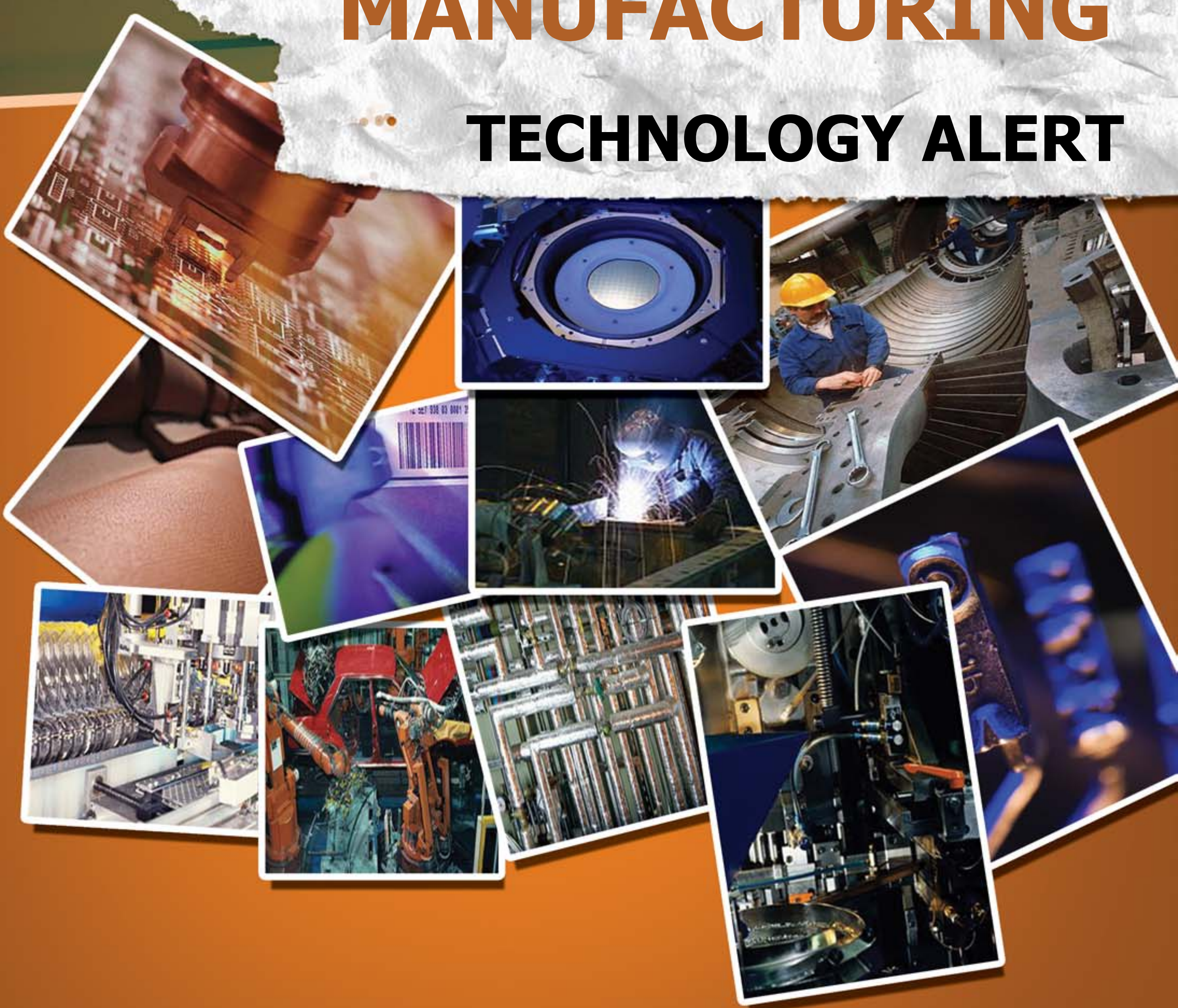
TECHNICAL INSIGHTS

ADVANCED MANUFACTURING

TECHNOLOGY ALERT



05th December 2014

1. REDUCING GALLIUM NITRIDE INTEGRATED CIRCUIT MANUFACTURING COSTS

The advantages of the semiconductor material gallium nitride (GaN) are well-known: it provides high power from a relatively small physical size. Its limitation is equally familiar to researchers, that is, the manufacturing process needed to grow a GaN wafer upon which integrated circuits can be made is costly.

