Manufacturing Science and Technology Group
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Manufacturing Science and Technology Poster Session

MS-ThP-1 Evaluation of Mechanical Properties of Infill Structures Change during 3D Modeling, ***Seita Ogawa***, *A Matsumuro,* Aichi Institute of Technology, Japan

By products with a 3D printer, modeling of complex shapes is possible based on the data obtained by 3D CAD and 3D scanner. In recently, 3D printers are actively used for products from the stage of being used for prototyping. Therefore, we have focused on the filling rates and infill structures for 3D printing products. There are cavities in the shaped object, and the mechanical properties of the object change depending on infill structures and filling rates. Our purpose of this study is to evaluate mechanical characteristics for infill formation conditions due to create an important database in future. we considered it to be important creating a database of their mechanical properties for products used 3D printer.Conventional tensile test and three-point bending test were performed using typical types of materials, ABS resin, PLA resin, and Primalloy（ Mitsubishi Chemical Co., Ltd.). In this research, the infill structures of several kinds of default set with slicer software used, i.e. hatching, zigzag, honeycomb and 3D honeycomb. The filling rates were increased to 50% every 10%. The test pieces used the dumbbell shape based on JIS.K7161. I used a MUTOH 3D printer MF-2200D as a device, and used an Imada measuring stand and a force gauge for a tensile test and a three-point bending test. In the three-point bending test, we tested from both side of flat surface and edge side to the stacking direction.As a result, the ABS test piece of the filling rate 30% and 50% increased 60% and 70% higher than the filling rate 10% and 50% respectively in the tensile strength. It was found that an increasing of the filling rates leads to an increasing of mechanical properties. Summarizing results of all test conditions, it was cleared that the tendency of the mechanical properties of bending from two directions was different in the all materials. The tendency of mechanical properties was different depending on different kinds of material.From our results, we considered it to these databases will be great important for products of large field using 3D printers. Furthermore, we try to investigate several kinds of infill structures that have higher strength. Finally, we hope that our study contributes to innovative industry in the near future.

MS-ThP-2 Development of Innovative CNT/Extra Super Duralumin Composite Materials, ***Chihiro Fujiwara***, Aichi institute of Technology*; A Matsumuro,* Aichi Institute of Technology, Japan

Current science and technology should serve as it overcoming the issues of global environment and realization of the new industrial revolution immediately. To solve these important problems, drastic challenge from every field is accomplished. We focus on materials development with innovative characteristics in this study. In late years technology development about the space utilization become much active. Importance of the aerospace apparatus will increase more and more. Due to contribute to current technological development, we should design creatively an innovative high specific strength material. As our research objective, we came up with the idea of the development of an Extra Super Duralumin (ESD) based composite material with Carbon Nanotube (CNT), which has been well known as unprecedented excellent characteristics. ESD is an aluminum base alloy with high tensile strength and pressure resistance. The basic fabrication process of metal based composite material with nano-carbon materials have been established in various materials system. We established original successful uniform dispersion of CNT with in Al based materials, and we demonstrated already that Vickers hardness of CNT/Al composite pellet-formed sintered materials showed several times up in comparison with that of conventional Al bulk material.

In this study, pellet-plate type specimens consisted of our CNT/ESD composite materials were fabricated using compression sintering method with commercial single wall carbon nanotube and ESD powder of dozens of micrometers of particle size powder. The heat-treatment after sintering specimen was done under the conventional method. The obtained main optimum conditions as follows: CNT composite ratio of 1wt. %, ultrasonic dispersion time of 4 h and sintered temperature of 723 K for 4 h.

It has already been demonstrated that Vickers hardness of CNT/ESD composite showed about 6 % increase in comparison with sintered ESD bulk material, and the density decreased down to 1.5 %. So, the specific strength improved up to 10 % just as expected. This result shows clearly possibility to develop a product with innovative characteristic by the effect of composition with nano-carbon materials. These results would suggest bringing a change in the concept of manufacturing process. From now on, we will estimate tensile and bending characteristics with quantity evaluation. Furthermore we would intend challenge to develop CNT/ESD and graphene/ESD composites bulk materials made using the melting process due to lead the innovative materials to practical use. We would like to present charming results at the conference.

