Size dependence of electronic transport in multiwalled carbon nanotubes

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In a semiconducting single walled carbon nanotube (SWNT), the electronic conduction can be modulated with a (capacitively) strongly coupled gate electrode. The bandgap Eg, has (in the simple tight-binding theory) the inverse dependence on diameter (D). As graphene does not possess a bandgap, an important direction in current research is to create constricted channels, graphene nanoribbons, where a gap is created via quantum confinement due to the narrow width of the channel. The size of the gap is then roughly in a similar inverse relation with the width of the constriction as in the case of the diameter dependence of semiconducting SWNT's. In SWNT's, however, the diameter range is rather narrow; 1-3 nm.

Reported transport measurements on multiwalled nanotubes (MWNT) have been performed on tubes with diameters of 10 nm or more. In most studies the working assumption has been that the outer layer is solely responsible for the low bias transport properties. In MWNT's with D larger than 10 nm, the semiconducting behavior of the outer wall is smeared out at room temperature. Our group has done pioneering work on the basic transport data of intermediate sized MWNTs ranging in diameter from 2 to almost 20 nm.

We have measured low temperature transport properties of the MWNT's of different diameters. In nearly all samples the gate dependent conductance exhibits a gap whose size increases with decreasing tube diameter and increasing electrode separation. This so called transport gap is attributed, based on the experimental findings, on a combination of localization effects and narrow diameter induced gaps in the electronic band structure.

Our work complements and bridges previous works on both SWNTs and MWNTs. We also find substantial similarities between our results on the size dependence of MWNT's and the comparable current intense research on graphene nanoribbons, whose dimensions are relatively easy to control.