Aberration-Corrected TEM/ETEM-Based Research on Single-Walled Carbon Nanotubes

Hua Jiang[1], Ying Tian[1,2], Yongping Liao[1], Qiang Zhang[1], Nan Wei[1] and Esko Kauppinen[1]

[1] Department of Physics, Aalto University School of Science, Espoo, Finland
[2] Department of Physics, Dalian Maritime University, Dalian, Liaoning 116026, China
hua.jiang@aalto.fi

In this contribution, we will review methods of chiral structure analysis of single-walled carbon nanotubes (SWCNTs) with the aid of electron diffraction (ED) technique [1]. On the basis of this, we have established an approach using ED as a means to evaluate the validity of Raman spectroscopy for quantification of concentrations of metallic SWNTs (M%) or of semi-conducting tubes (S-SWNT%) [2]. Chirality distribution maps of SWNTs produced by CVD methods with Fe nanoparticles as catalysts at various synthesis conditions have been analyzed. As a recent advance [3], we have successfully achieved direct synthesis of single-walled carbon nanotube thin films with various colors using a novel floating-catalyst-CVD process with ferrocene-based iron catalyst particles and CO as the carbon source. The color is tunable by adjusting the reactor conditions, i.e. the temperature and especially the addition of CO_2. Based on electron diffraction analysis of individual SWCNTs in our colorful SWCNT thin films, we were able to attribute the colors of the SWCNT thin films to their narrow diameter in certain ranges which give rise to absorption peaks in the visible region. It is demonstrated that the narrow (*n, m*) chirality distribution also accounts for the display of certain color of a SWCNT thin film.

We also demonstrate that structural control of SWNTs is achievable by fabricating nanoparticle catalysts with a defined structure on crystalline substrates via controlled growth techniques. *In situ* time-resolved environmental transmission electron microscope (ETEM) observation at atomic resolution of nanoparticle formation and SWNT growth are accomplished.

References

[1] H. Jiang, et. al, Carbon, **45** (2016), 662.
[2] Y. Tian, et. al, Anal. Chem. **90** (2018), 2517.
[3] Y.P. Liao, et. al, Submitted to JACS, 2018.