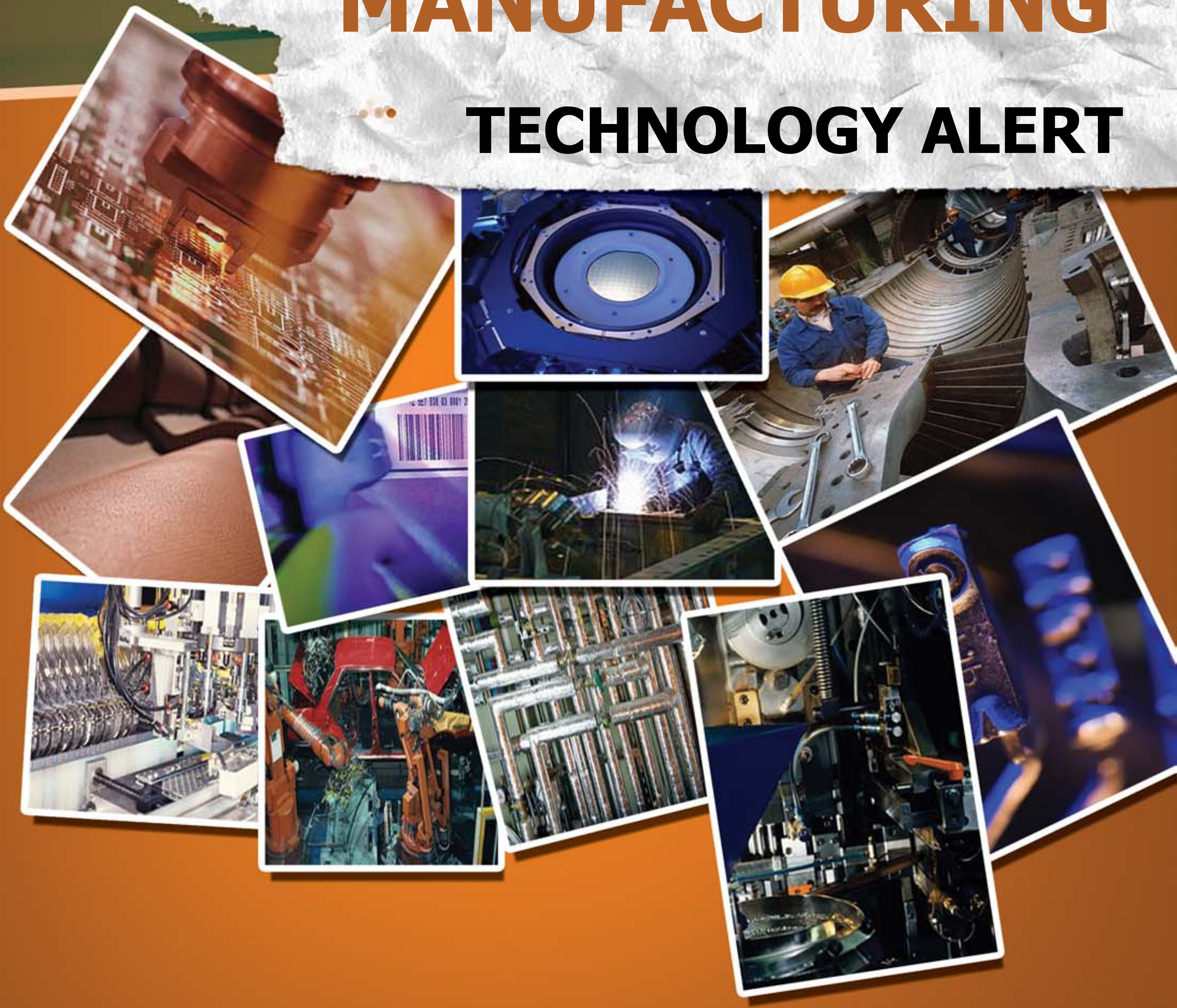
TECHNICAL INSIGHTS

ADVANCED MANUFACTURING

TECHNOLOGY ALERT



30th October 2015

1. COLLABORATIVE ROBOT AVOIDS COLLISIONS

Collaborative robots, which are able to work more safely besides humans, are finding increased interest and opportunities in manufacturing (including autonomous inspection, maintenance, and repair operations), due to such factors as the increasing lack of skilled labor in developed countries and the increasing median age of the population. In manufacturing operations, collaborative robots provide key benefits, such as enhanced safety, a smaller footprint, greater flexibility, and ease of achieving reconfigurable manufacturing.

