TECHNICAL INSIGHTS

ADVANCED MANUFACTURING

TECHNOLOGY ALERT

12th June 2015

1. MINIATURE MEMS MICROVALVE FOR OPTIMIZED FLUID CONTROL

A valve regulates, directs or controls the flow of a fluid or gas by opening, closing, or partially obstructing a passageway. Valves are vital for manipulating fluid flow.

Micro-electromechanical systems (MEMS) miniature valves, made using microfabrication techniques, provide key benefits over conventional valves (such as, electromechanically operated solenoid valves that are controlled by an electric current through a solenoid). Advantages of MEMS-based micro valves include improved reliability, streamlined operation, and more compact size and weight.

MEMS micro valves are finding expanding opportunities in diverse application areas, including those other than lab-on-chip applications involving control of micro liters of fluid or gas flow. For example, MEMS micro valves can increase the efficiency and reliability of heating ventilation and air conditioning (HVAC) systems and refrigeration systems and can enable smaller, lighter, less expensive automobile transmissions.

In a development that further enhances the features and capabilities of micro valves for flow control in applications such as HVAC, refrigeration, and automotive, US-based DunAn Microstaq, Inc. (DMQ) has reduced the size of its silQflo™ silicon servo valve by 36%, compared to the previous version. The reduction in size can enable further, significant reductions in the size, weight, and cost of the user's system.

DMQ's silicon MEMS-based micro valve technology consists of three bonded silicon layers. The valve uses the principles of electro-thermal actuation to open and close flow ports. MEMS thermal actuators generate motion via electrically induced thermal expansion (a change in volume due to change in temperature

through heat transfer). Thermal expansion of part of the device results in a large amount of deflection in another part of the device.

DMQ's SilQflo silicon servo valve, a 3-way proportional flow control device, can be used stand alone or in conjunction with a flow amplifier providing macro flow from a micro device.

The all-silicon valve has only one moving element, which is micromachined into the silicon affording qualities similar to a solid state device. Silicon provides key benefits for MEMS devices, including high reliability. The material silicon is immune to fatigue with age or use, providing millions of actuations without change in performance. The silicon servo micro valve can be batch processed in high volumes with a manufacturing consistency equal to that of MEMS sensor products. The MEMS flow control device can help enable a range of new integration, packaging, and operational opportunities.

The initial application segment for DMQ's SilQflo device has involved electronic expansion valves for refrigerant flow control. The company has developed a turnkey system that includes measurement of pressure and temperature, electronic control, and actuation to optimize refrigerant flow, and thereby, the heat exchanger's efficiency. Other applications under development include automotive air conditioning, battery thermal management in electric vehicles, and drivetrain hydraulic systems such as those found in automatic transmissions.

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2. ULTRA-MINIATURE OPTICAL GYROSCOPE

Optical gyroscopes can offer highly reliable performance, and are free from certain mechanical effects that can impede the performance of conventional mechanical (such as, spinning mass) gyroscopes. Optical gyros are used in such applications as aircraft navigation.

Researchers at Staten Island College, City University of New York, are working on a device that may result in the smallest gyroscope. The manipulation of two light waves spinning around a microscopic track—one rotating clockwise, the other counterclockwise—may result in a device that measures a fraction of

the width of a human hair. Such a tiny, light-weight gyroscope would, for example, be beneficial for air or space travel.

In contrast to mechanical gyroscopes, optical gyroscopes have no moving parts. Mechanical gyroscopes use Newtonian laws of motion for stability and orientation; however, the same physics principles do not apply to light, which requires measuring motion by looking for subtle and specific optical signals instead, such as the Sagnac effect.

The Sagnac effect phenomenon creates an interference pattern because of light waves splitting and then recombining when leaving a spinning system; this pattern is measurable. Commercial optical gyroscopes employing the Sagnac effect can vary in size from about that of a baseball to a basketball. If made much smaller, measurements would need a higher level of sensitivity than is currently available.

There are two approaches for making optical gyroscopes based on the Sagnac effect. In one, light is confined using an optical cavity, and in the other, light is guided using an optical fiber. To miniaturize the package, optical cavities seem to be the preferable option, where the Sagnac effect is evidenced as a subtle color change. However, the sensitivity of this type of optical gyroscope degrades as the cavity becomes smaller.

