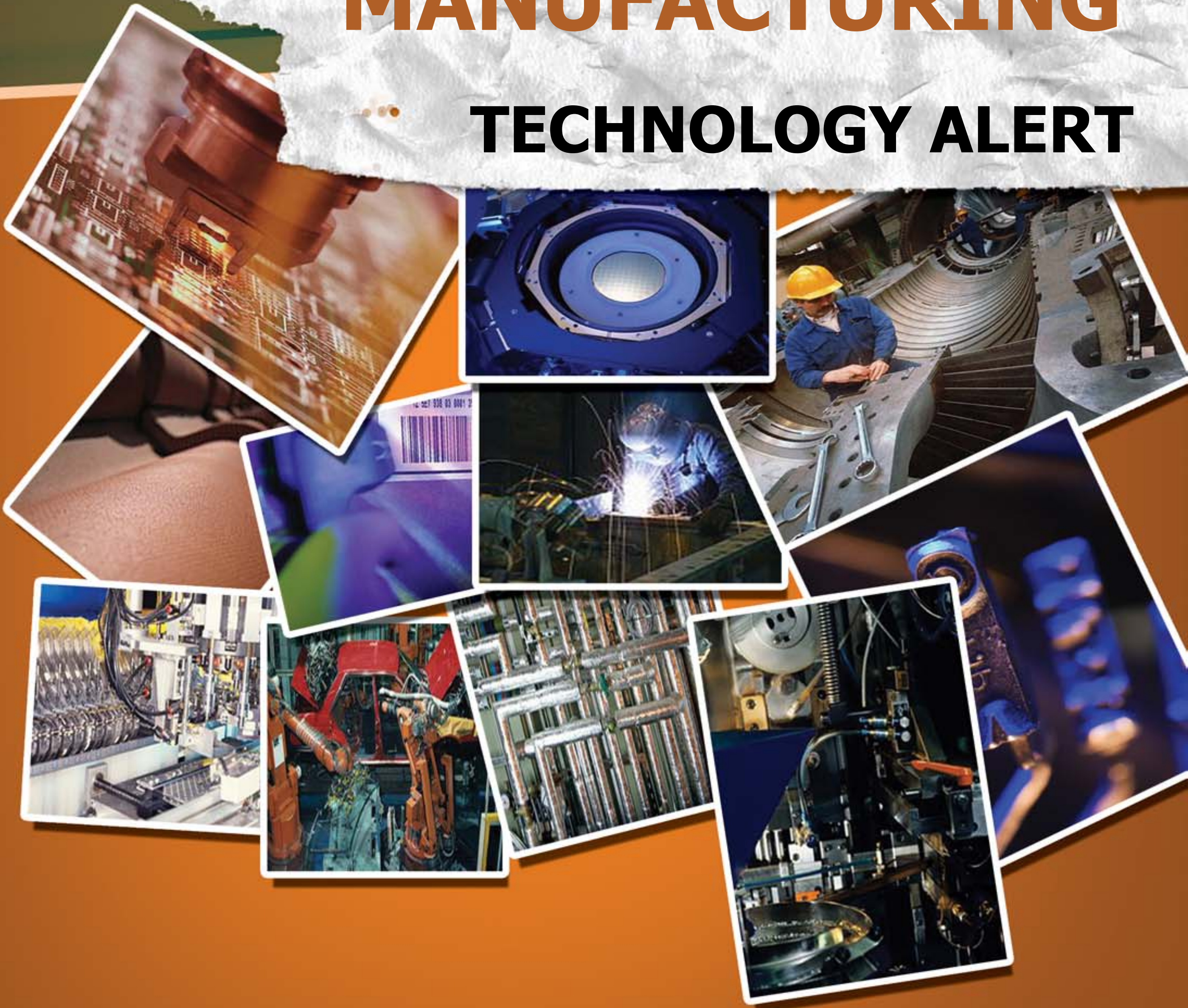
TECHNICAL INSIGHTS

ADVANCED MANUFACTURING

TECHNOLOGY ALERT



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1. BEST PRACTICES FOR WELDING OF TITANIUM ALLOYS

Titanium metal is widely used in the aerospace industries to save weight in aircraft, as well as in chemical process plants, for its exceptional corrosion resistance in oxidizing environments. Welding of titanium (Ti) metal components does require methods that differ from steel. This is related to the fact that Ti, unlike steel, is a highly reactive metal that has an exceptional affinity for oxygen. In fact, immediately upon exposure to air (containing around 20% oxygen), a thin, transparent and tenacious titanium oxide protective film will form on the Ti metal surface.

Given the reactivity of Ti in air, inert gas welding processes are mandatory. That includes tungsten inert gas (TIG) arc welding, also known as gas tungsten arc welding (GTAW), plus certain plasma welding methods. The preferred inert gas is argon (Ar), which must be very pure (99.995 %). The Ar continues to flow until the welding zone has cooled below 500 degrees F. A trailing shield can concentrate the Ar while the seam cools. The welding apparatus can be manual or automated in computer numerical control (CNC) apparatus for more consistent welds.

TIG uses a tungsten electrode to strike an arc with the Ti work piece. It may be necessary to Ar-shield both the front and back of the weld seam. If not shielded properly, the Ti weld zone will become useless and brittle. A Ti weld done nicely will have a shiny silvery surface (like frozen mercury in appearance) matching the color of the workpiece. A bad weld is immediately evident by discoloration (such as blueing) of the weld seam.

Exhibit 1 depicts TIG welding of Ti tubing.

Picture Credit: http://www.thefabricator.com/article/arcwelding/tig-for-titanium-tubing

Experts in TIG welding of TI urge that the welder must start with a clean workpiece (free of grease, oxides, oil and other undesirable contaminates). In the critical heating zone of 900 to 1000 degrees F, Ti can unfortunately form a brittle oxygen-stabilized alpha phase (also known as alpha case) on the weld surface. That is why Ar shielding is recommended for the back side (as well as front side) of a hot weld. TIG welding of stainless steel, by contrast, has no such requirement, illustrating again how fussy Ti is during welding operations. Grinding wheels that inadvertently raise TI surfaces to 900-1000 degrees F in air can ruin the exterior with brittle alpha case.