In contrast to conventional robots, collaborative robots will not be subjected to fixturing and permanent bolting. The collaborative robots are light-weight and can have special mechanical mating interfaces that will help them be very stable during operation and yet easily repositionable. The collaborative robot can be repositioned on the shop floor in a minimal amount of time and be reprogrammed to adjust to its new position in considerably less time compared to conventional robots.

To proliferate in manufacturing environments, collaborative robots must have enhanced safety features to ensure safety when working in close collaboration with humans.

To address this need, researchers at SINTEFF, based in Norway, are enabling robots to more seamlessly navigate and operate in highly complex, dynamic environments. Such robots can adjust their movements to avoid colliding with any individuals or equipment around them. Under the SEAMLESS (Simultaneous navigation and manipulation in complex dynamic scenes) project, which spans from January 2011-December 2015, the SINTEFF researchers, led by Marianne Bakken, research scientist, have achieved rapid, efficient mapping between the robot's sensor data and its motions, using graphics processing unit (GPU) accelerated programming.

The researchers have been addressing key challenges in attaining real-time three-dimensional (3D) mapping and synchronized robot arm and base navigation in order to enable robots to seamlessly navigate and operate in complex dynamic environments. Such challenges include the ability to fuse data from sensors, account for sensor uncertainties, deal with localization problems, merging sensor data over time and representing dynamic events and predictions. The researchers have been developing methodologies and algorithms for navigation of mobile robot manipulators.

Industrial robots are typically heavy and are placed within enclosures to prevent collisions with people or objects in the surroundings. Such robots are static and perform repetitive tasks separated from the human operators on the production line. The operation of robots could be expanded if there was no concern for robot arms colliding with people or objects in the vicinity.

The sensor used in the SEAMLESS project is a Microsoft Kinect, off-the-shelf, 3D sensor based on structured light technology. Structured light illuminates patterns to detect or scan 3D objects. The structured light technique projects a pattern of light onto a 3D scene and infers or computes depth and the 3D structure from the deformation or distortion of that light pattern. The researchers needed a high frame rate but not high precision of the 3D data.

The 3D sensor detects objects in the surrounding environment and senses the location of any given object in relation to the robot arm. By being continuously fed with data, the robot can decide the direction in which it should move. The sensor generates data sent to a PC, where the data are processed and relayed to the robot arm. The researchers have succeeded in accelerating the calculations; and have been able to obtain updates of the robot's movements ten times per second. The combination of the rapid sensor technology and smart algorithms enables more uniform and seamless robot maneuvering.

The crux of the project's innovation is the rapid and efficient mapping between the sensor data and the robot's motions. Furthermore, by moving the pedestal on which the robot stands, the robot is able to move with greater autonomy. The researchers, who have been promulgating the concept to the industrial sector, envision robots that move around the workplace to perform tasks without any collisions with people, equipment, or objects in their environment.

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2. TWO-DIMENSIONAL MICROWAVE CAMERA

Microwave imaging, which involves electromagnetic waves at microwave frequencies of 300 MHz to 30 GHz, is used, or finding opportunities, in such application areas as medical diagnostics and biomedical, nondestructive testing, security (for example, detection of concealed weapons or through-wall imaging), underground exploration, and so on. Microwaves are able to penetrate a wide range of optically opaque and non-conducting materials such as composites, ceramics, concrete, wood, foam, and clothing and interact with their interior structure. Microwaves can also penetrate fog or soil. In biomedical applications, microwave imaging has generated keen interest in, for example, providing information about the physiological state or anatomical structure of human tissue. There is room for improving the speed and the amount of information that can be derived from microwave imaging.

