## Additive Manufacturing/3D Printing Focus Topic
## Room: Hall 3 - Session AM-ThP

## Additive Manufacturing/3D Printing Poster Session

**AM-ThP1 Anisotropic Evaluation of Mechanical Properties Related to Printing Direction and Development of Nanocomposite Materials to Establish Direct Digital Manufacturing**, *Hiroaki Sakaguchi*, *A. Matsumuro, K. Takeda*, Aichi Institute of Technology, Japan

3D printing technique is strongly leading the next industrial revolution in all over fields. The manufacturing methods are used by additive processes using successive layers of a lot of kind of materials. In the past few years, the rapid development of 3D technologies has changed from data visualization models and so on to the manufacturing of industrial production including mass-production (DDM). Many difficult problems should be overcome in order to establish DDM technology as the general industrial products manufacture method. One of the representative problems is the durability or strength of the products. 3D printing systems deposits melt or soften materials in a layer state on solid parts. Layered structures are formed in the whole products, and extreme low strength interfaces are fabricated at the same time. It is necessary to optimize a printing direction according to the load that determines the strength and durability of the product as one of manufacturing process.

Our study investigated an optimal molding direction procedure with respect to mechanical properties. Tensile and three points bending tests were done for standard plate type specimen made of polymer (ABS-like, Strasys Co., Ltd) using Ink-Jet-Type 3D printer (Connex500). We made three types of specimens, which were varied in the printing direction, respectively. These experiments mean that the effect of directions of layers entering in the molds on important mechanical properties. Three type specimens for tensile direction were molded as follows: (S1) plane molding with printing layers parallel to tensile direction, (S2) plane molding with vertical layers to tensile direction and, (S3) vertical molding with vertical layers to tensile direction. Experimental results of tensile strength, Young's modulus and rupture stress of each specimen showed remarkable differences. The detail results were as follows: tensile strength of (S1) 50 MPa, (S2) 39 MPa, (S3) 35 MPa, Young's modulus of (S1) 1.1 GPa, (S2) 0.8 GPa, (S3) 0.7 GPa and rupture stress of (S1) 59 MPa, (S2) 46 MPa, (S3) 37 MPa. Bending test results showed the similar tendency of those of Young's modulus. These results became clear strongly significant specific anisotropy of mechanical properties related to printing directions. Therefore, establishment of DDM needs the logical molding process and construction of the database of mechanical properties of individual materials. Furthermore, another important problem concerning DDM must be development of new materials with strength enough for practical use. Now we have studied new nanocomposite materials with innovative high strength. We will present the results at the conference.

**AM-ThP2 A New Technique to Make an Insulating AlN Thin Film to be Conductive by Spontaneous via Holes formed by MOCVD and its Application to realize Vertical UV LED on $n^+$Si Substrate**, *Noriko Kurose*, *Y. Aoyagi*, Ritsumeikan University, Japan

**A new Technique to make an insulating AlN thin film to be conductive by spontaneous via holes formed by MOCVD and its application to realize vertical UV LED on $n^+$Si substrate**

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**Abstract**

For growing AlGaN epitaxial layer on Si substrate, AlN buffer layer between Si substrate and AlGaN epitaxial layer is indispensable to avoid Si melt-back phenomena coming from direct contact of AlGaN to Si substrate. However, AlN is insulating material even though highly doped. To fabricate vertical type device like vertical UV LED and vertical UV light sensor, the conductive n-AlN is indispensable to insure direct current flow from p-electrode to n-Si substrate. We have succeeded in developing a new technique to grow conductive n-AlN using spontaneous via holes in AlN buffer epitaxial layer grown on n+Si substrate using MOCVD and succeeded in fabricating and operating vertical UV-LED and vertical UV sensor using this technique.

