Symposium I: Self-Organized Processes in Semiconductor Alloys—Spontaneous Ordering, Composition Modulation, and 3-D Islanding

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Atomic-Resolution *Z*-Contrast Imaging and Its Applications in Studies of Ordered Structures*

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In the last few years the scanning transmission electron microscope (STEM) has become capable of forming electron probes of atomic dimensions, as small as 0.13 nm in diameter. This has made possible a new approach to high-resolution electron microscopy, *Z*-contrast imaging. The *Z* -contrast image is an incoherent image, formed by mapping the intensity of high-angle scattered electrons as the probe is scanned across the specimen, and can be directly inverted to atomic structure. Because high angle scattering comes predominantly from the atomic nuclei, the scattering cross section depends on atomic number (*Z*) squared. The images therefore represent a direct map of the scattering power at atomic resolution. *Z*-contrast imaging is therefore an ideal technique to study compositional ordering at the atomic scale. In this presentation, examples are given of ordering in ferroelectric materials and III-V semiconductor alloys.

In ferroelectric materials, the atomic structure of ordered domains, both La-doped and undoped in $Pb(Mg_{1/3}Nb_{2/3})O_3$ is studied. The ordered domain structure in both cases is determined to be in agreement with the charge-balanced random-site model, and inconsistent with the space-charge model. It is shown that La doping in $Pb(Mg_{1/3}Nb_{2/3})O_3$ enhances not only the domain size but also the degree of ordering. In K-doped $PbZrO_3$, antiparallel cation displacements are observed but do not present any ordered structure. K is found to substitute for Pb uniformly in most ordered domains, while in some ordered domains, nonuniformly distributed K sites are also observed.

In III-V semiconductor alloys, spontaneous atomic ordering is common. It has profound effects on the electrical and optical properties of the materials. To understand the details of the ordered structures is important to understand their properties. Ordered structures in $GaAs_ySb_{1-y}$ and $Ga_yIn_{1-y}P$ are presented. In $GaAs_ySb_{1-y}$, a new ordered structure is observed, containing a periodic array of antiphase domains with Cu-Au ordering of the As and Sb atoms on the [110] and [100] planes. The antiphase domain boundaries are along the [110] direction and spaced by 2d [110] of the zinc-blende structure. In $Ga_yIn_{1-y}P$, the ordered domains exhibit Cu-Pt ordering of As and P atoms. The ordered

domains show two variants, [111] and $[1\bar{1}1]$ arranged periodically to form an orientational superlattice resulting in a discontinuity of the angular momentum. The structures of the antiphase domain boundaries, the orientational domain boundary and the interface between two ordered variants are discussed.

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