DOMAIN MATCHING EPITAXY: A NEW PARADIGM FOR EPITAXIAL GROWTH OF OXIDES

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Abstract

This talk discusses Domain Matching Epitaxy (DME) as a new paradigm for epitaxial growth and integration of oxides having a large lattice misfit with the substrate.[1] Next-generation oxide electronics and integration of magnetic and photonic devices with nanoelectronic devices require high-quality single crystal oxide films on substrates such as silicon and sapphire, which involve a large lattice misfit. The DME concept is based upon matching of integral multiples of lattice planes across the film-substrate interface. As an example, TiN or MgO films can grow epitaxially, where lattice misfit is close to 25%, by matching 4 planes of the film with three planes of the substrate. If the misfit falls between the integral multiples, the residual misfit beyond the integral matching is accommodated via domain variation, where two domains alternate with a certain frequency to attain a zero misfit. The planar matching in DME could be different in different directions. Thus, epitaxy in this new paradigm is defined as the film having a fixed orientation with respect to the substrate rather than having the same orientation as the substrate. Under the large misfit, if the critical thickness is less than one to two monolayers, most of the misfit dislocations are set from the beginning, corresponding to a complete relaxation of the film. Detailed atomic scale characterization showed that if the initial growth is two-dimensional, most of the dislocations are confined near the interface so that rest of the film can grow virtually strain-free. Thus, using the DME paradigm, it is possible to grow single-crystal films with fewer defects and less strain on substrates having a large lattice misfit, compared to small lattice misfit substrates. We will illustrate DME of ferroelectric, piezoelectric, magnetic and nonmagntic perovskites, III-nitrides and II-oxides with atomic-level details using high-resolution TEM, STEM-Z, and in-situ X-Ray diffraction techniques, and presented integration of oxide nanoelectronic devices.

1. J. Narayan and B. C. Larson, Journal of Applied Physics, Vol. 93, 278-285(2003); US Patents: 5,406,123; 6,518,077; 6,734,091.