Nowhere are the benefits of advanced GaN technology more valuable than in defense applications. For example, advances in gallium nitride technology can result in enhanced GaN solid-state power amplifiers (SSPA) in the V and W bands; the 40 to 75 gigahertz (GHz) and 75 to 110 GHz ranges of the electromagnetic spectrum. GaN high electron mobility transistors (HEMTs) can have two to five time the output power of standard gallium arsenide-based monolithic microwave integrated circuits (MMICs). Although there has been laboratory progress in developing GaN HEMT MMIC technology, it has been elusive to develop an affordable, high-yield method of fabricating these semiconductor devices to serve the V/W band.

The US Department of Defense (DoD) has sponsored research to develop an economical manufacturing method for making GaN HEMT MMICs that can be used for airborne communications and other anti-access area denial (A2AD) environments. Researchers at the US Air Force Laboratory's Manufacturing and Industrial Technologies Division at Wright Patterson Air Force Base in Ohio have recently completed an advanced communications affordability (ACA) program that dramatically enhances the manufacturing readiness level and affordability of advanced GaN MMICs.

The US Air Force Research Laboratory (AFRL) is that service's organization dedicated to the uncovering and development of warfighting technologies integrated to air, space, and cyberspace forces of the US. The AFRL's Manufacturing and Industrial Technologies Division, also known as ManTech, manages and fulfills Air Force industrial preparedness programs in the areas of manufacturing technology and industrial base analysis.

The Mantech team was led by Dilip Punatar, and worked with counterparts at Northrop Grumman Aerospace Systems' microelectronics facility located in Redondo Beach, California. That Northrop Grumman facility holds a foundry to process MMICs, as well as hetero-junction bipolar transistors and high electron mobility transistors in commercial volumes for aerospace, defense, commercial, and scientific applications.

The public and private sector researchers were determined to scale up the wafer fabrication process for GaN from its present 76 millimeters in diameters to 100 mm in diameter in a volume production environment. The team automated some manufacturing steps and eliminated others to dramatically shorten cycle times by 43%. By implementing 14 manufacturing improvements, increasing wafer size, and enhancing capital equipment, the Mantech/Northrup Grumman designers cut production costs to one-third of previous manufacturing costs and increased the yield of GaN HEMT MMICs 100%.

Just as importantly, the new GaN devices manufactured in the ACA program demonstrated improved W-band performance and record V-band performance greater than 32 decibel-milliwatts of output power (1.6 W) and 10-decibel power gain from 60 to 64 GHz. The GaN HEMT MMICs operated reliably during high-temperature and radio-frequency driven accelerated life testing, and had a projected median lifetime failure at 200 degrees C junction temperature of over one million operating hours.

The results of a long-term operational life test of the GaN HEMT standard-evaluation circuits showed the devices possessed superior stability, with less than 0.5-decibel change in output power after 8,570 hours of testing under nominal operating conditions. These reliable and zero-maintenance characteristics translate into operations and maintenance costs for the US Air Force.

The ManTech team assessed Manufacturing readiness levels (MRL) multiple times during the ACA program, and found that the GaM HEMT MMICs rose from MRL 2 to MRL 6 upon completion, that is, the devices can be put into production.

The ACA program for MMICs is the latest ManTech development of GaN technology for the US Air Force. Specifically, the Air Force incorporated GaN HEMT MMICs in aircraft communications equipment to enable fourth generation aircraft to receive information from fifth generation F-22 Raptor and F-35 Lightning II aircraft in an A2AD environment. Mantech provided GaN technology to the Air Force's Jetpack program to validate the technology's ability to simultaneously link and translate both the F-35 Lightning II's multifunction advanced data link (MADL) and the F-22 Raptor's intra-flight data link (IFDL) to a common terminal.

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2. RECOVERING WASTE HEAT TO ENHANCE MANUFACTURING

The practice of capturing and recycling the free energy in hot gas emissions is useful and fairly widespread, especially in Europe, while other global regions are catching up. One popular configuration is co-generation: a gas turbine-driven generating set (typically in the multiple MW class) that not only produces on site electric power, but with fugitive heat capture via a heat exchanger, can generate steam for process purposes or steam heating of the air in manufacturing workspaces. Some establishments use the waste steam heat to fire absorption-type air-conditioning chillers. Quite a few manufacturing processes rely on steam heat to cook materials, such as beer making. Technically, a gas turbine generating set (genset) is a turboshaft engine driving an electric power generator.