The researchers overcame this hurdle due to the Sagnac effect by using a principle based on far-field emission. Instead of measuring the color change of the light waves, the researchers measured the pattern the light produced as it went out of the cavity.

To initiate the optical gyroscope, light waves are pumped into the optical cavity. This process produces light waves traveling in both clockwise and counterclockwise directions. The researchers designed the shape of the optical cavity so as to precisely control where both waves would exit. They needed to balance the light trapping properties of the cavity with the requirement for some light to escape to create a far-field emission pattern. To observe the pattern, the researchers placed a pair of camera-like detectors facing the cavity at different angles that move along with the cavity. This technique enabled continuous monitoring of the pattern for distortions that would reveal the speed of rotation.

Although this technique reveals only one plane of motion, multiple sensors at different orientations would be able to provide a three-dimensional view of how the object is moving. Further work is needed to enable many light paths to exist

simultaneously in the cavity. The far-field emission patterns may change in different ways, causing a reduction of the sensitivity to rotation.

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3. ULTRASENSITIVE MAGNETIC FIELD DETECTOR

Advancements in magnetic field sensing technology are considerably driven by the need for enhanced sensitivity, miniaturization, power consumption or energy efficiency in key applications, and more seamless compatibility with electronic systems.

Addressing key challenges in magnetic field sensing, researchers from US-based Massachusetts Institute of Technology (MIT) developed an ultrasensitive magnetic-field detector. The device leverages laser probing of nitrogen vacancies in diamonds and is described as 1,000-fold more energy-efficient than its predecessors. Nitrogen vacancy magnetometers have potential for measuring magnetic fields with high sensitivity and spatial resolution under ambient conditions.

Synthetic diamonds with nitrogen vacancies (NVs) have had potential for application in efficient, portable magnetometers. (Nitrogen vacancies are defects that are very sensitive to magnetic fields.) A diamond chip measuring about one-twentieth the size of a thumbnail could contain trillions of nitrogen vacancies, each one able to conduct its own magnetic-field measurement.

However, there have been issues in aggregating all of the measurements. A nitrogen vacancy is probed with laser light. The intensity of the emitted light conveys information about the vacancy's magnetic state. Traditionally, only a fraction of the pump light was used to excite a fraction of the NVs. In contrast, the MIT researchers use nearly all of the pump light to measure almost all of the NVs.

A pure diamond comprises of a lattice of carbon atoms that do not interact with magnetic fields. A nitrogen vacancy is a missing atom in the lattice, adjacent to a nitrogen atom. Electrons in the vacancy interact with magnetic fields and, therefore, can be applied for sensing.

When struck by a light particle (or photon), an electron in a nitrogen vacancy goes into a higher energy state. When the electron returns to its original energy state, the excess energy could be released as another photon. However, a magnetic field can flip the electron's magnetic orientation, or spin, which increases the difference between its two energy states. This phenomenon affects the brightness of the light emitted by the vacancies.

To achieve accurate measurements with this type of chip, it is important to collect as many of the photons as possible. In prior experiments, the researchers excited the nitrogen vacancies by directing laser light at the surface of the chip. Only a minute amount of light could be absorbed, while the bulk of the light would pass through the diamond. The researchers benefitted by adding a prism facet to the corner of the diamond and coupling the laser into the side. All of the light sent into the diamond could be absorbed and utilized.

The researchers calculated the angle at which the laser beam should enter the crystal so that it will remain confined, bouncing off the sides in a pattern that spans the crystal’s length and breadth before all of its energy is absorbed. Close to a meter in path length can be attained; so the chip uses the pump laser's energy 1,000 times as efficiently compared to its predecessors. Due to the geometry of the nitrogen vacancies, the re-emitted photons emerge at four angles. Reliable measurement cab attained, since a lens at one end of the crystal can collect 20% of such photons and focus the photons onto a light detector.

The magnetic field detector developed by the MIT researchers has potential to lead to miniaturized, battery-powered devices for applications such as medical and materials imaging, contraband detection and geological exploration.

