Manufacturing Science and Technology
Room Hall D - Session MS-TuP

Aspects of Manufacturing Science and Technology Poster Session

MS-TuP2 Study of Mechanical Properties of Nanographene/Al Composite Materials for Purpose of Industrial Applications*, **Yusuke Oguro**, A. Matsumuro,* Aichi Institute of Technology, Japan

Basic science of graphene with various superior characteristics has been made clear rapidly on the frontier technology. Especially, development of superior nano-scale electronic devices and bio systems has been studied energetically. Nevertheless, various surprising mechanical properties of graphene have been not attracted great attention, such as extreme low density, tensile strength with 100 times stronger than steel by weight, Young's modulus with 1 TPa and more flexible than rubber. Since our original successful isolation techniques of creating single layer nanographene sheets from nanographene with a several sheet and uniforming dispersion of nanographene within based materials, we have been challenging in fabrication innovative nanographene reinforced Al composite sintered materials and established the fabrication method. It has already been demonstrated that Vickers hardness of nanographene/Al composite pellet-formed sintered materials showed the maximum value of 323 Hv, which means about 5 times up in comparison with that of Al bulk material, and the density decreased down to 2.45 g/cm^3 . So, the specific strength increased up to 414 kN・m/kg. The value increased up to 1.4 times for sintered Al material, and the value surprisingly exceeded that of commercial used magnesium alloys. These results would suggest bringing a change in the concept of industrial use materials.

In this study, we investigated possibility that industrial applications of our nanographene /Al composite materials would take advantage of their bulk properties. Standard flat-plate type specimens consisted of our nanographene/Al composite materials were fabricated under the same sintered condition in order to compare various mechanical properties of the standard data. Bending, tensile and fatigue mode tests were performed in precisely. Elastic and fracture properties were analyzed using four-point bending test apparatus without few artificial errors. The results revealed that Young's modulus increased from 40 GPa of sintered Al up to 45 GPa of nanographene/Al composite materials. Fracture characteristics showed that the breaking stress of the composite material showed drastic improvement up to 75 %, and the breaking strain of the composite material also increased up to 70 %. These great improvements of mechanical properties can be attributed to reinforcement effect of nanographene. Other mechanical properties tests should show the same tendency. Therefore, nanographene/Al composite materials give us excellent possibility of the innovative industrial use materials with a promising future.

MS-TuP3 Development of High-Strength Resin Composite Materials Reinforced with Nanocarbon for 3D Printing Manufacturing*, **Hiroaki Sakaguchi**, A. Matsumuro,* Aichi Institute of Technology, Japan

Now technologies related to 3D printing are strongly leading the industrial revolution in all fields. However, unavoidable basic technical problems of 3D printing have prevented from an ideal technology of manufacturing products with conventional characteristics. This serious problem must be caused by the layer structure of products used by additive process, and the insufficient mechanical strength of the molding materials specific to each type of 3D printer.

In this study, we strongly focused on develop innovative high strength resin-based composite materials reinforced with nanocarbon, i.e. C_{60}, CNT and graphene. These nanocarbon show extraordinary mechanical, physical and chemical properties with each superior characteristics. It is worth noticing that the mechanical properties, such as a strength, elastic modulus, hardness and so on, can be investigated incommensurably high values compared with those of commercial materials. Furthermore, these kinds of nanocarbon have superior geometric and nanometer-scale dimension characteristics as reinforcement materials considering various 3D printing processes. We researched the possibility of the application of nanocabon composite materials with ABS base resin used widely in industry for the purpose of innovative strength increment of 3D printed products. To clarify each characteristic of C_{60}, CNT and graphene to ABS resin composites, these three-type nanocarbon composite specimens were fabricated. The fabrication method with a uniform composite material reinforced with distributed each nanocarbon have established on our own. The uniform and dispersion of nanocarbon around ABS base powder particles should be the key point for fabrication of specimen by melt and solidification method. We applied our original technique using ultrasonic vibration with isopropyl alcohol as a solvent for 4 hours. And we investigated the optimal composition rates of each composite material. Each pellet-type solidified specimens was prepared at about 500 K for 30 minutes by atmospheric furnace cooling.

As the result of one of representative mechanical property, Vickers hardness for each specimen excellently increased up to about 10 % for 7.0 wt.% C_{60} and 7 % for 1.0 wt.% graphene in comparison with the value of pure ABS resin bulk sample. The evaluation of important other mechanical properties such as pulling strength, break strength, fatigue strength, elastic modulus and so on have been examined in detail. These results should give us great conclusive evidence for achievement of this study.