Details: Larry Rinek, Senior Technology Consultant, Technical Insights, Frost & Sullivan, 331 E. Evelyn Avenue, suite 100, Mountain View, CA 94041. Phone: 650-475-4521. E-mail: lrinek@frost.com. URL: www.ti.frost.com

2. NOVEL METHOD TO DEVELOP THERMOELECTRIC MATERIALS

Every electronic device, ranging from cars, laptops, and other devices that are used on an everyday basis, consumes a significantly high amount of energy through heat loss. In order to counter the above-mentioned challenge, thermoelectric materials are used for converting heat to electrical power and vice versa. These materials have the potential to harness the heat that is wasted, thereby providing green technology energy efficiency that is required for a sustainable future. To create the technology needed to capture this heat, researchers around the world have been trying to engineer more efficient thermoelectric materials. Among the promising materials is one that is filled with tiny holes that range in size from about a micron to about a nanometer. Heat travels through a material through phonons, which are quantized units of vibration that act as heat-carrying particles. When a phonon runs into a hole, it scatters and loses energy. Phonons thus cannot carry heat across a porous material as efficiently, giving the material low thermal conductivity, which in turn increases the efficiency of electricity that is obtained from heat.

A group of researchers from the American Institute of Physics has developed a novel method to manufacture thermoelectric materials that address the above-mentioned challenges and develop thermo electric materials with significantly high efficiency. In this method, the pores of the thermo electric material have been made smaller and packed closely together, thereby lowering thermal conductivity. Based on various tests, it has been found out that the theoretical calculations made by the researchers have matched with the practical experiments. It has been also been found that the micro-and nano-porous materials can be significantly more efficient when compared to the conversion of heat energy into electricity by materials containing no pores.

