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Nanoscience and Nanotechnology of Carbon Nanotubes

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Unique properties of CNTs depend on their structures and morphologies, and well-controlled specimens (diameter, length, quantity, chirality, structural perfection, impurity, homogeneity) will be needed for precise and reliable experiments as well as for their industrial applications. Regarding the production of well-controlled single-wall carbon nanotubes (SWCNT), two important breakthroughs in the SWCNT growth were made in our group at AIST [1]. One is a direct injection pyrolytic synthesis (DIPS) method, which can provide controlled tube diameters and extremely high purity tubes on the industrial scale production. Some of industrial use of the product is for transparent and flexible conductive films, SWCNT threads, sheet and thin film transistors (TFT). Successful separation of semiconducting tubes and metallic ones has been achieved recently in several groups and a good TFT performance has been demonstrated using only semiconducting tubes [2]. Another is the "Super-Growth" of SWCNTs, which grow vertically on various substrates including metal foils of "A4 size". Thus produced low-cost SWCNTs are promising for industrial use such as for high power density capacitors. Using a film of such oriented SWCNTs on a Si substrate, three dimensional MEMS devices, made up of only a SWCNTs sheet, have been built for multipurpose use such as relay and cantilever operating under various environments [3].

For characterization of the SWCNTs Raman spectroscopy of radial breathing mode (RBM) is a standard method. Another spectroscopic characterization of SWCNTs is two-D mapping of photo luminescence (PL) particularly for semiconducting tubes that can be specified in terms of band gaps. The method has been applied to study the band-gap modulation of SWCNTs mostly due to stress, which is induced by doping various molecules inside the central hollows of thinner SWCNTs [4].

The importance of characterization of nano-structured materials will be demonstrated by showing the latest HRTEM results of atomic structures of CNTs and their related structures, which have been revealed by an ultra-high resolution TEM with a spherical aberration corrector. Individual carbon atoms, local atomic defects of SWCNTs, molecular structures of fullerene and metallofullerene molecules were directly recorded. Dynamic behaviors of some of those atoms and defects such as carbon-vacancies and their coalescence phenomena, connecting two particular CNTs by joule heating after locating them in a precise position, will be demonstrated [5].

References

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