Yoshio Nagayama, professor from the National Institutes of Natural Sciences National Institute for Fusion Science, and colleagues, in a collaborative research with Kansai University, Tokyo University of Agriculture and Technology, Ube National College of Technology, the Institute for Molecular Science, Kyushu University, and other institutions, have developed a high-speed two-dimensional (2D) microwave camera for diagnostics of high-temperature plasma.

High-temperature plasmas that exceed 100,000,000 degrees C are generated in the large helical device (LHD) at the National Institute for Fusion Science. The large helical device for fusion research is an extremely large superconducting stellarator for confining hot plasma with magnetic fields to sustain a controlled nuclear fusion reaction. The LHD contains a heliotron magnetic field and is used for fusion plasma confinement research with respect to helical plasma reactors.

The researchers noted that in the US, plasma diagnostics has typically been conducted using one-dimensional microwave imaging sensors. Two-dimensional microwave imaging sensors, on the other hand, would be able to provide more information in a single diagnosis.

However, it has been challenging to achieve two-dimensional microwave imaging sensors in applications such as high-temperature plasma diagnostics. Arranging the sensors in rows for 2D imaging leads to mutual interference among the sensors and problems in obtaining accurate information. Moreover, one-dimensional microwave imaging using radar or scanning techniques has been hampered by slow speeds.

The researchers addressed the issue of mutual interference among the sensors by using aluminum plates and creating an internal structure. They developed a two-dimensional microwave image sensor that comprises 8 x 8 image pixels, which are able to detect microwaves at high speed with high sensitivity. The achievement allowed for successful high-speed imaging of LHD plasmas of nearly 100,000,000 degrees C at 1,000,000 frames per second.

The two-dimensional microwave image sensor is comprised of 64 individual sensors. In diagnostics using microwaves, the key indices of strength and phase can be diagnosed simultaneously. The technology has been used to build a high-speed microwave color television that converts diagnostics data into images.

The 2D microwave image sensor technology has potential opportunities in diverse applications. For example, it helps confirm the location of airplanes or ships even in poor atmospheric conditions, such as dense fog. It has potential for safety inspection at airports, detection of weapons or metal objects concealed in clothing, searching for metals underground or non-destructive inspection. However, as the number of pixels in the developed image sensor is sufficient for high-temperature plasma diagnostics, the number of pixels would need to be increased for industrial applications. In the future, with the collaboration of experts in electronic circuits, the researchers plan to increase the number of pixels.

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3. NOVEL 3D BIOPRINTING TECHNIQUE TO PRINT CORONARY ARTERIES

Three-dimensional printing is poised to profoundly impact the manufacturing sector with its wide range of applications, spanning nanotechnology, airplane building, tissue engineering and automobile engineering, and so on. New materials, new possibilities and new applications of 3D printing are constantly emerging. This is a promising sign that 3D printing will see more applications in various new fields in the future.

A new 3D bio-printing technique, which has the potential to save millions of lives, is making news among the medical fraternity across the world. A 3D bio-printing technique developed by Carnegie Mellon University (CMU) has yet again proved the life-saving potential of 3D printing. The technique is an achievement of a group of scientists at CMU which can print non-living replicas of coronary arteries.

The research team was able to print the artery replicas by modifying a 3D printer. Apart from printing coronary arteries, the research team has also been successful in printing embryonic hearts using the new 3D bio-printing method. In fact, the researchers claim that the ultimate aim of the research project at CMU is to bio-print a heart for transplantation at low cost.

In order to achieve this feat, the researchers had to overcome a major challenge of 3D printing. In traditional 3D printing, objects and structures are printed by depositing materials layer by layer in air. The materials usually used are metals and different types of plastic, which are rigid, require strong support structures from the layers below, and can harden in a few seconds after depositing as a layer. However, for printing tissues such as arteries, the raw materials are collagen and fibrin. These materials are very soft and collapse with their own weight when deposited in layers using traditional 3D printing techniques.

The researchers used a new technique to address the issue of using soft materials for 3D printing by using a gel as a support bath material. The approach is to print a gel- collagen or fibrin in a gel (hydrogel) bath material. In this way, the desired structure can be accurately printed by depositing collagen or fibrin layer by layer. This novel technique of CMU is named FRESH (Freeform Reversible Embedding of Suspended Hydrogels).