The researchers had developed four different models for their experiments. In the first model, the researchers had used material filled with holes of random sizes, ranging from microns to nanometers in diameter. The second model had multiple layers in which each layer containing pores of different size scales, thereby giving it a different porosity. The third is a material that was composed of a three-dimensional cubic lattice of identical holes. The fourth is another multilayered system. From the analysis of the above-mentioned models, it was seen that the first and fourth models have lower thermal conductivity than the second. The third model was found to be having lower thermal conductivity than the fourth model. It was also found that the method used in the first model would be more suited for the development of materials that are to be used in the devices.

The advantage of this method is that it significantly increases efficiency of products manufactured with the developed thermoelectric materials. All the above-mentioned capabilities and advantages increase its chances of adoption in variedf industrial sectors.

Details: Jason Bardi, Director, Media Relations, American Institute of Physics, One Physics Ellipse College Park, MD 20740. E-mail: jbardi@aip.org. Phone: 301-209-3091. URL: www.aip.org.

3. TECHNIQUE TO DEVELOP LIGHTWEIGHT AUTOMOTIVE AND AEROSPACE COMPOSITES

The sandwich construction of materials is used on a large scale by a wide range of manufacturing industries in different industrial sectors. For instance, the automotive and aerospace sectors are known to have the above type of construction in their materials for manufacturing different products. The manufacturers of turbine blades are looking for newer methods to achieve the precise performance requirements of turbine blades and other sophisticated applications. In order to meet the above-mentioned requirements, turbine manufacturers are looking for novel sandwich construction and material options.

Researchers from the Harvard School of Engineering and Applied Sciences (SEAS) and the Wyss Institute for Biologically Inspired Engineering have developed cellular composite materials that have unprecedented stiffness and are light in weight. The material has been developed using a cocktail of fiber-reinforced epoxy-based thermosetting resins and 3D extrusion printing techniques. Due to the mechanical properties and fine scale fabrication of the novel material that has been developed, it has significantly high potential in the manufacturing of turbine blades. The researchers also believe that it has the potential to mimic and improve conventional materials, such as wood and even the commercial 3D-printed polymers and polymer composites that are currently available. Until now, 3D printing has tended to be developed for thermo plastics and UV curable resin materials that are not typically considered as engineering solutions for structural applications. By moving into new classes of materials, such as epoxies, the researchers believe that they have opened up new applications sectors for 3D printing, enabling its use in the construction of lightweight products. The direction in which the fillers are used for depositing the ink controls the strength of the materials. Using the technique adopted by the researchers yields cellular composites that are as stiff as wood, 10 to 20 times stiffer than commercial 3D-printed polymers, and twice as strong as the best printed polymer composites. The ability to control the alignment of the fillers has enabled the researchers to digitally integrate the composition, stiffness, and toughness of an object with its design. Some of the potential applications of the research are in varied industrial sectors, such as automotive, where lighter materials hold the key to achieving reduced fuel standards. It is also seen that the lightweighting of parts used in automotive products will allow significantly high savings in terms of money spent on fuel.

The advantage of this novel technique is that it can opes up potential market sectors for 3D printing technology and also help in manufacturing light weight components for various products.

Details: Paul Karoff, Executive Director of Communications, Harvard SEAS, 29 Oxford Street, Cambridge, MA 02138. E-mail: karoff@seas.harvard.edu. Phone: 617-496-0450. URL: www.harvard.edu

4. PATENT ANALYSIS OF SOLID STATE SINTERING PROCESS

Sintering pertains to heat treatment of powder at elevated temperature. The solid state (or laser) sintering process is a type of layer manufacturing process employed forfabricating a wide variety of three-dimensional (3D) parts which have a complex geometry. In this process, the parts are manufactured by merging consecutive layers of powder material on top of each other. Consolidation of the powdered particles on top of each other is carried out using thermal energy. A focused laser beam is used in this process for developing the thermal energy that is required. Each layer of the powdered particle is examined with galvano mirrors and is correlated with the corresponding cross sectional area that is calculated from the computer-aided design model.