Gas turbines may convert 40% to 60% of the consumed fuel energy into waste heat--better efficiency than piston-type internal combustion engines (where a 70% to 80% loss is typical), but there is still a substantial loss. Large surface area heat exchangers with hot exhaust on one side and a liquid on the other are accepted approaches. In Europe, these plants are known as CHP (combined heat and power). In the recuperative gas turbine, the hot exhaust is passed through a plate-fin type gas to gas heat exchanger to preheat intake air to the combustors. This cuts back the fuel burn.

In addition, blast furnaces need to maintain a steady 1,100 to 1,300 degrees C (2,012 to 2,372 degrees F) in the hot blast section on a sustained basis--around the clock for 1 to 2 years. Heat recovery systems (please refer Exhibit 1) help that task to be achieved. Burning of the carbon coke feedstock also adds essential heat via the exothermic carbon oxidation reaction that melts and produces pig iron, subsequently and regularly tapped from the blast furnace. The melting point of iron is 1,538 degrees C, or 2.800 degrees F.

Exhibit 1 depicts the waste heat recovery system for steel-making blast furnace.

Picture Credit: http://www.kuttnerllc.com/waste_heat.php

Many manufacturers require a process boiler (think of petroleum refineries and petrochemical plants). Such boilers can benefit from a so-called economizer, which has hot flue gas flowing through a heat exchanger (capturing waste heat) flowing in close proximity to the intake fluid, thus reducing the BTU load needed to heat the process fluid stream.

To summarize the pros and cons of waste heat recovery, on the positive side process efficiency is improved, reducing energy consumption and the cost of fuel. There are some indirect benefits, such as pollution reduction (carbon footprint shrinkage), reduced auxiliary equipment expenditure, and reduced energy consumption attributed to auxiliary equipment, such as fans and pumps. On the negative side, there is substantial capital cost burden of the heat recovery apparatus--this investment has to have a reasonable payoff. Finally there is the fact that the waste heat may not be high grade (at elevated temperature). To cope with lower-quality heat, the size and cost of heat recovery heat exchangers escalates.

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3. INFRARED EQUIPMENT APPLICATIONS IN MANUFACTURING

Infrared (IR) processing involves exposure to an invisible sector of the light spectrum (from beyond 700 nm up to 1 mm wavelength) just beyond the visible red of the light spectrum. IR is a form of electromagnetic wave radiation, which propagates through space at the speed of light (186,000 miles per second). The IR spectrum of wavelengths can be split into near (0.75 to 1.4 micrometers), short (1.4 to 3 micrometers), mid (3 to 8 micrometers), long (8 to 15 micrometers), and far (15 to 1,000 micrometers). This division varies by standards organizations (such as the ISO). Astronomy as well as telecommunications professionals use their own IR spectrum split. It has been reported that IR radiation from the sun accounts for 49% of the heating of Earth, with the balance from absorbed visible light.

The targets of IR exposure (including people) receive a beneficial heating effect. Outdoor propane-fired heaters for chilly patios rely on IR radiation from glowing hot emitters to generate most of the comfort factor. At room temperature, most of the heat (thermal radiation) emitted from objects is IR radiation. IR heating is considered to be an environment-friendly process, with heating elements fired by clean-burning gas (propane, natural gas--mostly methane) or electric resistive coils. One attractive attribute of IR heating is that the air between IR emitters and target objects is not heated, saving energy.

One accepted industrial use of IR heating is thermoforming of plastics, often facilitated by electric-fired glowing ceramic heating elements. Thermoplastics will readily soften and conform to a mold. Paint drying is another commercial use, as in the manufacturing of coil-coated metal sheet (please refer Exhibit 2). Other manufacturing applications include cooking of food on a commercial scale, with IR readily absorbed by opaque objects such as food. Curing of coatings, can be performed with IR exposure. Plastic welding, annealing of metals, drying of print on pages (book and magazine making) are additional manufacturing applications. Efficiency is optimized by matching the IR wavelength to material characteristics, such as absorption sensitivity.

Exhibit 2 depicts an IR oven to dry paint on coils of metal (coil coating process).

