In situ crystallography and electrical dynamics of strained Ge-Si core-shell nanowires

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To get the critical information for future flexible electronics and optoelectronics based on nanoscale building blocks, force, electrical current and light are all important factors to be included into an *in situ* probing experiment. We demonstrate in this work that high-resolution Transmission Electron Microscope (HRTEM) coupled with electrical/mechanical probing on nanowire deformations can be applied for the *in situ* study of initiated flexible electronics mechanisms in free-standing individual nanoscale building blocks.

Among all inorganic nanowires, Germanium-Silicon core-shell nanowires (GSCS NWs) stands out for its special electrical properties. However, the behaviors under the strain are not well understood. The difference between lattice parameters of Si and Ge creates the uncompensated strain in the nanostructure which can lead to the specific behaviour of the material properties. It is well known that Si and Ge have semiconducting properties, and, moreover, can have conductive β-Sn (β-Si) and β-Tin (β-Ge) phases that can be obtained by applying an external pressure about 12 GPa and 19 GPa for bulk Si and Ge, respectively. The uncompensated strain along with external deformation of the NWs can lead to a phase transition with a consequent formation of metallic conductivity in the composite.

We have successfully performed electrical, force and photocurrent measurements for GSCS NWs inside the HRTEM. Using *in situ* probing technique, AFM cantilever and light illumination inside TEM, we have characterized the electronic and optoelectronic features of individual nanowires under mechanical deformation.

By taking HRTEM images and SAED patterns trough conventional HRTEM and Cs-corrected microscope, the strain-induced regular and irregular structural changes were observed during deformations. Hints are found that special phases might exist shortly and locally during deformations from TEM imaging. The experiments reveal that the structure of individual nanowires under strain can be in a dynamic state to take the additional energy; however, when a nanowire is deformed to be stable, strain behaves regular in crystal structure. Also, the electrical and force data are linked to the dynamic structural changes. It is expected that the dynamic research of GSCS NWs can provide valuable information for future flexible electronic applications.

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