From the patents exhibited below, the recent filings indicate that companies are carrying out research to improve the methods, processes, and materials to carry out this manufacturing process in order to increase the overall efficiency and increase the quality of the products manufactured using this process. For example, Patent WO2010045382 A1, assigned to The Boeing Company, refers to a geometry adaptive laser sintering system and process. Patent EP 1694875 B1, assigned to The ExOne Company, pertains to processes for sintering aluminum and aluminum alloy components.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Impregnated sintered solid state composite electrode, solid state battery, and methods of preparation	March 1, 2013/ WO 2013130983 A2	Excellatron Solid State, Llc	Joykumar S. THOKCHOM, Davorin Babic, David Ketema JOHNSON, Lazbourne Alanzo ALLIE, Lonnie G. Johnson, William Rauch	An impregnated solid state composite cathode is provided. The cathode contains a sintered porous active material, in which pores of the porous material are impregnated with an inorganic ionically conductive amorphous solid electrolyte. A method for producing the impregnated solid state composite cathode involves forming a pellet containing an active intercalation cathode material; sintering the pellet to form a sintered porous cathode pellet; impregnating pores of the sintered porous cathode pellet with a liquid precursor of an inorganic amorphous ionically conductive solid electrolyte; and curing the impregnated pellet to yield the composite cathode.
Processing of iron aluminides by pressureless sintering of elemental iron and aluminum	August 15, 2012/ EP 2425027 A1	Philip Morris USA Inc.	Seetharama C. Deevi, Shalva Gedevanishvili	A pressureless sintering process for producing FeAl wherein the heating rate is controlled in a manner which minimizes expansion of a mixture of elemental powders of iron and aluminum. During the process, the heating rate is maintained below 1 °C/min to minimize the volume expansion during the formation of the intermediate phase Fe_2Al_5. As a result of the process, the final density can be increased up to 95 % of the theoretical density. The sequence of phases formed during the heating of Fe+Al mixture were identified by X-ray diffraction, optical microscopy, SEM and along with DSC data were correlated to the expansion and shrinkage behavior of the samples.

Ore fine agglomerate to be used in sintering process and production process of ore fines agglomerate	November 17, 2010/ WO 2011061627 A1	Vale S.A.	Pimenta Hamilton Porta, Castro Dutra Flavio De	An ore fine agglomerate to be used in a sintering process is disclosed, wherein the ore fine agglomerate is formed by a mixture of ore fine particles and an agglomerating agent, and wherein the particles have diameters between 0.01 mm and 8.0 mm. A production process of ore fines agglomerate is disclosed comprising the steps of using ore fine particles with a granulometry lower than 0.150 mm, mixing the ore fine particles with an agglomerating agent in a ratio of 0.5 to 5.0% by mass of sodium silicate, forming wet particles with diameters between 0.01 mm and 8.0 mm with an addition of water, and drying the wet particles at a temperature varying from 100°C and 150°C to form dry particles that are resistant to mechanical efforts and the elements.
Process for sintering nanoparticles at low temperatures	March 24, 2010/ EP 2411560 A1	Yissum Research Development Company of the Hebrew University of Jerusalem, Ltd.	Michael Grouchko, Alexander Kamyshny, Shlomo Magdassi	A process for sintering nanoparticles (NPs) on a substrate, the process comprising contacting said NPs with at least one sintering agent at a low temperature, thereby obtaining a sintered pattern on said substrate.
Geometry adaptive laser sintering system and process using the same	October 14, 2009/ WO 2010045382 A1	The Boeing Company	David M. Dietrich, Richard L. Eason	An apparatus comprises a deformable platform (530) and a laser delivery system. The deformable platform (530) has a surface capable of changing to conform to a shape of an object as the object is being manufactured during a sintering process. The laser delivery system is capable of sintering powder on the deformable platform to manufacture the object.
Solid-state image capturing device; manufacturing method for the solid-state image capturing device; and electronic information device	August 28, 2008/ US 20090078974 A1	Sharp Kabushiki Kaisha	Kenichi Nagai, Noboru Takeuchi, Kazuo Ootsubo, Yuji Hara	A solid-state image capturing device is provided with a plurality of light receiving elements arranged on a surface section of a semiconductor substrate, a color filter of each color for each of the plurality of light receiving elements, and a plurality of microlenses each for condensing incident light into each of the plurality of light receiving elements, in which the interlayer insulation film is provided directly below the color filter of each color in a state where a passivation and hydrogen sintering process film is removed from the interlayer insulation film.