The same technique has been used earlier to 3D print structures using soft materials. What makes this technique unique with respect to CMU is that this is that now the hydrogel bath technique has been used to bio-print structures using delicate and essential tissue engineering materials such as collagen and fibrin.

Apart from the potential to save lives, this new technique also packs a set of other advantages that might make it commercially available soon. Firs, the unique property of the gel used in the FRESH technique is that it can be removed easily by melting it away via heating to body temperature. This means that the technique will cause no danger to living cells and other molecules when used in the human body. Another major advantage is that the cost of the 3D printer would be far less than that of 3D bio-printers available today. This can be attributed to the fact that the researchers at CMU are conducting the research by modifying only consumer-level 3D printers. Additionally, the printers utilize open-source hardware and software, which brings even more cost benefits. In the long term, the researchers are planning to release the 3D printer under an open-source license.

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4. 3D PRINTED WAVEGUIDES

Waveguides are components of microwave circuits and form the equivalent of conducting paths in electronic circuits. Waveguides are used not only in microwave transmission, but are also used in millimeter and radio wave and other electromagnetic (EM) wave transmission. They are very commonly used in various applications such as radio communications, radar, astronomy and space science. The main purpose of a waveguide is to propagate EM waves from one place to another.

Rectangular waveguides made of metal are most commonly used in all applications because of their low-loss properties. The metallic rectangular waveguides are manufactured by specialized methods in order to provide optimum wave transmission properties. Usually, metal pipes are restructured to make waveguides by using methods such as dyeing, milling or erosion machining. These techniques are quite expensive and the processes cost more if the shapes of the waveguides are complex. This limits the application of metallic waveguides in low-cost applications. Furthermore, waveguides manufactured using conventional processes involve complex methods to achieve precision structures that are required for microwave and millimeter wave propagation.

Researchers at Imperial College London in association with National Physical Laboratory (NPL) have found a way to make waveguides that are cost-effective and that can be used in low-cost applications. The team has found that the answer to making cost-effective waveguide manufacturing lies in 3D printing.

The research team has used the fused deposition modeling (FDM) technique to make waveguides for microwave applications; and they used the stereolithography technique for millimeter wave applications. Stereolithography was used for millimeter wave propagation because millimeter waveguides require very high physical precision, which is rendered by stereolithography.

FDM involves melting and selectively depositing a thin filament of thermoplastic polymer (such as acrylonitrile butadiene styrene [ABS], plastic, polycarbonate, and investment casting wax) in a cross-hatching mode to form each layer of a part. A plastic filament or metal wire is unwound from a coil and supplies material to a heated extrusion nozzle that controls the flow. The nozzle is heated to melt the material.

In stereolithography, a low-power ultraviolet laser, programmed using precviously created CAD (computer-aided design) data, traces the first layer of the part with a focused ultraviolet light beam. It scans and cures the resin within the boundaries of the outline of the slice until the entire area within the slice cross-section is solidified.

After printing the waveguides, their functioning needed to be validated against the waveguide standards. This validation and performance measurement was performed by the National Physical Laboratory (NPL). All the measurements were carried out in NPL’s facility under the supervision of NPL’s metrology experts.

The measurements of wave propagation through waveguides manufactured using 3D printing techniques were rendered comparable to the waveguide standards. When microwaves and millimeter waves of certain frequencies were used for testing, the propagation measurements were actually better than the measurements in waveguides manufactured using conventional methods.

Apart from the performance benefits, the 3D printing technique also gives another advantage that will define new opportunities for waveguides to be used in low-cost and lightweight applications. This is because the waveguides printed through 3D printing are lightweight as they are printed using plastic. The plastic used in this application has a honeycomb structure which makes it lighter than rigid plastics. In applications, such as satellite payloads and space vehicles where weight is an issue, waveguides made by 3D printing can be used to reduce the weight.

The 3D printed waveguide is yet another example of how transformational 3D printing can be for the future of manufacturing. These novel waveguides not only offer relatively better performance than conventional waveguides, they can also be manufactured cost effectively.

