Interface Orientation Dependent Field Evaporation Behavior in Multilayer Thin Films

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Atom probe tomography (APT) is a characterization technique in which a position-sensitive detector is utilized in order to determine the position of atoms as they are field evaporated from a needle-like specimen. In general, these reconstruction algorithms assume a constant evaporation field across the surface of the specimen. In reality, chemical inhomogeneity modulates the evaporation field at the specimen surface which introduces reconstruction artifacts and degrades the spatial resolution of the technique. Multilayer thin films provide ideal specimen geometries to measure and quantify these artifacts. Thin films can be deposited with near atomic layer precision and can exhibit large planar surfaces with various degrees of intermixing across the interfaces. Quantifying and rectifying interfacial compositional differences in atom probe data sets is critical, as such information can be used to understand the growth and intermixing of species in nanolaminate devices, such as giant magneto-resistance multilayers. [1]

A series of Fe/Ni and Ti/Nb multilayers with approximate equal individual layer thicknesses and bilayer repeat distances of 4 nm have been sputter-deposited onto n-doped Si [001] substrates. The Fe/Ni system has similar evaporation field strengths (Fe is 33 V/nm and Ni is 35 V/nm [3]) where Ti/Nb has significantly different evaporation field strengths (Ti is 26 V/nm and Nb is 37 V/nm [3]). This provides the research the ability to compare atom probe reconstruction and their accompanying artifacts as a function of differing field strengths across an interface. For comparison, each multilayer's compositional profile was measured by Electron Energy Loss Spectroscopy (EELS) in an aberration corrected TEMFor the atom probe specimens, the multilayers were annular focus ion beam (FIB) milled into the required needle-shaped geometry. Specimens were prepared with the film interfaces oriented with the chemical modulations for a given bilayer spacing parallel and perpendicular to the specimen apex to compare field evaporation behavior at these limiting geometries.

For the Fe/Ni multilayers, the atom probe reconstructions of chemical modulation had the best agreement with the EELS compositional profiles in terms of bilayer thikness reconstruction and compositional slope profiles of Ni grown on Fe and Fe grown on Ni. Both microscopy determined profiles revealed Ni intermixed within the Fe layers. In contrast, the Ti/Nb multilayers showed discrepancies in the reconstructed bilayer thicknesses and compositional slope profiles of Nb on Ti and Ti on Nb between the two microscopy techniques and limiting evaporation geometries. This has been rationalized in terms of the how atom probe reconstruction is based on a single evaporation field. Quantifying these artifacts provides better understanding to the limits and fidelity of atom probe reconstructions across interfaces.

<u>References</u>:

1. X. W. Zhou *et al*., *Acta Materialia* **49**(19) (2001) 4005-4015
2. A. Genc *et al.*, *Ultramicroscopy* **109**, (2009) 1276-1281
3. TT Tsong *Surface Science*, **70**, (1978), 211-233
4. G.B. Thompson, *et al.* *Journal of Materials Research* **19**(3) (2004) 707-715