

Magnetic properties of Fe catalysts included in carbon nanotubes

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Use of catalytic particles is indispensable to mass-production of carbon nanotubes (CNTs). In order to understand the physical properties of CNTs, not only the property of the catalyst particles but also their interplay with CNTs should be examined.

We have synthesized the multiwalled carbon nanotubes (MWNTs) including Fe catalysts by the vapor phase growth method at 950°C. By the measurements of transmission electron microscopy (TEM), the diameters of the MWNTs were found to be several tens nm. The Fe concentration, which is linearly proportional to the Ar/CO gas flow ratio, was controlled by changing the flow ratio (25 ~ 300) during the vapor phase growing of the CNTs. The magnetic properties of the MWNTs with different Fe concentrations were characterized using a SQUID magnetometer at 5 T magnet in the temperature range 5-350 K.

Superparamagnetic behaviors were found in the zero-field cooled and field cooled magnetizations for all the Fe concentrations [1]. Besides, vortex phase-like magnetic hysteresis loops [2], with very small coercive field H_C , were shown at low and high Fe concentrations (Fig. 1). Figure 2 displays the temperature dependent H_C for a small Fe concentration, which decreases with lowering temperature. Our measurements show that an increase in the Fe concentration as well as a decrease in temperature gives rise to the vortex phase-like behaviors of magnetic hysteresis loops, indicative of a relation between the increase of the spin correlation and the formation of the vortex phase.

References

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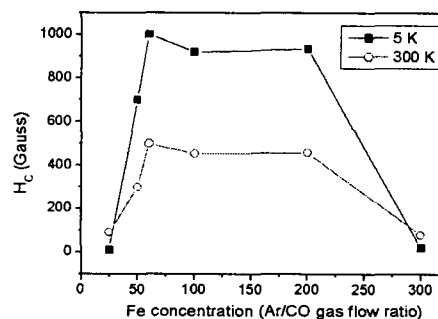


Fig.1 The relative Fe concentration dependent H_C in the MWNTs.

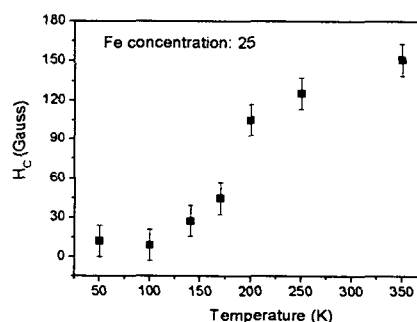


Fig. 2 Temperature dependent H_C , for a Fe relative concentration of 25.