Process for producing sintered porous materials	June 27, 2006/ EP 1896379 B1	K.U.Leuven Research & Development	Jan Fransaer, Bram Neirinck, Der Biest Omer Van, Jozef Vleugels	The invention provides a process of making porous structures or materials, including the colloidal processing (e.g. slip casting, pressure casting, tape casting or electrophoretic deposition) of solid particle emulsions to form a green body that can be directly sintered without a de-binding step.
Processes for sintering aluminum and aluminum alloy components	December 1, 2003/ EP 1694875 B1	The Ex One Company	Jianxin Liu	Methods for sintering aluminum powder comprise providing aluminum powder and heating the aluminum powder in a nitrogen atmosphere containing a partial pressure of water vapor in the range of about 0.001 kPa to about 0.020 kPa to sinter the aluminum powder to a transverse rupture strength of at least about 13.8 MPa. The aluminum powder is not pressed together by a mechanical force that substantially deforms particles of said aluminum powder either prior to or during the step of heating. Articles comprising sintered aluminum powder. The sintered aluminum powder has a transverse rupture strength of at least about 13.8 MPa. The microstructure of the sintered aluminum powder contains no compositional concentration gradients indicative of the use of a sintering aid and no evidence of particle deformation having occurred by an application of a mechanical force prior to or during the sintering of the aluminum powder.
Process for forming 312 phase materials and process for sintering the same	December 21, 2000/ EP 1268362 B1	Sandvik Intellectual Property AB, Drexel University	Tamer El-Raghy, Michel W. Barsoum, Mats Sundberg, Hans Pettersson	Metals are generally easily machined but do not retain their machined form at high temperatures. Ceramics retain their shape at extremely high temperatures, but are brittle and very difficult to machine into a desired shape. Materials scientists have directed a great deal of effort towards finding compositions that are easily machined into a desired shape and are stable at extremely high temperatures.
Simplified deformation-sintering process for oxide superconducting articles	April 1, 1998/ EP 0832050 A2	American Superconductor Corporation	William L. Carter, Qi Li, Alexander Otto, Eric R. Podtburg, Gilbert N. Riley, Jr., Martin W. Rupich, Elliott Thompson, Patrick John Walsh	A method is described to prepare a highly textured oxide superconductor article in a single deformation-sinter process. A precursor article including a plurality of filaments comprising a precursor oxide having a dominant amount of a tetragonal BSCCO 2212 phase and a constraining member substantially surrounding each of the filaments is provided. Each of the filaments extends along the length of the article. The oxide article is subjected to a heat treatment at an oxygen partial pressure and temperature selected to convert a tetragonal BSCCO 2212 oxide into an orthorhombic BSCCO 2212 oxide

				and, thereafter, roll worked in a high reduction draft in a range of about 40 % to 95 % in thickness so that the filaments have a constraining dimension is substantially equivalent to a longest dimension of the oxide superconductor grains. The rolled article is sintered to obtain a BSCCO 2223 oxide superconductor.

Exhibit 2 depicts patents related to solid state sintering.

Picture Credit: Frost & Sullivan

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