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Defects of SiC nanowires studied by STM and STS

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ABSTRACT

For the first time the scanning tunneling microscopy (STM) and scanning tunneling spectroscopy (STS) are employed to investigate the morphology and the surface electronic structure of the defective silicon carbide nanowires (SiCNWs). The SiCNWs produced via combustion synthesis route are studied. The STS measurements are performed in the current imaging tunneling spectroscopy mode (CITS) that allows us to determine the correlation between STM topography and the local density of electronic states (LDOS) around the bend of an isolated SiCNW. The measurements reveal fluctuations of LDOS in the vicinity of the defect. The local graphitisation and the inhomogeneous concentration of doping impurities (e.g. nitrogen, oxygen) are considered to explain these fluctuations of metallic-like LDOS in the vicinity of the SiCNW's deformation.

1. Introduction

Because of its outstanding physical properties, silicon carbide (SiC) is a very promising material for high power, high temperature and high frequency applications [1,2]. In recent years, SiC has been also found to form various one-dimensional (1D) nanostructures (e.g. nanowires and nanotubes) and this fact makes SiC attractive for construction of nanoelectronic devices like SiC nanowire-based transistor [3]. SiC-based 1D nanostructures have been synthesized using many different processes (see [4,5] and references therein). Recently, it has been demonstrated that SiC nanowires (SiCNWs) can be produced also via thermolysis-induced carbonization of halocarbons (combustion synthesis) which is efficient single step chemical reaction performed in a closed reactor without external heating of the reactants [6].

The ideal SiCNWs are generally thin elongated SiC nanocrystals. However, SiCNWs usually possess various structural defects that can be divided into two classes: (i) 'large-scale' deformations (e.g. diameter fluctuations [7], Y-junctions [8], bends [9], springs [10] or "S"-shaped sections [11]) and (ii) 'atomic-scale' defects (e.g. vacancies and antisites [12] or interstitials [13]). In general, the first class of defects is characteristic of all 1D nanostructures (e.g. like in the case of carbon nanotubes [14]) and the second class is related to the specific crystallographic properties of SiC material. These two families of defects are of course in close relationship because the deformation of SiCNW must be accompanied by the existence of defects at atomic level. Furthermore, it is widely known that the atomic-scale defects perturb the local electronic structure of bulk SiC crystals [15–18]. In this context it is reasonable to expect that the defects influence the local surface electronic structure of SiCNWs as well. The electronic structure of the cubic 3C-SiC crystal can be altered by the existence of unintentionally introduced nitrogen dopant [19]. Similarly, the band structure of 1D SiC nanostructures (nanotubes [20] and nanowires [21,22]) can be affected by nitrogen. It is also shown that electronic structure of SiCNWs can be modified when their surface is passivated with hydrogen [23]. Due to these facts, the local contamination and doping of the defected SiCNW's region should be also taken into account to explain local density of electronic states (LDOS) fluctuations. The present knowledge about defects and deformations of SiCNWs is very limited. However, this knowledge is necessary for understanding and designing the future SiCNWs-based nanoelectronic devices.

The aim of this study is to explore, for the first time, the fluctuations of the LDOS in the vicinity of a SiCNW's deformation. Scanning tunneling microscopy (STM) and scanning tunneling spectroscopy (STS) are applied to reveal the topography and the local electronic structure of a bended SiCNW. STS is used in the current imaging tunneling spectroscopy (CITS) mode which allows us to correlate STM images with the surface LDOS distribution. We

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