【Grant-in-Aid for Scientific Research(S)】
Science and Engineering (Engineering Ⅰ)

Title of Project : Development of Design-Fabrication-Evaluation Methodology for High Performance Composites Reinforced by Carbon Nanotube

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Research Area : Engineering

Keyword : Carbon Nanotube, Composite, Ceramics, Precursor Method, Mechanical and Electrical Properties

【Purpose and Background of the Research】

Carbon nanotubes (CNTs) have attracted enormous attention from many researchers of material science, and their physical properties have been intensively clarified. The next step of carbon nanotube research should be development of high performance CNT materials with industrial applications. Production of CNT composites represents one of great targets for the application. Compositing polymer with CNT has been advancing more than ceramics, commercial products being released. Ceramic composites are stable at high temperatures and can be available for wide industrial fields. However, the mechanical properties of CNT ceramic composites prepared to date have not been sufficient for industrial applications. The most difficulty is the inhomogeneous dispersion and agglomeration of CNTs in the composite, resulting in the formation of defects and the low mechanical performance.

In this study, alumina has been selected as the matrix of CNT composites because of its low cost and high performance. The final goal is to develop a design-fabrication-evaluation methodology for CNT ceramic matrix composites and to produce high performance composites on the basis of the method to be developed..

【Research Methods】

Multi-walled carbon nanotubes (MWNTs) are chosen to fabricate CNT composites because of its low cost and high volume production. This research attempts to overcome the above-mentioned processing difficulty using the following approach. The effect of thickness of MWNTs on the dispersion will be examined, first. Thick MWNTs consist of a lot of graphens and provides higher stiffness. The difference of CNT stiffness should affect the agglomeration and dispersion of MWNTs in the composites. The other point of this research is the development of a precursor method for fabricating CNT composites. Aluminum hydroxide will be used as a starting material instead of alumina powder in the precursor method. Over 500˚C, alumina nucleus evolves from aluminum hydroxide and grows in heating processes. The pure alumina prepared from aluminum hydroxide tends to grow into large crystals at the sintering temperature. The small amount of SiO_2 and MgO will be added to prevent excessive grain growth of the alumina matrix. The approach described above is expected to improve the dispersion of CNTs in the composites to be developed.

【Expected Research Achievements and Scientific Significance】

When thin MWNTs are used in Al_2O_3 composite, large agglomerates of thin MWNTs tend to be formed and no homogeneous dispersion has been achieved yet. The strength of the composite has been restricted by the CNT agglomeration and not available for industrial application. Our preliminary examination has shown that composites of thick MWNTs and Al_2O_3 exhibited higher strength than 400 MPa which may be sufficient for industrial applications. The nano-scale structure of the composite consisted of well dispersed MWNTs with only limited amount of agglomeration. The range of the electrical conductivity of the CNT composites is changed from the insulator of alumina to the conductor by addition of only 0.3 mass% of MWNTs.

The CNT composites will be prepared by pressureless sintering method in addition to pressure sintering such as spark plasma sintering method. The pressureless sintering to be developed represents a practical technique to fabricate low-cost and near-net shaped products. The composites will be examined in terms of mechanical and electrical properties, such as strength and fracture toughness, tribology, biocompatibility, piezoelectric effect, and interactions with magnetic waves. The CNT composites may have potential applications in bearings, mechanical shields, liners for hip stem, electromagnetic wave absorbers, antennas, electric conductive parts for semiconductor manufacturing process, and so forth.

【Publications Relevant to the Project】

1.“A Novel Structure for Carbon Nanotube Reinforced Alumina Composites with Improved Mechanical Properties”, G. Yamamoto, M. Omori, T. Hashida and H. Kimura, Nanotechnology, 19, (2008), 315708 (7pp).
2."Structural Characterization and Frictional Properties of Carbon Nanotube/Alumina Composites Prepared by Precursor Method", G. Yamamoto, M. Omori, K. Yokomizo, T. Hashida and K. Adachi, Mater. Sci. and Engineering B, 148, (2008), 265-269.
3. Patent: High performance composites and their production method, No. 2006-98760
4. Patent: High performance composites and their production method, No. 2006-155736

【Term of Project】 FY2009-2013

【Budget Allocation】 103,500 Thousand Yen

【Homepage Address and Other Contact Information】
http://www.rift.mech.tohoku.ac.jp/hashida-lab/cnt-kakenhi