On resistance formulation for carbon nanotubes

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On Resistance Formulation for Carbon Nanotubes

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Abstract. A brief introduction to the nano-scale resistance is given, and a new resistance formulation is given.

Sundqvist et al. found the resistance of SMNTs does not follow what metal conductors do[1], and suggested the following formulation

$$R(L) \propto \exp(L)$$

Hereby we suggest another formulation for non-metal conductors[2,3]:

$$R \propto L^d r^{-(1+D)}$$

where \( R \) is the resistance, \( L \) and \( r \) are, respectively, the length and the radius of the non-metal conductor. \( D \) is the fractal dimension of its perimeter of the section of the carbon nanotubes, \( d \) is the fractal dimension of longitudinal length.

When \( D=1 \) (infinite smoothness of the section perimeter) and \( d=1 \) (infinite continuity of the wall), Eq.(2) turns out to be the formulation for metal conductors.

For single-walled carbon nanotubes, we consider a special case as illustrated in Fig.1. The fractal dimensions can be calculated as

$$d = \frac{\ln 4}{\ln(\sqrt{3})} = 2.52$$

and

$$D = \frac{\ln 2}{\ln(\sqrt{3})} = 1.26$$

Our prediction, therefore, reads

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where \( k \) is a material constant.

In order to verify our theoretical prediction, we have to re-analyze the Sundqvist et al.’s experiment data[1]. It is obvious that \( R=0 \) when \( L=0 \). But in Sundqvist et al.’s experiment[1], we found \( R(0) \approx 50 \text{ k}\Omega \), this is the error due to the contact resistance at the tip, so every obtained data is taken away the initial error, the modified experimental data are illustrated in Fig.2. We find our prediction agrees well with the experimental data.

\[
R = \frac{kL^{2.52}}{r^{2.26}}
\]  

Figure 1. Fractal boundary of carbon nano-tube.

Figure 2. Sundqvist et al.’s experiment 1. Resistance(k \( \Omega \)) vs. length (\( \mu \text{m} \)) for SWNTs.
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