MS-ThP-3 Development of Composite Resin Materials with High Dispersion Cellulose Nanofibers, ***Naoki Iwanaga***, *A Matsumuro,* Aichi Institute of Technology, Japan*; K Osawa,* Aichi Institute of Technology, Japn, Japan

Progress of science and technology should serve as it overcoming the problem of global environment immediately. The challenge from every field is accomplished to solve this important problem. In terms of material issues, high strength and environmentally friendly objects are required. So, we strongly focused on cellulose nanofibers(CNF).

CNF show extraordinary mechanical, physical and chemical properties. Furthermore, CNF is a biodegradable material with low environmental impact and excellent recyclability. Therefore, it is possible to suppress the occurrence of micro plastics, which is a problem in global issues.

In addition, development of the advanced composite resin filaments with CNF for uses 3D printing leads to extend especially application field, due to excellent environmental problem and mechanical properties as one of core of current technology Industry revolution.

In this study, we try to development an innovative high strength resin based composite materials reinforced by CNF with characteristics of eco-friendly and material characteristics.

At first, we researched the possibility of the application of CNF composite materials with ABS base resin, in order to investigate possibility of fabrication of composite material with CNF and improvement of characteristics in comparison with conventional resin materials. The fabrication method with uniform dispensation of CNF in ABS resin powder was applied with the ultrasonic method established on our own. Specimen were made by the die molding method at 250K for 30minutes.

In our results, the optimum dispersion time was determined 6 hours by surface observation.

FT-IR measurement showed that CNF and ABS resin could be dispersed while maintaining its structure. We should remarkable results of representative mechanical property. Tensile strength and young's modulus for specimen excellently increased up to about 70 % for 1.0 wt% CNF and 97 % for 0.5 wt% CNF in comparison with the value of pure ABS resin specimen. Furthermore, strength improvement using nylon 6 was clarified as the same trend in the case of ABS resin.

These results described above should clarified the development important guidelines for fabrication process, of an innovative composite resin materials with enough specific characteristics of CNF.

Furthermore, in order to expand the possibility of practical realization, we are now challenging, to apply to biodegradable PLA resin.

MS-ThP-4 Improvement of Laminated Interface Strength of Printed Objects by FDM 3D Printer, ***Li Song***, Aichi institute of technology, Japan

Indispensable 3D printing technique in manufacturing has made us an important unavoidable problem until now. It is unquestionably laminated interfacial existence in molded products. The problem become obviously that the strength of printed products in a vertical direction for printing direction is extremely weaker than the strength with along direction about almost same strength of original filament. The reason is absolutely clear for existence of laminated interfaces with a heterogeneous structure.

In this study, we tried to chanllenge an innovative improvement method of the excellent laminated interface strength which is the ultimate purpose to obtaine conventional products with strength of the bonding force with uniformization of the upper layer and the structure. We tried to create a new 3D printer by installing a compact halogen spot heater attached to one direction at the extruder of the FDM 3D printer with commercially black PLA filament as our first step. We consructed our original system in conjunction with the extruder with spot optical heating on fabricating lower layer interfaces due to change semi-melted state of already fabricated solid satate molded object during modeling. This effect contributes to the homogenization of the interface organization that is improvement of the interface strength.

In this study, it is great important to optimize optical radiation conditions of halogen spot heater due to change lower layer state to semi-melt again while maintaining the shape of the solidified lower layer part, while maintaining the shape of a product. Through trial and error, Optimum conditions of geometric placement of the devices and the irradiation temperature of 393 K estimated using a thermocouple. In order to evaluate a change of the interface strength by a tension test more definitely, we loaded perpendicularly in the laminated direction.

We showed great results that the tensile strength of typical specimen increased from 27 MPa to 34 MPa, and the surface smoothness drastic increase from Ra of 24 to 11 simultaneously by a mild fusion effect by the heat. Both surprisingly results was supported by the fracture surface observations. Using laser microscope, the microstructure of the unheated fracture surface was broken at the specific layer, but that of of heated product was observed at complex layers. These results were attributed to the interfacial texture homonigetion because of optimal semi-meltirized under layers.

The above-mentioned result makes the great effectiveness of the laminate spot heating method at the same time of molding heating remarkable clear.

