X-Ray Diffraction Characterization of Mo_m/V_n Superlattices with Ultrathin Layers ($m+n \lesssim 4$ monolayers) Prepared by Sequential Sputter Deposition

Jens Birch[#] and Jan-Eric Sundgren,

Thin Film Physics Division, Department of Physics, Linköping University, S-581 83 Linköping, Sweden.
[#] Present adress: ESRF, B.P. 220, F-38 043 Grenoble, France.˝e-mail: birch@esrf.fr

Abstract

Artificial superlattices with sub-unit cell layer thicknesses have attracted an increasingly amount of interest during the last years. For example, in the III-V semiconductor systems such layers can be produced routinely with the goal of spatially confining electrons in 1, 2, or 3 dimensional quantum wells. Also in metallic systems there is an interest in realizing such structures. For example, 3d bcc transition metals have shown to have strongly enhanced ferromagnetic moments when the dimensionality is reduced from 3 to 2. In particular, a monolayer of V(001) is predicted to be magnetic if it is prepared on Ag(001) or Au(001) while the surface layer of a bulk V crystal is non-magnetic. In this work, we have used Mo/V(001) to show that it is indeed possible to prepare metallic superlattices with layer thicknesses down to sub-monolayer dimensions even though the phase diagram predicts a solid solution over the entire˝composition range for this material system.
Single crystal Mo/V(001) superlattices were grown on˝polished MgO(001) substrates held at 700°C by sequential dc magnetron sputtering using Ar as the sputtering gas. Four Mo_m/V_n samples were prepared: $Mo_{0.6}/V_{1.5}$, Mo_1/V_1, $Mo_{1.1}/V_{3.0}$, and Mo_2/V_2 where m and n are the nominal number of monolayers in each layer of Mo and V respectively. All samples were investigated by x-ray diffraction (XRD), using low resolution reciprocal space mapping (RSM) as well as conventional Bragg-Brentano geometry producing specular θ-2θ scans with medium resolution. Superlattice reflections in the θ-2θ scans confirmed the chemical modulations in the growth direction in the $Mo_{0.6}/V_{1.5}$, $Mo_{1.1}/V_{3.0}$, and Mo_2/V_2 superlattices while for the Mo_1/V_1 sample no signs of compositional modulation were observed. RSM did not give any indications of any long range ordering of the Mo and V atoms in the plane of the layers. The $Mo_{0.6}/V_{1.5}$ superlattice reflections, associated with two neighboring 00*l* Bragg-peaks did not coincide, instead two narrow peaks appeared close to each other. This is due to the incommensurability between the superlattice period and the MoV bcc sublattice. Moreover, this splitting shows that the growth mode is 2 dimensional layer-by-layer and that the interfacial roughness is controlled (by the ability of accurately syncronizing the shutters with the growth of complete monolayers) rather than random. The $Mo_{0.6}/V_{1.5}$ superlattice is thus equivalent to an *artificially layered alloy* in the [001] direction where each second monolayer consists of V and each second monolayer is a 2 dimensional mixture of Mo and V. The lattice parameters determined by RSM were consistent with complete accomodation of the misfit strain in the the layers. This was confirmed by cross-sectional HREM images from the Mo_1/V_1 and Mo_2/V_2 superlattices which showed that the films were of a very good qrystalline quality. A few threading dislocations were present while no misfit dislocations could bee seen. The Mo_2/V_2 superlattice exhibited clear Z-contrast from the layers of Mo and V and selected area electron diffraction gave strong superlattice reflections, which is in agreement with the XRD results.

X-Ray Diffraction Characterization of Mo_m/V_n Superlattices with Ultrathin Layers ($m+n \lesssim 4$ monolayers) Prepared by Sequential Sputter Deposition

Jens Birch[#] and Jan-Eric Sundgren,

Thin Film Physics Division, Department of Physics, Linköping University, S-581 83 Linköping, Sweden.
[#] Present adress: ESRF, B.P. 220, F-38 043 Grenoble, France.˝e-mail: birch@esrf.fr

Abstract

Artificial superlattices with sub-unit cell layer thicknesses have attracted an increasingly amount of interest during the last years. For example, in the III-V semiconductor systems such layers can be produced routinely with the goal of spatially confining electrons in 1, 2, or 3 dimensional quantum wells. Also in metallic systems there is an interest in realizing such structures. For example, 3d bcc transition metals have shown to have strongly enhanced ferromagnetic moments when the dimensionality is reduced from 3 to 2. In particular, a monolayer of V(001) is predicted to be magnetic if it is prepared on Ag(001) or Au(001) while the surface layer of a bulk V crystal is non-magnetic. In this work, we have used Mo/V(001) to show that it is indeed possible to prepare metallic superlattices with layer thicknesses down to sub-monolayer dimensions even though the phase diagram predicts a solid solution over the entire˝composition range for this material system.
Single crystal Mo/V(001) superlattices were grown on˝polished MgO(001) substrates held at 700°C by sequential dc magnetron sputtering using Ar as the sputtering gas. Four Mo_m/V_n samples were prepared: $Mo_{0.6}/V_{1.5}$, Mo_1/V_1, $Mo_{1.1}/V_{3.0}$, and Mo_2/V_2 where m and n are the nominal number of monolayers in each layer of Mo and V respectively. All samples were investigated by x-ray diffraction (XRD), using low resolution reciprocal space mapping (RSM) as well as conventional Bragg-Brentano geometry producing specular θ-2θ scans with medium resolution. Superlattice reflections in the θ-2θ scans confirmed the chemical modulations in the growth direction in the $Mo_{0.6}/V_{1.5}$, $Mo_{1.1}/V_{3.0}$, and Mo_2/V_2 superlattices while for the Mo_1/V_1 sample no signs of compositional modulation were observed. RSM did not give any indications of any long range ordering of the Mo and V atoms in the plane of the layers. The $Mo_{0.6}/V_{1.5}$ superlattice reflections, associated with two neighboring 00*l* Bragg-peaks did not coincide, instead two narrow peaks appeared close to each other. This is due to the incommensurability between the superlattice period and the MoV bcc sublattice. Moreover, this splitting shows that the growth mode is 2 dimensional layer-by-layer and that the interfacial roughness is controlled (by the ability of accurately syncronizing the shutters with the growth of complete monolayers) rather than random. The $Mo_{0.6}/V_{1.5}$ superlattice is thus equivalent to an *artificially layered alloy* in the [001] direction where each second monolayer consists of V and each second monolayer is a 2 dimensional mixture of Mo and V. The lattice parameters determined by RSM were consistent with complete accomodation of the misfit strain in the the layers. This was confirmed by cross-sectional HREM images from the Mo_1/V_1 and Mo_2/V_2 superlattices which showed that the films were of a very good qrystalline quality. A few threading dislocations were present while no misfit dislocations could bee seen. The Mo_2/V_2 superlattice exhibited clear Z-contrast from the layers of Mo and V and selected area electron diffraction gave strong superlattice reflections, which is in agreement with the XRD results.