the first and second linear bearings are connected to the mounting plate.
Method for producing a watch case middle of reduced weight	August 8, 2012/ EP 2485099 A2	Richemont International S.A.	Laurent Cataldo, Greg M. Morris, Eli Liechty	A method for producing a watch case middle (10) having reduced weight is disclosed. A 3-D data set is generated for the case middle, the model comprising at least one internal cavity (50) within the case middle. The 3-D data set is converted into a plurality of layers, each layer representing a cross-sectional layer of the middle, and then the case middle is formed layer-by-layer from powdered material using an additive manufacturing process such as DMLS in order to

				provide the case middle with a unitary construction. Loose powder is removed from each cavity via one or more powder evacuation holes (60,62) formed between the cavity and an external surface of the case middle, and a through hole (40,42) formed through the middle is machined to a desired finish and/or precision, the through hole being designed to receive a control member stem when a watch movement is mounted inside the middle.
Methods for fabricating gradient alloy articles with multi-functional properties	October 30, 2012/ WO 2013112217 A2	California Institute Of Technology	Douglas C. Hofmann	Systems and methods for fabricating multi-functional articles comprised of additively formed gradient materials are provided. The fabrication of multi-functional articles using the additive deposition of gradient alloys represents a paradigm shift from the traditional way that metal alloys and metal/metal alloy parts are fabricated. Since a gradient alloy that transitions from one metal to a different metal cannot be fabricated through any conventional metallurgy techniques, the technique presents many applications. Moreover, the embodiments described identify a broad range of properties and applications.
Methods for fabricating gradient alloy articles with multi-functional properties	October 30, 2012/ WO 2013112217 A2	California Institute Of Technology	BORGONIA, Robert P. DILLON, Eric J. SUH, Jerry L. MULDER, Paul B. GARDNER,	A method of fabricating a multi-functional multilayer article comprising: determining a shape for the article and defining at least two spatially separated regions on said article, said two regions to be formed of at least two distinct materials being joined by at least one compositional gradient transition region;
Ultrasonically-assisted extrusion methods for manufacturing powdered nutritional products	December 22, 2011/ Abbott Laboratories	Abbott Laboratories	Terrence B Mazer, Gary M Gordon, Rima Tabash	Disclosed are methods of manufacturing powdered nutritional products, including powdered infant formulas and powdered adult nutritional products, using extrusion. The methods include utilizing ultrasonic energy in the extruder during manufacturing. The application of ultrasonic energy to the extruder allows the fat globules present in raw materials to be effectively emulsified by hydrated protein present in the feed stream such that the resulting powdered extruded product has a low free fat level, is less susceptible to oxidation and rancidity, and can be reconstituted without substantial fat separation.

Surface roughness reduction for improving bonding in ultrasonic consolidation rapid manufacturing	May 24, 2007/ US 20070295440 A1	Stucker Brent E, Gabbita Durga J R	Brent Stucker, Durga Gabbita	A method for enhancing the bonding and linear weld density along the interface of material layers deposited in accordance with an ultrasonic consolidation manufacturing process, the method comprising: initiating an ultrasonic consolidation manufacturing process; depositing a first material layer having a contact surface; reducing surface roughness of the contact surface to prepare the contact surface to receive a subsequent material layer, the step of reducing facilitating an increased percentage and quality of material contact between the first and subsequent material layers; and bonding a subsequent material layer to the contact surface of the first material layer, as prepared.
Ultrasonic object consolidation system and method	October 8, 2002/ US 6463349 B2	Solidica, Inc.	Dawn White, David E.E. Carmein	Machine tools combine material addition via ultrasonic object consolidation and subtractive techniques for imparting high-dimensional accuracy to a finished object. A material supply and feeder, ultrasonic horn, and feedstock cutting device are integrated with a material removal subsystem preferably including a cutting tool and an excess material removal system. Any metal, plastic or composite material suitable for ultrasonic joining may be employed as a feedstock, and these material may assume the form of tapes, sheets, wires, filaments, dots or droplets, with the feeding and material cutting components being designed for the specific feedstock employed. The cutting tool for excess material removal, may be a knife, drill/mill, grinding tool, or other tool capable of accurately cutting the external contour of a cross section of the part being built, and for removing excess feedstock remaining following the application process. The material removal could consist of a vacuum or blower system, chip auger, or other suitable apparatus. A machine disclosed as part of the preferred embodiment is able to deposit material in one step, and optionally and selectively remove it in another. Through the expeditious combination of deposition and removal, the fabrication of objects of arbitrary shape may be realized.

Exhibit 1 depicts patents related to ultrasonic additive manufacturing process.

Picture Credit: Frost & Sullivan

5. TECHVISION 2015

The TechVision program is the premier offering of Technical Insights, the global technology innovation-, disruption-, and convergence-focused practice of Frost & Sullivan. TechVision embodies a very selective collection of emerging and disruptive technologies that will shape our world in the near future. This body of work is a culmination of thousands of hours of focused effort put in by over 60 global technology analysts based in six continents.

A unique feature of the TechVision program is an annual selection of 50 technologies that are driving visionary innovation and stimulating global growth. The selected technologies are spread across nine Technology Clusters that represent the bulk of R&D and innovation activity today. Each Cluster represents a unique group of game-changing and disruptive technologies that attract huge investments, demonstrate cutting-edge developments, and drive the creation of new products and services through convergence.

Our technology analysts regularly collect deep-dive intelligence on several emerging and disruptive technologies and innovations from around the globe. Interviews are conducted every day with innovators, technology developers, funders, and others who are a part of various technology ecosystems. The respondents are spread across public and private sectors, universities, research institutions, and government R&D agencies. Each technology is rated and compared across several parameters, such as global R&D footprint, year of impact, global IP patenting activity, private and public funding, current and emerging applications, potential adoption rate, market potential, and so on. This organic and continuous research effort spread across several technologies, regions, organizations, applications, and industries is used to generate an annual list of Top 50 technologies that have the maximum potential to spawn innovative products, services, and business models.

Furthermore, we analyse several possible convergence scenarios where two or more of the Top 50 technologies can potentially come together to disrupt, collapse, and transform the status quo. Driven by IP interactivity emanating from each of the top technologies, a whole range of innovative business models, products, and services will be launched at unprecedented speed in the future. We have come up with over 25 such unique convergence scenarios.

The Top 50 technologies we have selected for TechVision 2015 have the power to drive unique convergence and catalyse wide-scale industry disruptions. Frost and Sullivan's TechVision program empowers you with ideas and strategies to leverage the innovations and disruptive technologies that can drive the transformational growth of your organization.

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