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5. PATENT ANALYSIS OF METROLOGY METHODS

Metrology is the science of measurement. Measurements are crucial for all manufacturing processes. Measurements quantify the quality of the product rendered at the end of the production process.

In the highly competitive manufacturing industry, there is a demand for very high-quality products. To meet this demand, it is essential to ensure that each part in the product is made with utmost precision. Metrology techniques and methods help to achieve the quality standards of each part while they are manufactured. The manufacturing industry today is constantly adopting various novel metrology techniques and methods to produce superior quality products.

The exhibits show some of the metrology patents filed during September and October 2015. It should be noted that the number of patents in metrology has been almost consistent since 2010. This indicates that there is immense research and development activity taking place in metrology.

One of the interesting patents from the exhibit belongs to Palo Alto Research Center (PARC) (EP 2930694) which pertains to a system and method to automate metrology, measurement, and model correction of the 3D printed model for 3D printing. Another interesting patent in recent times is for a definition of system architecture for a wireless metrology device, which is filed by General Electric Company (WO/2015/142477).

Title	Publication Date/ Publication Number	Assignee	Inventor	Abstract
Scatterometry-based imaging and critical dimension metrology	October 22, 2015/ US 20150300965	KLA-Tencor Corporation	Abdurrahman Sezginer	Methods and systems for performing measurements of semiconductor structures and materials based on scatterometry measurement data are presented. Scatterometry measurement data is used to generate an image of a material property of a measured structure based on the measured intensities of the detected diffraction orders. In some examples, a value of a parameter of interest is determined directly from the map of the material property of the measurement target. In some other examples, the image is compared to structural characteristics estimated by a geometric, model-based parametric inversion of the same measurement data. Discrepancies are used to update the geometric model of the measured structure and improve measurement performance. This enables a metrology system to converge on an accurate parametric measurement model when there are significant deviations between the actual shape of a manufactured structure subject to model-based measurement and the modeled shape of the structure.
Air quality metrology system	October 22, 2015/ WO/2015/158998	BULL SAS	Benrachi, Samia	Metrology system (2) for the management of observation data and the quality of the air, this system being configured to collect at least one observation datum, and to associate with this observation datum a quality code reflecting the utilizable character of this observation datum with respect to a predefined quality criterion, this system comprising: - a data acquisition module (21); - a centralized data management module (22); - a data presentation and dissemination module (23); and - transverse functional bricks (24): o for data processing and production; o for end-to-end data quality control; o for intermediation so as to urbanize the architecture and allow the exposition of services.
High speed metrology with numerically controlled machines	October 14, 2015/ EP 2929287	GRALE TECHNOLOGIES	Garvey Michael	Systems, apparatuses and methods are described for integrating an electronic metrology sensor with precision production equipment such as computer numerically controlled (CNC) machines. For example, a laser distance measuring sensor is used. Measurements are taken at a relatively high sample rate and converted into a format compatible with other data generated or accepted by the CNC machine. Measurements from the sensor are synchronized with the position of the arm of the machine such as through the use of offsets. Processing yields a detailed and highly accurate three-dimensional map of a workpiece in the machine. Applicable metrology instruments include other near continuously reading non-destructive characterization instruments such as contact and non-contact dimensional, eddy current, ultra-sound, and X-Ray Fluorescence (XRF) sensors. Various uses of measurements include: multiple component matching, correction of machine drift, closed loop control of machines, and verification of product tolerances via substantially complete serialized dimensional quality control.
Automated metrology and model correction for three dimensional (3D) printability	October 14, 2015/ EP 2930694	PALO ALTO RES CT INC	Nelaturi Saigopal	A system and a method automate metrology, measurement, and model correction of a three dimensional (3D) model for 3D printability. Slices of the 3D model are received or generated. The slices represent 2D solids of the 3D model to be printed in corresponding print layers. Medial axis transforms of the slices are calculated. The medial axis transforms represent the slices in terms of corresponding medial axes. A local feature size at any point along a boundary of the slices is determined as the shortest distance from the point to a corresponding medial axis.
Plating bath metrology	October 8, 2015/ US 20150284871	MOSES LAKE INDUSTRIES, INC.	Muneharu Kondo	Techniques for performing bath metrology on electroplating mixtures are disclosed. In particular, the disclosed techniques can be used in conjection with traditional metrology methods such as cyclic voltammatric stripping (CVS), and are capable of detecting changes in bath components at a more sensitive level than CVS in some circumstances. In some instances, deviations in observed current values from potentiostatic methods vis-à-vis a calibration standard can provide indications of changes in the mixture, and provide an indicator when a depleted component has been sufficiently added to restore the mixture to a previous state.

