Electrodeposition of Semiconductor Metal Oxide Superlattices

Jay A. Switzer
University of Missouri-Rolla
Department of Chemistry
103 Materials Research Center
Rolla, Missouri 65409-1170 USA

Superlattices are crystalline multilayered structures in which there is coherent stacking of atomic planes and periodic modulation of the structure or composition, or both. Superlattices are an ideal architecture for devices based on quantum confinement effects, because the modulation wavelength can be on the nanometer scale, yet the superlattice can be produced as a large area film.

We have previously used electrodeposition to produce compositional superlattices in the Pb-Tl-O system (1,2) and defect-chemistry superlattices based on Tl_2O_3 (3). These early superlattices had an out of plane orientation (i.e., fiber texture), but no in-plane orientation (4). Recent work has shown that epitaxial superlattices can be deposited onto single-crystal Au(100) (5). Layered structures based on Cu_2O and Cu were also produced in a self-oscillating system (6). These materials were layered, but they were not superlattices. The Cu_2O/Cu layered materials exhibited NDR in perpendicular transport measurements, with evidence that quantum confinement of holes occurred in the valence band of Cu_2O (7).

Epitaxial superlattices in the Pb-Tl-O system were electrodeposited onto Au(100) by pulsing the applied current density between 0.05 and 5 mA/cm^2. The compositions of the films grown at the two current densities were $Pb_{0.46}Tl_{0.54}O_{1.7}$ and $Pb_{0.74}Tl_{0.26}O_{1.9}$, respectively. The lattice mismatch for the two materials is 0.12%. A 2θ x-ray scan around the (400) Bragg reflection for a superlattice with a modulation wavelength of 18.9 nm is shown in Fig. 1. The scan shows superlattice satellites out to seventh order. The (111) pole figure in Fig. 2 shows that the superlattice is single-crystal-like, with little or no fiber texture. Azimuthal scans (Fig. 3) show that the film is rotated 45 degrees relative to the Au(100) substrate. The in-plane orientation lowers the lattice mismatch from +31% to -7.6%. An epitaxial relationship consistent with this rotation is Pb-Tl-O(100)[011]//Au(100)[010].

Ongoing work is focused on magnetic superlattices based on the half-metallic ferrimagnet, Fe_3O_4. We have shown that epitaxial films can be deposited onto single-crystal Au (8). We are now attempting to deposit Fe_3O_4 defect-chemistry superlattices and Fe_3O_4/Fe_2O_3 compositional superlattices for spintronic applications.

References

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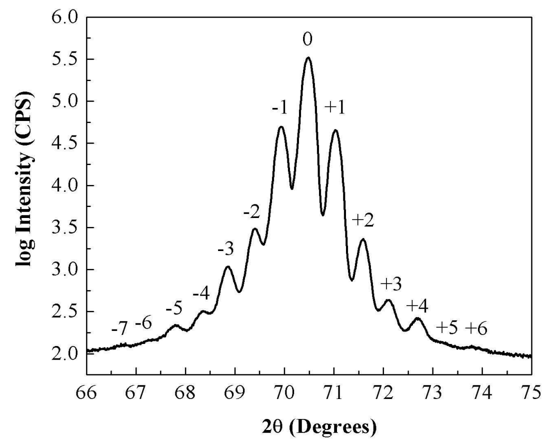

Fig. 1 X-ray 2θ scan of Pb-Tl-O superlattice with 18.9 nm modulation wavelength.

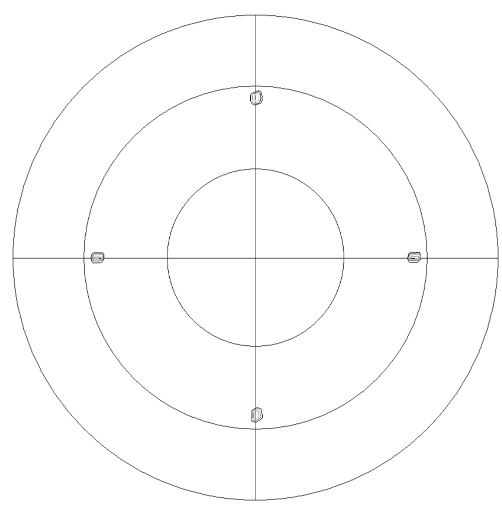

Fig. 2 (111) X-ray pole figure of Pb-Tl-O superlattice with 18.9 nm modulation wavelength.

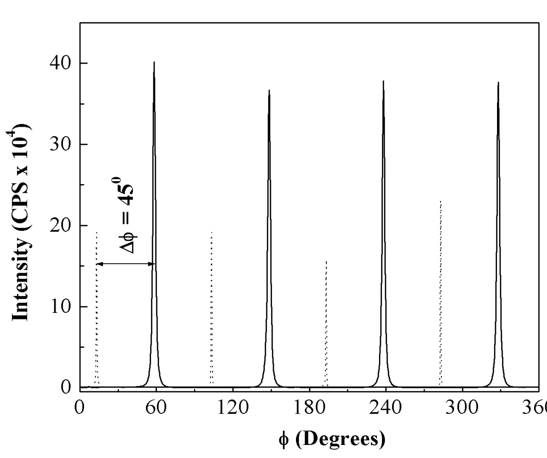

Fig. 3 Azimuthal X-ray scans of Pb-Tl-O superlattice and Au(100) substrate (dotted line).