SCIENCE AND NANOTECHNOLOGY OF NANO-CARBON MATERIALS

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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 experiments and also for their industrial applications. Regarding these requirements, two important breakthroughs in single-wall carbon nanotube (SWCNT) growth were made recently in our laboratories at AIST (1). One is a floating catalyst-assisted CVD method of growing SWCNTs, which can provide controlled tube diameters and extremely high purity tubes with high production yield. Some of industrial use of the product is for transparent and flexible conductive films and threads. Another is the "Super-Growth" of SWCNTs, which grow vertically on various substrates including *metal foils* as high as one centimeter. The method has being developed into a level for the industrial production, which will be used for *high power density capacitors*.

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 photoluminessence particularly for semiconducting tubes which are specified in terms of band gaps and excitation wavelength. 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 the tubes.

The importance of characterization of nano-structured materials will be demonstrated by showing the latest results of atomic structures of CNTs and their modifications, which have been revealed by an ultra-high resolution TEM with a spherical aberration corrector. *Individual carbon atoms, local atomic defects* of SWCNTs and individual fullerene molecules were directly recorded. Dynamic behaviors of those atoms and defects as well as doped metal atoms and organic molecules inside the tubes are of interest in terms of sophisticated device application of CNTs (2).

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