MS-ThP-5 Investigation of Multi-Level ReRAM in 65nm CMOS for Logic-in-Memory Applications, ***Sarah Rafiq***, *K Beckmann, J Hazra, M Liehr,* SUNY Polytechnic Institute*; S Jha,* University of Central Florida*; N Cady,* SUNY Polytechnic Institute

Resistive Random Access Memory (ReRAM) has been extensively investigated as a non-volatile memory due to its low energy consumption and scalability. Bipolar ReRAM devices integrated in array architectures with selector devices is a prime candidate for high density memory arrays, novel logic-in-memory applications, and neuromorphic computation. Using a 65nm CMOS process technology, we have integrated 100 x 100 nm^2 HfO_2-based ReRAM devices at the metal 1 / via 1 (M1/V1) interface in a 1 transistor – 1 ReRAM (1T1R) configuration. Arrays of 1T1R cells were evaluated for binary switching between high resistance states (HRS) and low resistance states (LRS), exhibiting excellent yield and performance across a full 300mm wafer. Multi-level switching of 1T1R cells was then investigated by adjusting the gate voltage of the control transistor, which in turn, modulates the current compliance during programming (set operation) of the ReRAM device. Individual 1T1R cells within 8 x 8 arrays were programmed using increasing compliance current from 20 uA to 0.14 mA , which resulted in a 5-fold change in resistance level from 36 kOhm to 6.6 kOhm respectively. Multiple arrays from multiple 300 mm wafers have been evaluated to determine the variability within arrays, and the effects of changing processing conditions between wafers. Our results show that within a single wafer, 1T1R performance is consistent, but that variation in processing conditions for the HfO_2 switching layer can dramatically affect resistance levels and endurance of 1T1R. When comparing arrays on a single wafer, the standard deviation of the resistance state (for 100 switching cycles) decreased from 15 kOhm when programmed with current compliance of 20uA , to less than 500 Ohm at higher current compliance. Therefore, multiple distinguishable resistance states were achieved with higher current compliance. Using the two states (LRS and HRS), a 2 x 2 sub-array of 1T1R cells was then used to implement XOR logic functionality in a logic-in-memory configuration. Despite one of the cells having a low HRS not exceeding 20 kOhm, the output of the XOR logic was still unaffected. This demonstrates the robustness of logic-in-memory applications. The distinct binary state based logical computations, enabled by the appropriate selection of current compliance, also paves the way for ternary state logic and memory. Ongoing efforts are focused on higher precision control of the multi-level memory performance for 1T1R arrays up to 512 x 512 cells, and understanding the effects of wafer processing conditions on stochasticity of multi-level memory states, with the ultimate goal of full analog operation.

MS-ThP-6 III-V NanoWires for Junctionless Transistors Fabricated by Focused Ion Beam (FIB) System with Silicon Nitride Passivation, ***Cássio Almeida,*** University of Campinas, Brazil*; P Souza,* PUC-Rio, Brazil*; M Pires,* Federal University of Rio de Janeiro, Brazil*; J Diniz,* University of Campinas, Brazil

III-V Junctionless semiconductors devices were fabricated on InGaP and GaAs substrates using Gallium (Ga^+) Focused Ion Beam (FIB) System. Two groups of samples, with n^+-InGaP (10nm)/GaAs-buffer layer (300nm) and n^+-GaAs (10nm)/GaAs-buffer layer (300nm), both on semi-insulating GaAs (001) nominal orientation substrates, were studied. The samples were grown by Metalorganic Vapor Phase Epitaxy (MOCVD) in an Aixtron AIX 200 horizontal reactor at 100mbar, where the samples are heated by infra-red (IR) lamps. The total hydrogen carrier gas flow rate was 8L/min. The precursors used for the GaAs growth were trimethylgallium (TMGa) and arsine (AsH_3). Silane (SiH_4) was used for the n doping. The layers were grown at 630°C with a growth rate of 0,36nm/s and a V/III ratio of 70 for the n doped layer. A pre-growth treatment for de-oxidation at 700°C was applied to the GaAs substrates for 15minutes under AsH_3 over pressure. Furthermore, for the first time, the silicon nitride layer (SiN_x), thickness of 10nm, deposited by ECR-CVD, was used as gate dielectric of Junctionless and as passivation layer of the surfaces of structures. The morphology of the samples was observed by Atomic Force Microscopy (AFM). X-Ray diffraction (XRD) analysis was used in order to determine the InGaP lattice parameter and mismatch to the GaAs substrate. Hall measurements provided silicon doping levels of $10^{+19}cm^{-3}$ for both groups of samples, indicating the formation of n^+-type layers. These samples were used for MOS Junctionless (JL) Transistors applications, since III-V semiconductors present higher electron mobility values than silicon. These JL transistors (with three terminals: gate, source and drain) are fabricated using a Focused Ion Beam (FIB) System. Thus, Gallium (Ga^+) Focused Ion Beam (FIB) is used to define the III-V (InGaP or GaAs) nanowires (III-V NWs), which are the electron conduction channel between source and drain and Pt deposition (as gate, drain and source electrodes) layers. Finally, drain-source current (I_{DS}) versus drain-source voltage (V_{DS}) and drain-source current (I_{DS}) versus gate-source voltage (V_{GS}) measurements of JL devices will be extracted and will be able to indicate if these InGaP or GaAs nanowires and the passivation, with the SiN_x deposited by ECR-CVD are of high quality and suitable for Junctionless technology.