MS-TuP4 Development of Innovative 3D Printer with Superior Multifunctional Surface Modification*, **Kentaro Horiuchi**, Y. Hasegawa, A. Matsumuro,* Aichi Institute of Technology, Japan

Direct manufacturing process using 3D printing technologies is spreading rapidly in all fields. Many difficult problems should be overcome in order to establish 3D printing technologies as the general industrial products manufacture method. One of the representative problems is the durability or strength of the products. But now this problem is overcoming rapidly by passionate R&D for specific products, and the material stead studies with various characteristics to satisfy the requirement of each product have conducted wide fields. Furthermore, studies of 3D printing systems with superior functions of various post processes at molding simultaneously are indispensable. The particular expected functions are removal of support materials from printed products, full-color painting, and surface modification for improvement of the mechanical, electrical, chemical and biological properties. The development of removal of support materials and full-color molding have been already solved using automatic machine cutting machine and ink-jet-type paint system equivalent to the same mechanism of a printer used in the office as typical examples, respectively. On the other hand, the surface modification technologies have been applied in wide industrial field in order to control great various characteristics of hardness, wear resistance, electrical conductivity, thermal conductivity and so on at arbitrary places of metal products using vacuum apparatus. So the surface modification technologies should be necessary applied to 3D printing products using resin materials.

In this study, our unique 3D printing system with multifunctional surface modification has been developed using the conventional air brush painting technique for resin and metal products. The air brush apparatus consist of only three parts: paint flow nozzle, paint container and air compressor. So high extensibility of the function and the mechanism of the spray system, the synchronization with the printer and numerical flexibility of the air brush can be possible easily. For confirmation of our trial apparatus, the full-color painting on the surface of 3D printing products has been succeeded by mix-spraying from three air brushes with suitable spray ratio using paint of cyan, magenta and yellow. The commercial paints using a air brush or a spray gun are widely used due to improve many kinds of charming surface characteristic such as lubricity, electric property, glossiness, fireproof property, corrosion resistance, luminous color property, et cetera. Therefore we could find great attractive possibility of realization of development of the innovative 3D printer with multifunctional surface modification.

MS-TuP5 Controlling the Diameter, Uniformity, and Spatial Distribution of Electrospun PVDF Nanofibers through Experiment and Simulation*, **Omar Ali**, T. Grier, A. Ueda, C. Marvinney, S. Avanesyan, C.S. Carson, W.E. Collins,* Fisk University*; J. DeCoste,* US Army Research, Development, and Engineering Command*; R. Mu,* Fisk University

Polyvinylidene fluoride (PVDF) is a polymer which has important applications in insulation, sensors, and battery production. The thermal, electrical, elastic, and morphological behaviors and properties of PVDF, on which the applications depend, are intimately related to the structure of the polymer on various physical length scales. Retained PVDF solid structures on different scales are also related. For example, stretching and poling a PVDF membrane causes the PVDF monomer chain to change phase from the non-polar alpha phase to the polar beta phase, which imparts significant piezoelectric and pyroelectric properties. Controlling the properties of PVDF by tuning the solid structures is, therefore, of key importance for various applications. Efforts have been made by our team into electrospinning technology, which is a relatively simple and scalable method of nanofiber production, for energy storage and biomedical applications.

We have investigated the effect of varying the electrospinning conditions and polymer solution properties on the diameter size and uniformity, and the spatial distribution of the produced PVDF nanofibers. Experimentally, we varied both the concentration of PVDF in the initial solution, and the voltage applied during electrospinning. Using optical imaging and scanning electron microscopy (SEM), we obtained a set of images for several voltage-concentration parameter pairs. Based on the experimental data, we were able to examine the diameter and uniformity as functions of the concentration and applied voltage. Additionally, we simulated different electric field distributions in an effort to design a method for controlling fiber deposition area.

The results indicate that increased concertation can lead to a significant increase in average fiber diameter. Fibers produced at lower concentrations are not only thinner, but also had significantly less uniform diameters and a greater number of beads in the fibers. The effect of voltage on diameter size and uniformity was somewhat less clear. There does not appear to be any correlation between voltage and average diameter size. However, voltages around the middle of the range we studied seem to lead to slightly more uniform fibers. Further, COMSOL simulation has been conducted and showed that using conduction rings to manipulate the electric field lines can make the field diverge sufficiently at first to allow for the electrospinning process to take place and then converge to direct the fibers to a smaller area of the grounded substrate. Such control over where the fibers are distributed can be very useful when producing fibrous mats and other macro-structures from nanofibers.

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