n-Type Thermoelectric Properties of Single-walled Carbon Nanotubes encapsulating Molecular Dopants

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n-Type single-walled carbon nanotubes (SWNTs) have been investigated for the development of flexible p-n junction devicesincluding solar cells[1]and FETs[2]. n-Type SWNTs have been regarded as unstable under ambient condition, which has motivated us to improve air-stability by means of molecular doping. We have recently demonstrated that adsorption of phosphine derivatives alters the sign of majority carriers of SWNTs from p-type to n-type[3]. However, phosphine-SWNT composites showed limited stability in air.

In this work, we report on the n-type doping and the stabilization of n-type SWNTs using the encapsulation of phosphine derivatives in SWNTs. The internal space of nanotubes is expected to suppress the oxidation. We chose 1,1'-Bis(diphenylphosphino)ferrocene (dppf) as a dopant since it shows a stable redox behavior. We prepared SWNTs encapsulating dppf (dppf@SWNTs) by heating dppf/SWNTs composite films at 200 °C *in vacuo*.

TEM observation reaveled that dppf was encapsulated into SWNTs (Fig 1). The conductivity of the dppf@SWNTs was significantly higher than that of raw SWNTs, presumably due to the electron transfer from dppf to SWNTs. This composite showed comparatively high power factor ($195\mu W/mK^2$) with the negative Seebeck coefficient ($-51\mu V/K$) by encapsulation of dppf. Moreover, we found this n-type film was stable over 120 h in air[4].

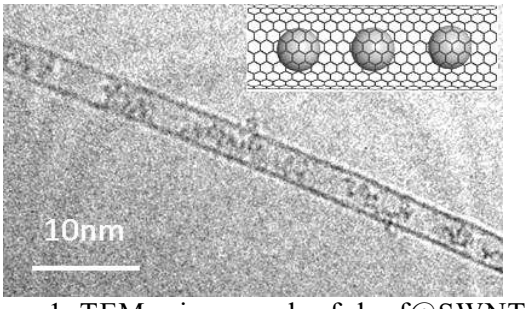

Figure 1: TEM micrograph of dppf@SWNTs

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