MS-ThP-7 The Development of High Efficiency X-ray Tube with Carbon Nanotube Yarn based-cold Cathode, ***Hyun Suk Kim***, *C Lee,* Wonkwang University, Korea

It is development high-efficiency X-ray rube using carbon nanotube yarn as an electronic source of field emission. It is inevitable to secure durability for uniform electronic emission characteristics of materials and to improve the stable structure of the emitter due to the miniaturization of the X-ray tube. Aimed at a high-efficiency X-ray generator with a new concept of cold-polar emission e-meter structure that can control the gap of uneven field discharge by a Chaos of uncontrolled faults in the process. The effects of various structures on the beam focusing performances and emission currents were simulated and fabricated. In the design of the X-ray sources, it is important to ensure that the fine beam focus and efficient electron emission can be simultaneously obtained. Therefore, the geometrical parameters, such as electrode shape and the gaps between parts should optimized. Owing to the unique design of the cathode, the electron beam emitted from the cathode was focused onto the anode without using electric lenses or extra biased electrodes. It was indicated that the beam spot sizes on the anode plate different with the changing electrode shape design. It will be studied that the optimum x-ray yield condition and focusing electrical shape effect in the CNT micro-focus CNT x-ray tube.

MS-ThP-8 High Aspect Ratio Carbon Nanotube Optical Collimator, ***Tyler Westover***, *R Davis, R Vanfleet,* Brigham Young University

Patterned carbon nanotube forests are finding an increasing number of applications due to their high aspect ratios and the characteristics of the nanotubes themselves. For example carbon nanotubes are highly absorptive of light in various wavelengths including visible and near infrared. Due to the high absorption of light that comes into contact with a carbon nanotube forest these structures work as sidewalls for an optical collimator. Here we will present our results using a carbon nanotube collimator in the visible and the IR.

MS-ThP-9 Development of a Fabrication Process for Integrated inductors on Flexible Substrate, ***Wilson Freitas,*** State University of Campinas, Brasil*; M Oliveira Piazzetta,* Brazilian Nanotechnology National Laboratory, Brazil*; L Manera,* UNICAMP, Brazil*; A Gobbi,* Brazilian Nanotechnology National Laboratory, Brazil

This paper presents the development of a fabrication process for integrated inductors on flexible substrate. The process consists of two metal and one dielectric layer on a polyimide flexible substrate. Kapton was the choice for the substrate due to its attractive characteristics such as high dimensional stability and thermal and electrical insulation. The first metal layer was 0.5 µm thick gold deposited by electroplating on a nickel film. Nickel was deposited by sputtering and used both as a seed for the electroplating deposition process and to improve the adhesion of gold to the substrate. Gold lines were patterned by lift-off and serve as mask for nickel wet etching. The second metal layer was made through the same

process, with thickness of 1 µm. Silicon dioxide was selected as dielectric, also patterned by lift-off and preceded by a chrome e-beam deposition step to enhance adhesion. Structures were formed by conventional photolithography process, with minimum line and space dimensions of 10 µm. With the use of intermediate layers of nickel there was no need for substrate modification to improve metal layers adhesion. The first metal layer thickness was optimized to improve dielectric step coverage, and the second layer was made thicker to reduce series resistance and provide better performance in both quality factor and frequency response. With this technology, it was possible to fabricate integrated inductors with 1 to 5 nH, maximum quality factor of 8, and self-resonant frequency in excess of 20 GHz, with values compatible with those from simulation with Keysight ADS, allowing for the implementation of VCOs and others RF circuits for hybrid flexible electronic structures.

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