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In-plane conductivity of carbon nanotube forest formed on silicon carbide

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Dense Carbon nanotube forest formed by silicon carbide surface decomposition method (CNTs on SiC) consists of nearly ideally close-packed CNTs[1,2]. Generally, CNT conducts in its on-axis direction, yet such highly dense CNT forest may cause high in-plane direction conductivity. Here we report on the in-plane conductivity evaluation of CNT forest formed on SiC.

On-axis C-face (000-1) of semi-insulating SiC substrates (< 10^{-8} S/cm) were annealed at 1600 ºC in vacuum (~10^{-2} Pa). The in-plane conductivity was measured by van der Pauw method. Fig. 1 shows (a) the schematic image of sheet conductivity measurement and (b) its equivalent circuit. There are four parts which contribute to CNTs on SiC in-plane conductivity, CNT caps, CNT bulk, CNT/SiC interface, and SiC bulk. To determine which part(s) is/are dominant in conduction, CNT lengths were varied by controlling decomposition time.

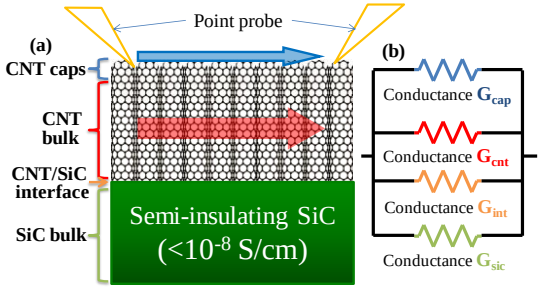

Fig. 1 (a) Schematic image of sheet conductivity measurement and (b) its

Fig. 2 shows the relationship between CNT on SiC sheet conductivity and CNT length. The slope measured as ~50 S/cm corresponds to the in-plane CNT bulk conductivity. The intercept corresponds to the conduction of the others. The SiC bulk conduction is negligible because the initial SiC substrate conductivity was extremely low as ~10^{-9} S. The CNT/SiC interface conductivity was checked by removing CNTs[3] and was also sufficiently small. Therefore, the intercept indicates the sheet conductivity of CNT caps as ~7×10^{-4} S/sq.

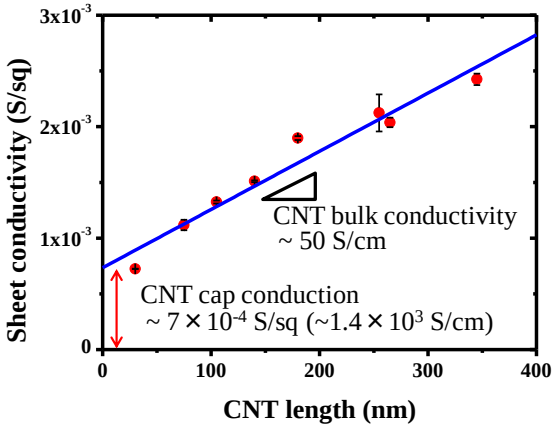

Fig. 2 Relationship between CNT sheet conductivity and CNT length

In CNT bulk region, CNT should be parallel adjacent to each other. We assumed three approximations to conduct the contact resistivity. First, CNTs have the same diameter and are densely packed with the hexagonal pattern. Second, CNT/CNT contact conductivity is the same for CNTs with the same diameter. Third, CNT conductivity is much higher than the CNT/CNT contact conductivity. With these approximations, CNT forest is described as the net-like circuit in Fig.3. The contact conductivity normalized by CNT contact length was written as $\sigma_{C,CNT/CNT} = \sigma_S / \sqrt{3}t$. $\sigma_S t$ is the slope of Fig. 2. Thus the CNT/CNT contact conductivity is yielded as ~30 S/cm (contact resistivity: ~3×10^{-2} Ωcm).

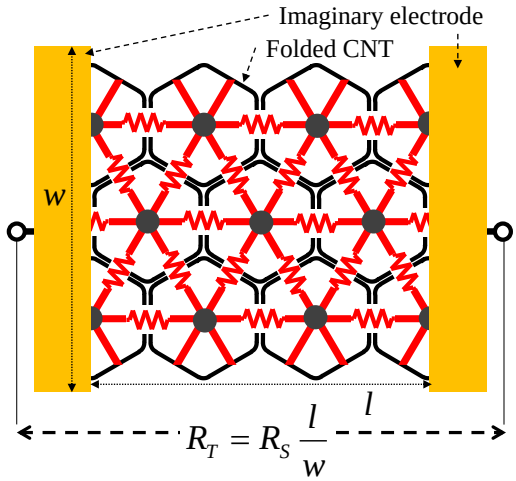

Fig. 3 Upside view of approximated electrical circuit of dense carbon nanotube forest.

References

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3) R. Marega et al., Carbon **47**, 675 (2009).