Low Dimensional Materials and Catalysts

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Synthesis and structural properties of SiC nanowires encapsulated in carbon nanotubes

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Carbon nanotubes (CNT) have attracted great attention since their discovery in 1991 by Iijima [1]. Their good thermal as well as electrical conductivity and high mechanical strength make them promising materials for applications such as field emission devices, tips for AFM or field effect transistors [2].

Silicon carbide, in particular as nanowires, has emerged as an interesting material for semiconductor industry due to its wide band gap [3]. One possibility to produce such carbide nanowires is using CNT as templates [4,5]. For that the CNT is converted into a SiC nanowire in a reactive SiO atmosphere. In order to produce novel functional electronic devices on the nanometer scale, several groups have been working on the combination of CNT and SiC nanowires, for instance, in form of SiC-SiO_2-C/CNT coaxial nanocables [6,7]. By high-temperature annealing these can then be transformed into SiC-CNT junctions. CNT filled with pure SiC nanowires were reported by Kokai *et al.* [8] by means of laser ablation using Si-C targets.

In this study, we present CNT filled with pure SiC nanowires that were grown via plasma-enhanced chemical vapour deposition (PE-CVD) from $Fe_{20}Ni_{80}$ ("permalloy") nanoparticles on Si/SiO_2 substrates. Characterization of the as-grown CNT was performed by means of aberration-corrected high resolution transmission electron microscopy (HRTEM) on a FEI TITAN^3 80-300 microscope operating at 80kV in order to reduce knock-on damages. Electron energy loss spectroscopy (EELS) was employed to confirm the filling being SiC without impurities of Fe or Ni. Measurements of the band gap by means of EELS were conducted utilizing a monochromized electron beam.

Figure 1 shows a CNT filled with crystalline SiC. The figure evidences that the interface between the SiC and the concentric graphene layers of the CNT is characterized by a bending of the graphene layers towards the SiC core. This leads to the assumption that both, the CNT growth as well as the formation of the SiC nanowire occur simultaneously. However, further TEM studies are necessary in order to better understand the nature of this interface.

For the measurement of the SiC band gap the surrounding CNT needed to be removed due to the carbon plasmon peak appearing in the low loss spectrum range. This would have impeded an unambiguous detection of electronic excitations across the band gap in the low loss region of the EEL spectrum. Figure 2 shows the low loss EEL spectrum of the SiC (dotted line). The solid line represents the spectrum after the subtraction of the zero loss peak. For determining the direct band gap the upper region of the spectrum was fitted by a function of the type $(E-E_g)^{0,5}$ (red line) [9]. From this fit the value for the direct bandgap E_g was therefore estimated to be 5.2 eV. This result will be compared with previously reported data in the literature.

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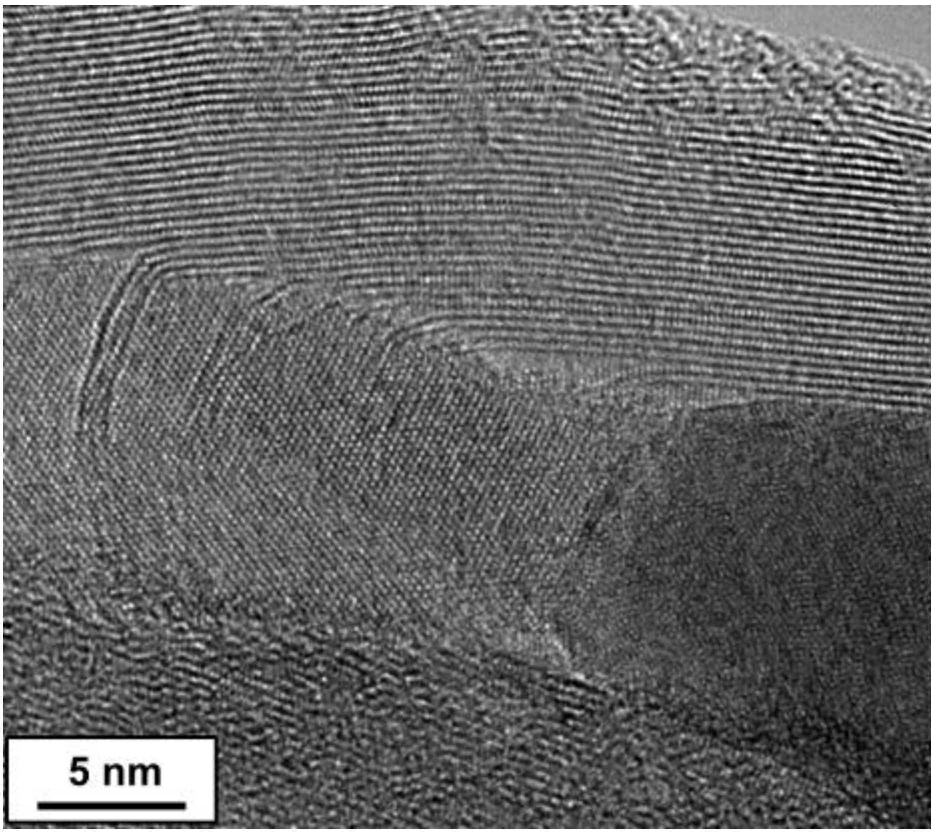