Picture Credit: http://www.iec.ch/etech/2012/etech_0712/ind-1.htm

Another useful industrial application of IR is thermography, where detectors (e.g., focal plane arrays) can image a thermal map of an object. At extreme temperatures, as with steel melting (2800 degrees F) and manufacturing, pyrometers are used to measure thermal radiation. After machines and electrical apparatus are assembled, IR thermography, as a quality assurance tool, can detect hot spots, insulation breakdown, hot gas leaks, loose connections, current overloads, and other maladies.

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4. PATENT ANALYSIS OF COMPRESSION MOLDING

Compression molding is a molding method in which the molding material is preheated and is placed in an open, heated mold cavity. The mold is closed with a top force or plug member and the material is forced into contact with all the mold areas. The heat and pressure are maintained until the molding material has cured. Thermosetting resins in a partially cured stage, in the form of granules or preforms, are used in this process.

A recent patent in compression molding, US8847415 B1, is assigned to Henkel IP & Holding GmbH and pertains to liquid compression molding encapsulants and encapsulated silicon wafers that provide more resistance to warpage compared to unencapsulated wafers or wafers encapsulated with known encapsulation materials.

Companies are working on various compression molding methods. Examples include Shin-Etsu Chemical Co. Ltd.'s patent on a new compression molding method for electronic components and the associated compression molding apparatus (US8105524 B2), Owens-Illinois Closure Inc.'s patent on a method and apparatus for compression molding plastic articles (US6074582 A) and Kabushiki Kaisha Meiki Seisakusho's patent on an injection compression molding method and apparatus (US7021924 B2). Compression molding is a low-costing molding method compared to transfer molding and injection molding. It is known for its ability to mold large, fairly intricate parts.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Liquid compression molding encapsulants	September 30, 2014/ US8847415 B1	Henkel IP & Holding GmbH	Jie Bai, Afranio Torres-Filho, Kathryn Bearden	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.
Injection compression molding method of lens	August 13, 2013/ US8506857 B2	Hoya Corporation	Tatsuo Nishimoto, Kiyohiro Saito, Kenji Tanagawa, Tetsuya Uchida	An injection compression molding method of a lens is provided, where a toggle link mechanism (**65**) is actuated to close a molding die (**50**) and a movable die plate (**64**) is moved to a position establishing a cavity thickness of greater than a thickness of an article to be molded while the die is closed. After injecting a molten resin into the cavity, the molten resin is sealed in the cavity and the toggle link mechanism (**65**) is actuated to advance the movable die plate (**64**) toward a fixed die plate (**61**), the relative position of a rear die plate (**62**) and the movable die plate (**64**) is made constant at a position where extension of a tie bar (**63**) becomes a predetermined value, and the molten resin is cooled for a predetermined time after completion of pressurizing the resin.
Compression molding method for electronic component and compression molding apparatus employed therefor	January 31, 2012/ US8105524 B2	Shin-Etsu Chemical Co., Ltd.	Tetsuya Yamada, Tomoyuki Gotoh	First, a horizontal nozzle is inserted between an upper mold section and a lower mold section in a horizontally extending state. Then, liquid resin is horizontally discharged from a discharge port of the horizontal nozzle. Thus, the liquid resin is supplied into a cavity. Thereafter the upper mold section and the lower mold section are closed. Consequently, an electronic component mounted on a substrate is dipped in the liquid resin stored in the cavity. Therefore, the electronic component is resin-sealed on the substrate by compression molding.
Poly(arylene ether) compression molding	May 24, 2011/ US7947204 B2	Sabic Innovative Plastics Ip B.V.	Manatesh Chakraborty, Hua Guo, Lakshmikant S. Powale	A method for compression molding of poly(arylene ether) powder comprises introducing a powder comprising unheated poly(arylene ether) powder to compaction equipment comprising a compression mold and subjecting the powder in the compression mold to a pressure sufficient to produce an article having a density greater than the unheated poly(arylene ether) powder wherein the pressure is applied at a temperature less than the glass transition temperature of the poly(arylene ether) powder.
Compression molding apparatus	August 5, 2008/ US7407376 B2	Graham Packaging Company, L.P.	Scott W. Steele	Apparatus for compression molding plastic articles includes a plurality of molds mounted for travel around a first axis. Each mold includes an upper mold section and a lower mold section, with at least one of the upper and lower mold sections being moveable in a non-circular first endless path, and being moveable with respect to the other mold section to form a mold cavity. A mold charge delivery system delivers individual mold charges to the mold cavities and includes at least one delivery mechanism that travels in a second endless path around a second axis spaced from the first axis, wherein the second endless path overlies a portion of the first endless path.
