n-Type Carbon Nanotubes with Extremely High Thermal Stability in Air Produced by Doping with Organic Superbases

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Carbon nanotubes (CNTs) have the potential to be used as future component of electronic and energy devices such as thin-film transistors and thermoelectric generators. These devices use both p- and n-type materials to create p/n junctions. While CNTs accept autoxidation in air so that they show p-type polarity,[1] the development of stable n-type CNTs is still challenging. As devices are inescapably heated during operation, it is crucial to preserve not only the stability near room temperature but also the thermal stability.

Here, we demonstrate that organic superbases (Fig. 1a) can be used as n-type inducers for CNTs *via* electron transfer from the bases to the CNTs. Doping of CNTs could be performed by facile immersing process into the dopant solution (Fig. 1b). Thermoelectric measurement of the CNT films revealed that the Seebeck coefficient (thermopower) of CNTs changes from positive to negative upon doping, by which electron injection into CNTs and p- to n-type polarity switching could be confirmed. Importantly, the negative Seebeck coefficient doped with TBD and Me-TBD could be retained for more than 6 months during incubation at 100 °C in air (Fig. 1c). To highlight the potential capability of stable n-type CNTs, a thermoelectric device was constructed using the CNT p/n junctions, which exhibits a power output of ~4.7 μW from a temperature difference of 40 K.[2]

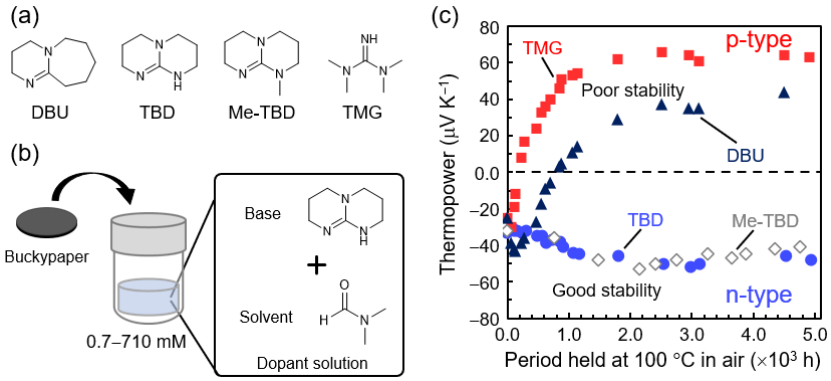

Fig. 1 (a) Chemical structures of organic superbases used as dopant for CNT. (b) Schematic of doping process. (c) Long-term stability of doped state of CNTs at 100 °C in air.

1) Kang *et al.*, *Nanotechnology* **2005**, *16*, 1048. 2) Horike *et al.*, *Nat. Commun.* **2022**, *13*, 3517.