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4. PATENT ANALYSIS OF COMPRESSION MOLDING PROCESS

Compression molding is an established processing method used in the plastics industry to mold plastics into different shapes. This molding method is very commonly used in making parts from thermoset plastics. Thermoset plastics, in the form of granules or preforms are used as raw materials for the compression molding process.

First, the raw materials are placed on a heated open mold cavity. Then, the plastic is forced to attain the shape of the mold by initially closing the open mold, and then applying pressure to the mold. Under pressure and heat, the plastic eventually takes the shape of the mold. The heat and pressure is maintained constantly throughout the molding process.

From the patents listed in Exhibit 1, it can be seen that the research is being carried out for developing compression molding tools and processes for new materials. This ongoing development in the compression molding process is enabling more materials other than plastics to be molded using this process. For example, Patent US 20150000858, assigned to Apple Inc., pertains to an injection compression molding process for molding amorphous alloys (bulk metallic glass).

Another interesting patent in this process is patent US 20150128359, assigned to Nike Inc., that pertains to making low density foamed articles using a compression molding process, where thermoplastic polyurethane foam beads are used as raw materials.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Compression molding of composite structures using flexible tooling	May 14, 2015/ US 20150129118	The Boeing Company	Gregory James Schoepen Hickman	A tool for compression molding a composite laminate charge has a tool face for compressing the charge. A flexible tool feature on the tool face forms a shape in the charge and compensates for tool surfaces that may be out-of-tolerance.
Low density foamed article made by bead foam compression molding method	May 14, 2015/ US 20150128359	Nike Inc.	Hossein A. Baghdadi	Disclosed is a molded foamed article, such as a midsole or outsole for footwear, made by a method in which a desired amount of thermoplastic polyurethane foam beads are placed in a compression mold in the shape of the article and the mold is brought to a peak temperature of from about 130° C. to about 180° C. over a period of from about 300 to about 1500 seconds, then cooled to from about 5° C. to about 80° C. over a period of from about 300 to about 1500 seconds within about 30 seconds after the peak temperature is reached. The foamed article made by the method has a density of from about 0.1 to about 0.45 g/cm3
Injection compression molding system and method	May 7, 2015/ WO/2015/066435	Cadillac Products Automotive Company	Zander, Robert J.	An injection compression molding system includes a mold having a fixed first half and a displaceable second half. The second half is initially positioned with a cavity between the mold halves having a first clearance sized to receive a molten material puddle shot injected by an injection molding device without the puddle shot filling the cavity. A displacement device acts during or immediately after puddle shot injection, displacing the second mold half toward the first mold half creating a second clearance less than the first clearance. The second clearance defines a finished part thickness whereby displacement of the second mold half to the second clearance compresses the puddle shot so that the puddle shot fills the cavity and forms a finished part between the mold halves. Total time to inject and compress the puddle shot is less than or equal to 1.0 seconds.
Rotary-type powder compression molding device and method of operating same	April 02, 2015/ WO/2015/045473	Hata Iron Works Co. Ltd.	Wada, Yasunori	Provided is a method of operating a powder compression molding device with which the mass and thickness of a molded product manufactured by compressing powder are maintained within a standard range irrespective of changes in the temperature of a powder compression molding machine. An estimated pressure variation and a thickness variation when the mass of a molded product is controlled are obtained, and the thickness variation and the mean thickness are used to obtain an estimated thickness. An estimated pressure variation and an estimated punch tip gap when the thickness of the molded product is controlled on the basis of the estimated thickness are obtained, and the set value of the punch tip gap is updated using the estimated punch tip gap. In conjunction with this, the estimated pressure variation values and the mean molding pressure value are used to obtain an estimated pressure control reference value, the pressure control reference value is updated using this estimated value, and a control pressure value in a pressure control unit is updated. The mass and thickness of the molded product are maintained within the standard range by updating the set value of the punch tip gap to control the punch tip gap, and by updating the control pressure value in the pressure control unit to control the molding pressure in this way while the molding machine is being operated.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Compression molding fastener	April 01, 2015/ EP 2852483	Continental Structural Plastics Inc.	Johnston Christopher	A method for forming an elevated surface feature for compression molded assemblies includes the placement of an afore-mentioned insert onto an actuated fixture pin with the pin initially in a retracted position. An upper portion of a mold configured with said retracted actuated fixture pin over a preform of pre-preg plies placed on the bottom portion of the mold is then closed. The fixture pin is actuated towards the pre-preg plies when a flowable material fills a molding cavity in the upper portion of the mold. The cavity is configured to form the elevated surface feature with the advancing action of the insert packs out the surface feature under the pressure of the pin to eliminate porosity in the elevated surface feature in the molding cavity.
