Interfacial kinetics in nanosized metal-semiconductor films: an in situ HRTEM study

Physics and engineering of low-dimensional structures is among the fastest growing areas of modern science. This is due to new physical phenomena observed in such structures. Each of these phenomena enables creation of novel materials and devices with unique features. In this project we will focus on search for novel effects in nanosized metal-semiconductor films.

Nowadays, thin crystalline Ge and Si films are a key material for innovative electronics. These films on insulating substrates are essential for the realization of flexible electronics, e.g. high-performance thin-film transistors, high-efficient optical devices, three-dimensional integrated circuits, and non-volatile spintronic devices. Thin crystalline Si films are also a key material for manufacturing low-cost, high-efficient solar cells. The market for these devices is rapidly growing, e.g. the printed, flexible and organic electronics market will grow from $29.80 billion in 2015 to $73.69 billion in 2025 (according to IDTechEx). But Si or Ge films grown from vapour phase are usually amorphous at low temperatures. The crystallization of such films requires annealing at temperatures above 500°C, which is often incompatible with the polymer substrates used in industry. The maximum operating temperature of typical commercially available polymer substrates does not exceed the value of 200-350°C. Among various techniques that crystallize amorphous semiconductor films, metal-induced crystallization is seen as a much simpler and more economically efficient approach, which could be easily integrated into current semiconductor industry. But a fundamental mechanism of the reaction still remains impenetrable in many aspects and the available models cannot predict accurately the crystallization temperature in the metal-semiconductor couple.

In this project we hope to unravel the secret of this reaction using a cutting-edge experimental technique. Recent progress in transmission electron microscopy allows a real-time observation of materials at nanoscale and is capable of providing both the atomic-level structural, compositional and dynamic information about such materials. In the current project we will use a state-of-the-art atomic-resolution FEI Titan S/TEM microscope fitted with a novel hot-stage sample holder to direct observation of the interactions between metal and semiconductor at the atomic level. We expect to see how the atoms are arranged at the interphase boundary, how a new phase nucleates and grows. Such information is essential for understanding the fundamental phenomena governing phase transformations in binary nanosystems. Moreover, there are a number of modern technologies that will directly benefit from the results of this project, e.g nanowires growth, soldering and data storage.