Figure 1. TEM image of a crystalline SiC nanowire encapsulated in a CNT and terminated with a permalloy catalyst particle. A pronounced bending of the graphene layers towards the SiC is visible.

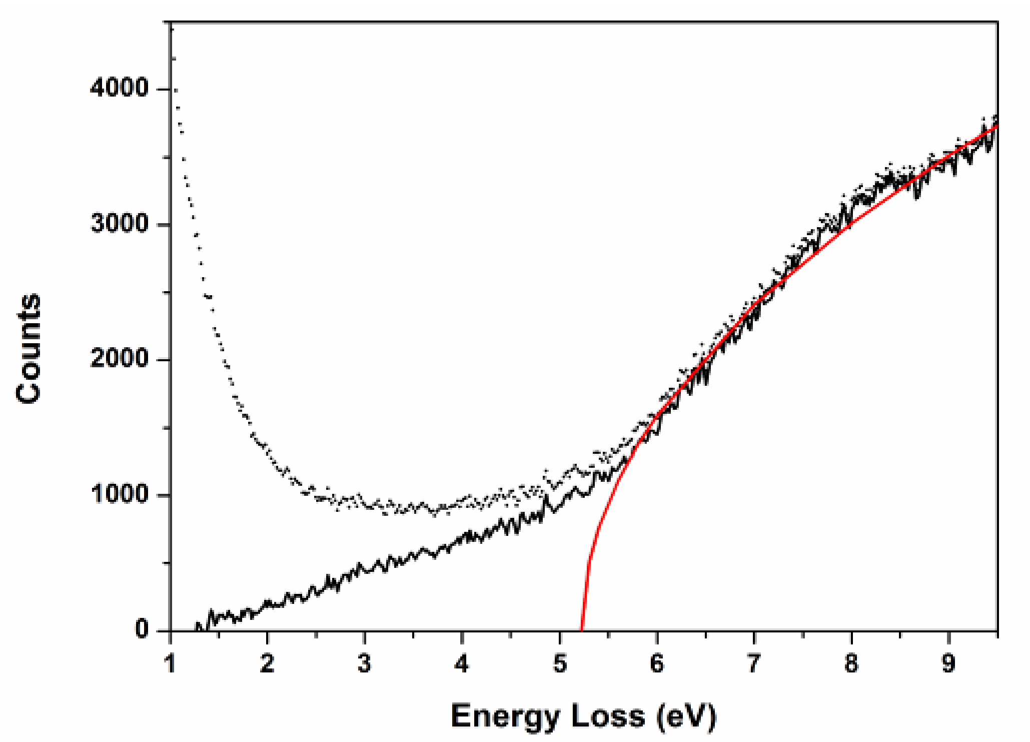

Figure 2. The dotted line represents the VEEL spectrum of the SiC nanowire (after removal of the graphene layers). The solid line results after the subtraction of the zero loss peak. The upper region of the spectrum is then fitted by the square root function $(E-E_g)^{0,5}$. This leads to a value for the indirect bandgap of 5,2 eV.