Release film, compression molding method, and compression molding apparatus	March 12, 2015/ US 20150072139	Dow Corning Toray Co. Ltd.	Yoshitsugu Morita	The present invention relates to a release film used by being interposed between a molding material and a mold when the molding material is compression molded using the mold in order to form a sealing material or reflective frame material for an optical semiconductor element, or a lens, wherein the release film comprises a silicone-based cured product layer (2) on at least a surface in contact with the molding material; as well as a compression molding method that uses the film; and a compression molding apparatus that uses the film. The release film for the compression molding of molding materials has good workability and has good releasability, and thereby, a compression molding method with which compression molding with good efficiency is possible and a compression molding apparatus with which molding with good efficiency is possible.
Injection compression molding of amorphous alloys	January 1, 2015/ US 20150000858	Apple Inc.	Waniuk Theodore A.	Various embodiments provide methods and apparatus for forming bulk metallic glass (BMG) articles using a mold having a stationary mold part and a movable mold part paired to form a mold cavity. A molten material can be injected to fill the mold cavity. The molten material can then be cooled into a BMG article at a desired cooling rate. While injecting and/or cooling the molten material, the movement of the movable mold part can be controlled, such that a thermal contact between the molten material and the mold can be maintained. BMG articles can be formed without forming an underfilled part. Additional structural features can be imparted in the BMG article during formation. At least a portion of the formed BMG article can have an aspect ratio (first dimension/second dimension) of at least 10 or less than 0.1.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Liquid compression molding encapsulants	September 09, 2014/ US 08847415	Henkel Corporation	Bai Jie	Thermosetting resin compositions useful for liquid compression molding encapsulation of a silicon wafer are provided. The so-encapsulated silicon wafers offer improved resistance to warpage, compared to unencapsulated wafers or wafers encapsulated with known encapsulation materials.
Thermal magnetic multi-field coupling electronic control magnetofluid compression molding 3D printing forming device and method	August 27, 2014/ CN 104002483	Beijing University of Chemical Technology	Yang Weimin	The invention discloses a thermal magnetic multi-field coupling electronic control magnetofluid compression molding 3D printing forming device and a method. The device is mainly composed of a conveying system, a temperature control system, a control system, a printing system and the like. The conveying system is composed of a motor, a conveying belt, a conveying guide rail and the like. The temperature control system is composed of an electromagnetic heater and a temperature sensor, the temperature sensor is connected with the electromagnetic heater, the temperature of magnetofluid is controlled by the temperature sensor, and the magnetofluid is made to reach optimized thermal molding forming temperature. The control system achieves control of an integrated system. The printing system is composed of a drawing meter, a permanent magnet, a magnetofluid vessel, the magnetofluid and the like. According to the thermal magnetic multi-field coupling electronic control magnetofluid compression molding 3D printing forming device and the method adopting the device, thermal molding forming is carried out on foam materials through high-temperature magnetofluid wave crests generated with the drawing meter as the center, the 3D printing technology is adopted, a compacting tool set or roller embossing equipment is avoided, cost is reduced, efficiency is improved, and patterns in any complex shape can be formed.
Powder filling device with redundant powder collection mechanism, and rotary compression molding machine	August 21, 2014/ US 20140234463	Kikusui Seisakusho Ltd.	Ozeki Yuichi	Disclosed is a powdery material filling device with a redundant (i.e., excess or waste) powdery material recovering mechanism. The powdery material filling device may be used in a rotary compression molding machine. In certain aspects, the redundant powdery material recovering mechanism is capable of actively recovering and reusing a redundant (i.e., excess or waste) powdery material even upon production of multi-layer tablets.

Exhibit 1 depicts patents related to compression molding 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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