# Temperature Dependence of the Optical Transitions in Single-walled Carbon Nanotubes

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Single-walled carbon nanotubes (SWCNTs) are promising candidates for a variety of electronic and optical applications. Optical transitions play a central role in the understanding of carbon nanotubes [1]. Both theoretical and experimental studies revealed that light absorption excites strongly correlated electron-hole pairs in semiconducting nanotubes, known as excitons, with binding energies of several hundred meV [2,3].
There is a strong debate on how much optical transitions are dominated by excitons in metallic SWCNTs as well. In general, binding energies are higher in nanotubes due to their one-dimensional character in comparison to bulk semiconductors. Theoretical calculations show that excitons exist even in metallic SWCNTs with binding energies predicted around 50 meV, depending on the nanotube chiral index *(n,m)* and the transition energy $E_{ii}$ [4,5].

Here we present results on the temperature dependence of the transition energies $E_{ii}$ of SWCNTs. Tunable Raman spectroscopy has been used to investigate the radial breathing mode (RBM).
We performed measurements of the optical transition energy $E_{ii}$ at different temperatures for both metallic and semiconducting SWCNTs in the range of 300 K and 873 K.
In case of semiconducting SWCNTs, we observe a monotonic decrease of $E_{ii}$ with increasing temperature. Metallic SWCNTs show a different behavior, which can be divided into three parts. First we observe a downshift of $E_{ii}$ as a function of temperature. At higher temperatures, we observe an upshift in the transition energy (blueshift) at approximately 573 K. At even higher temperatures there is again a downshift similar to the first one.
We suggest that this behavior can be interpreted in terms of excitons in metallic nanotubes, which are dissociated into free electron-hole pairs at temperatures related to the exciton binding energies.

**References:**

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