Title	Publication Date/ Publication Number	Assignee	Inventor	Abstract
Shape metrology for photomasks	October 8, 2015 / US 20150286130	Advanced Mask Technology Center GmbH & Co. KG	Clemens Utzney	A method of manufacturing a photomask includes forming a mask pattern with a critical mask feature on a photomask. Shape information which is descriptive for an outline of the critical mask feature is obtained from the photomask. The shape information contains position information identifying the positions of landmarks on the outline relative to each other. The landmarks may indicate local curvature extrema, points of inflexion, sharp bends in the curvature and/or local curvature-change maxima in the outline of the mask feature, respectively. The shape information may enable a shape metrology which is not completely based on rectangular approximations of mask features.
Metrology sampling method and computer program product thereof	October 1, 2015/ US 20150276558	NATIONAL CHENG KUNG UNIVERSITY	Fan-Tien Cheng	In a metrology sampling method, various index values that can detect various status changes of a process tool (such as maintenance operation, parts changing, parameter adjustment, etc.), and/or information abnormalities of the process tool (such as abnormal process data, parameter drift/shift, abnormal metrology data, etc.) appear in a manufacturing process are applied to develop an intelligent sampling decision (ISD) scheme for reducing sampling rate while VM accuracy is still sustained. The indices includes a reliance Index (RI), a global similarity index (GSI), a process data quality index (DQIX) and a metrology data quality index (DQIy).
System architecture for wireless metrological devices	September 24, 2015/ WO/2015/142477	GENERAL ELECTRIC COMPANY	Laflen, John, Brandon	System architecture that provides computer-based methods of wireless communication between a wireless metrological device and a mobile computing device that includes the sending/receiving of data (e.g., measurements) along with a universal generic data service that includes data descriptor(s) affiliated with the measurements. The architecture and methods, which may be communicated via BLE, allow for uniform communication between tools and mobile computing devices regardless of tool type, manufacturer, and measurement information.
Transfer chamber metrology for improved device yield	17 September, 2015 / US 20150263222	Applied Materials, Inc.	David P. Bour	Apparatus and method for control of epitaxial growth parameters, for example during manufacture of light emitting diodes (LEDs). Embodiments include PL measurement of a group III-V film following growth while a substrate at an elevated temperature is in a transfer chamber of a multi-chamber cluster tool. In other embodiments, a film thickness measurement, a contactless resistivity measurement, and a particle and/or roughness measure is performed while the substrate is disposed in the transfer chamber. One or more of the measurements performed in the transfer chamber are temperature corrected to room temperature by estimating the elevated temperature based on emission from a GaN base layer disposed below the group III-V film. In other embodiments, temperature correction is based on an absorbance band edge of the GaN base layer determined from collected white light reflectance spectra. Temperature corrected metrology is then used to control growth processes.
Method and system for planning metrology measurements	September 3, 2015/ WO/2015/128866	NOVA MEASURING INSTRUMENTS LTD.	Sendelbach, Matthew	A method for use in planning metrology measurements, the method comprising: providing inverse total measurement uncertainty (TMU) analysis equations for upper and lower confidence limits TMUUL and TMULL of the TMU being independent on prior knowledge of measurements by a tool under test (TuT) and a reference measurement system (RMS), thereby enabling estimation of input parameters for said equations prior to conducting an experiment of the TMU analysis; and determining at least one of a total number N of samples to be measured in the TMU analysis and an average number ns of measurements per sample by the RMS.

Exhibit 1 depicts patent analysis of metrology methods.

Picture Credit: WIPO/Frost& Sullivan

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