Method and apparatus for compression molding plastic articles	June 13, 2000/ US6074583 A	Owens-Illinois Closure Inc.	Keith W. Ingram	A method and apparatus for compression molding plastic articles including closures which includes providing co-acting sets of tools including a first set for moving a core and core sleeve into engagement with a cavity mold on a second set of tooling. An actuator is provided between the first set of tooling and a fixed upper cam. The second set of tooling includes an associated actuator supporting the cavity mold and associated with a lower fixed cam. A nitrogen cylinder in the second set of tooling provides for control of the compression molding force. In a preferred form, a plurality of sets of tooling are provided in circumferentially spaced relation on a rotating turret supported by a central column. A common manifold supplies the pressure at accurately controlled pressure to each of the nitrogen cylinders. A control system is provided for monitoring and changing the pressure.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Injection compression molding apparatus and injection compression molding method	April 4, 2006/ US7021924 B2	Kabushiki Kaisha Meiki Seisakusho	Yosuke Oyama	In an injection compression molding apparatus and an injection compression method according to the present invention, the structure of the dies can be simplified and a loss of resin as well as of heat due to solidification of the resin in the path at the time of molding can be eliminated. Further, injection pressure loss can be reduced when melted resin is injected into a cavity. A resin injection hole in a nozzle that is attached to an injection device is connected at a position between a stationary die and a movable die directly to the cavity that has a larger volume than a volume of a molded product by means of the movable die, melted resin is injected into said cavity directly from said resin injection hole by said injection device, then the movable die is moved, in the die closing direction, to reduce the distance of the connection between said resin injection hole and said cavity by means of a side wall of the movable die, and to reduce the volume of the cavity so as to compress said melted resin.
Compression molding to form compact with use of grinding chips from machining iron based metals/steels	November 14, 2006/ US7135053 B2	Koyo Seiko Co., Ltd.	Masataka Ishihara, Akio Maemoto, Mitsuma Matsuda, Yoshihiro Seo, Shouichi Kashino	Cotton-like aggregates (B) including grinding chips from an iron-based metal and a grinding fluid containing oil and water are compression molded for forming a brittle compact (C) having the fibrous grinding chips roughly sheared and excessive water and oil removed therefrom. The brittle compact (C) is crushed for further finely shearing the grinding chips and the resultant grinding chips are mixed with a solidification assistant (D) for producing an iron-based powder material (E) containing the solidification assistant (D).
Compression molding machine	February 13, 2007/ US7175405 B2	Apic Yamada Corporation	Kazuhiko Kobayashi, Tsutomu Miyagawa, Tomokazu Asakura, Shusaku Tagami, Hideaki Nakazawa, Naoya Gotoh	A compression molding machine capable of maintaining dies parallel while precisely clamping work pieces and improving quality of molded products and productivity. The compression molding machine includes a fixed platen; a movable platen; a fixed die being held by the fixed platen; a movable die being held by the movable platen; an open-close mechanism including a screw shaft connected to the movable platen, the open-close mechanism turning the screw shaft so as to move the movable die to and away from the fixed die, whereby the dies can be opened and closed. The fixed die can be taken out from the fixed platen in the direction crossing the open-close direction of the movable die.
Compression molding method and mold clamping apparatus	February 21, 2006/ US7001545 B2	Kabushiki Kaisha Meiki Seisakusho	Shoji Okado, Yasuhiro Yabuki	Disclosed is a compression molding method comprising the steps of: calculating an average value of mold clamping forces sensed in a plurality of mold clamping mechanisms for clamping a stationary and a movable mold half; obtaining a first control signal on the basis of deviation between a preset target mold clamping force and an average value of sensed mold clamping forces; sensing positions of movable members of the mold clamping mechanisms; obtaining an average value of sensed positions; setting the average value as a successive target position; obtaining a second control signal on the basis of deviation between each of the sensed positions and the successive target position; and obtaining a clamping control signal for each of the clamping mechanisms by adding the first control signal and the second control signal. An apparatus suitable for implementing the method is also disclosed.

Exhibit 3 depicts patents related to Compression molding.

Picture Credit: Frost & Sullivan

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