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Effect of electron beam irradiation on electrical properties of III-V semiconductor materials

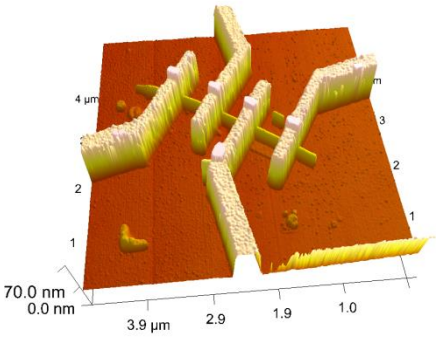
One of the most important probing techniques extensively used in nanowire based field effect transistor research is scanning electron microscopy (SEM). Focused electrons as probing particles in SEM interact with the sample and create detectable signals that provide information about the surface of the sample. Using high energy electrons as probing particles can adversely affect the transport properties of semiconductor nanowire. The modification of transport properties due to electron beam exposure is of technological and industrial importance.

SEM is an ideal imaging technique for nanowire based device fabrication because it is fast, easy to use and has high ultimate resolution >1 nm. The effect of energetic particle on physical properties of solids is known and has been an object of investigations from both fundamental and applied points of view. However, the effects of electron beam on a nanowire after imaging using SEM is unknown.

Nanowires are almost one dimensional nanostructures with large surface to volume ratio. Therefore, the nanowire surface plays a significant role in its electrical properties. Surface charge states and local work functions can be modified by uncontrollable charge absorbents on the surface. Exposing nanowires to high energy electron beams is believed to have effects on the native oxide of the nanowire and consequently modify the surface structure.

Here we fabricate field effect transistors using compound semiconductors such as InAs, GaSb and InSb, to investigate the effects of scanning electron microscopy on the electron transport inside nanowires. The approach is to measure the characteristics of fabricated field effect transistors before and after irradiation with electron beam in SEM. The differences in the two characteristics are studied to understand how the electron beam affects the transport.

Comparing the results from different semiconductor materials, it can be realized that irradiating n-type (p-type) semiconductors, in which the majority of carriers are electrons (holes), reduces (increases) the device resistances. Since the energy of the electrons in SEM is not high enough to induce atomic displacements, the effects might be due to detachment of water molecules (because of the humidity in air) and exodiffusion of adsorbed oxygen on the surface (native oxide) of the nanowires. Results suggest that electron beam may be used to locally tune the carrier concentration in nanowires. However, we cannot truly say we understand how the beam affects the electron transport of the nanowires.



AFM image of InAs field effect transistor.

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