Via holes in AlN buffer layer are spontaneously formed by introducing thin Al layer deposition on the Si substrate. This Al thin layer forms a mask to make spontaneous via holes. Formation of via holes are confirmed by AFM and EDX measurement. Via holes are filled by conductive n-AlGaN and the current flows through these via holes. This current flow through via holes is confirmed by EBIC measurement. The density and the size of via holes are controlled by changing the growth condition of MOCVD. The size of via holes can be varied from 0.1 to 2µm depending on the TMA feeding amount in an initial stage of Al thin layer formation. By growing the p-n junction on the layer with multi quantum wells we have succeeded in vertical LED fabrication (substrate removal free vertical LED, RefV-LED) and operation with direct current flow from p electrode to $n^+$Si substrate at the wavelength of 350-400nm with good I-L and I-V performance and near field pattern. The built in voltage of the p-n junction was 3.8V and the break down voltage was more than 35V. The built in voltage is almost same as the band gap of AlGaN used in this RefV-LED. The large breakdown voltage of this device shows us that good p-n junction is formed. Our device can be fabricated without any photoresist processes and is simple to fabricate. These results show us our techniques will open a new window to fabricate a new DUV LED and UV sensor as well.

**AM-ThP3 Novel Deep Si Etching Process for Green IOT**, *Takahide Murayama*, ULVAC Inc., Japan

TSV (Thru Silicon Via) application for 2.5D silicon interposers and 3D stacked devices is expected to realize a next-generation semiconductor device applied for upcoming IOT world with high packaging density, power saving, and high-speed signal transmission, etc. Generally, SF6 gas has been applied to form TSV in dry etching process because of its useful properties; reasonable cost, chemical safety, and dissociation property which generates a lot of fluorine radicals. Abundant fluorine radicals contribute to achieve higher silicon etching rate, but in the perspective of Global Warming Potential (GWP), SF6 has extremely high potential (GWP = 22200, 100 year base), gives a great impact to greenhouse effect. So, various gases have been offered to alternate SF6. In series SFx (x=0 to 6), there are limited species which have industrial stability, some of them characteristic properties in the points of low GWP and dissociation to generate fluorine radicals. SF4 gas has very low GWP in SFx series . Because SF4 immediately reacts with H2O in atmosphere, generates HF and SOx. GWP for HF and SOx have not been set due to their water-soluble property . In addition to low GWP property, the bond strength in SF4 has unique property. In SF6, SF5-F bond strength is 387 ± 13 kJ/mol. On the other hand, SF3-F bond strength in SF4 is 354 ± 13 kJ/mol . So, there is an expectation that SF4 can generate abundant fluorine radicals compared with SF6. From above properties, SF4 may be one of the SF6 alternative gases for TSV dry etching process.

**AM-ThP4 High Resolution Two Photon and 3D Holographic Lithography Structure Production and Conversion to Higher Index Materials**, *Steven Kooi*, MIT Institute for Soldier Nanotechnologies

3D structured polymeric materials are produced by multi-beam laser interference or two photon direct write lithography[1] using either a 355 nm pulsed Nd:YAG laser or a 780 nm Ti:Sapphire femtosecond laser. Samples are also constructed by combining the two techniques.

In order to obtain more interesting and measurable optical properties, the polymeric structures produced by holographic lithography and two-photon lithography are converted into higher index of refraction materials (Si and Ge) by atomic layer deposition, reactive ion etching and chemical vapor deposition techniques.

Optical properties of the photonic structures produced are calculated and measured by local reflectivity and transmission measurements as well as with near field scanning optical microscopy. The 3D structure quality and all steps of the transformation from polymeric to high index materials are also characterized by serial focused ion beam (FIB) milling and imaging.

[1] J. -H. Jang, C. K. Ullal, M. Maldovan, T. Gorishnyy, S. Kooi, C. Y. Koh, and E. L. Thomas, Adv. Funct. Mater **17**, 3027 (2007).

2 J. P. Singer, S. E. Kooi, and E. L. Thomas, Nanoscale, **3**, 2730 (2011).

# Authors Index

## Bold page numbers indicate the presenter