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Metal-Induced Crystallization – Fundamentals and Applications

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Abstract

Unified thermodynamic model providing fundamental understanding of the metal-induced crystallization (MIC) of amorphous Si (a-Si) and Ge (a-Ge) at low temperatures is presented. Innovative applications of the MIC process in advanced technologies are discussed.

Metal-induced crystallization (MIC) involves that the crystallization temperature of amorphous semiconductors, as a-Si or a-Ge, is significantly reduced if in contact with a metal, such as Al, Ag, Au, or Ni [1]. The MIC process is utilized for low-temperature production of crystalline semiconductor thin films in advanced technologies such as high-performance displays and solar cells, and recently has also been explored for applications in blue-ray data storage devices and in electronic packaging. In recent years, we have reached fundamental understanding of the MIC process in various metal/semiconductor systems (e.g. Al/a-Si, Al/a-Ge, Au/a-Si, Ag/a-Si etc.) and for various microstructural architectures, by combining thermodynamic model predictions of the successive reaction stages [2-4] with comprehensive experimental investigations using (in situ) TEM, XRD and AES [2,5,6]. Accounting for the crucial role of interface thermodynamics, the different MIC temperatures and behaviours can now be understood and predicted on a unified basis [1-4].

The predicted MIC reaction stages for the Al/a-Si system have been confirmed experimentally by direct visualization of the MIC process on the atomic scale using in situ heating high-resolution TEM and valence energy-filtered TEM [5,6]. In particular, these in situ TEM experiments have proven the initial wetting stage of Al grain boundaries (GBs) by amorphous Si (Fig. 1), prior to the subsequent nucleation of crystalline Si at the wetted Al GBs at an exceptionally low temperature of 150 ºC (Fig. 2) [5], as well as the development of convective Al "plumes" in a-Si, driven by the MIC-induced stress gradients in the evolving system [6]. This solid-state convection process eventually leads to the reversal of the Al and Si layer sequence and the formation of a continuous crystalline Si layer.

Our fundamental understanding of the MIC process allows systematic adjustment of the crystallization temperature of a-Si from 700 ºC down to 150 ºC, as required in various state-of-the-art technologies. Further, innovative processes, e.g. for growth of interconnected crystalline semiconductor nanostructures (nanowires) at exceedingly low temperatures, have now been developed.

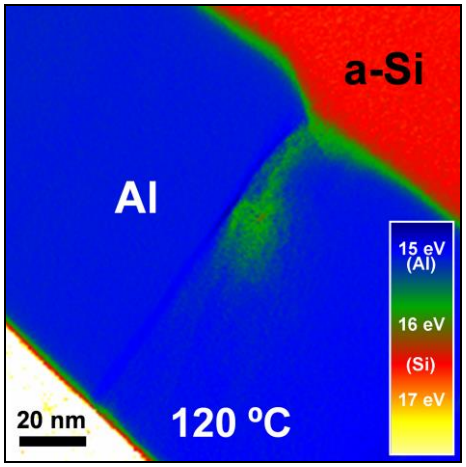

Fig. 1. *In situ* energy-filtered TEM observation of Al GB wetting by a-Si at **120 ºC** (plasmon-loss energy mapping) [5].

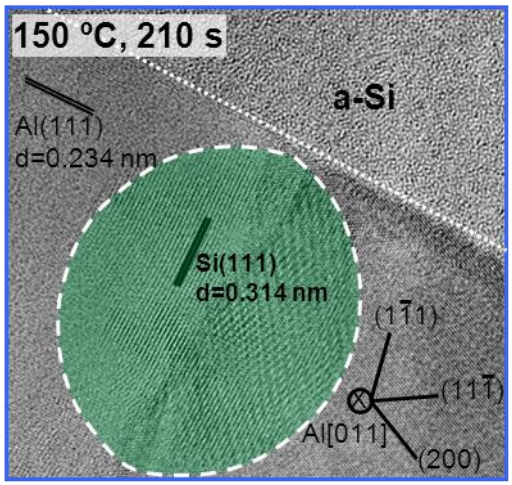

Fig. 2. *In situ* HRTEM observation of the nucleation of c-Si at a high-angle Al GB, at 150 ºC [5].

References

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