Atom Probe Analysis of Planar Multilayer Structures

D. J. Larson[1], T. F. Kelly[2] and N. Tabat[3]

1 Metals and Ceramics Division, Oak Ridge National Laboratory, PO Box 2008, Oak Ridge, TN 37831,

2 Dept. of Materials Science and Engineering, University of Wisconsin, Madison, WI, 53706,

3 Recording Head Operations, Seagate Technology, 7801 Computer Ave. South, Minneapolis, MN 55435

Artificial multilayer structures are an integral part of advanced magnetic sensors such as spin valve magnetoresistive elements. The interfaces between the individual layers in spin valve stacks are important in determining the magnitude of the GMR effect. There is a crucial need for a characterization technique that accurately maps the composition of these layers, and their interfaces, on the atomic scale. Three-dimensional atom probes have been shown to be capable of generating the required data, but heretofore, research has been limited to structures with layers oriented parallel to analysis direction. The resolution of the atom probe is significantly improved (~1 atomic layer), however, when the interfaces are oriented normal to the atom probe specimen axis. The present work reports the first atom probe analyses from planar-deposited multilayer structures using specimens fabricated normal to the layers. A multilayer structure consisting of Ta/CoFe/(Cu/CoFe)x15/Ru/(CoFe/Ru)x5/Ru/NiFe (7/13/(3/3)/50/(3/1)/50/150 nm) was sputter deposited on oxidized (100) silicon substrates which had been lithographically patterned and partially etched into posts ~130 microns tall. The posts were sharpened into the needle geometry required for atom probe analysis, Fig. 1, using annular focused ion beam milling. Fig. 2 shows a field ion image (plan view) of the fine-grained NiFe layer, which forms the top region of the multilayer structure shown in Fig. 1. Atom probe analysis may be performed at any point on this image, as shown in Fig. 2. The average composition of the layer was 82.30 at. %Ni-17.45 %Fe-0.15% C-0.10%O, in good agreement with XPS measurements of 82.5 at. %Ni-17.50%Fe. These results demonstrate that atom probe analyses may be obtained from planar-deposited multilayers in a direction normal to the stack and show the feasibility of this characterization technique for these nanoscale multilayer structures. Detailed analysis of the various layers' grain structures and heterointerfaces will be presented.

This research was sponsored, in part, by the Division of Materials Sciences, U. S. DOE, and through a CRADA with Honeywell Solid State Electronics Center and Nonvolatile Electronics Inc. sponsored by the Laboratory Technology Research Progrentilayinedfacfacphstvoaked paul/F2ys be ultibeeilayructu ial ilay str waisis Tj/

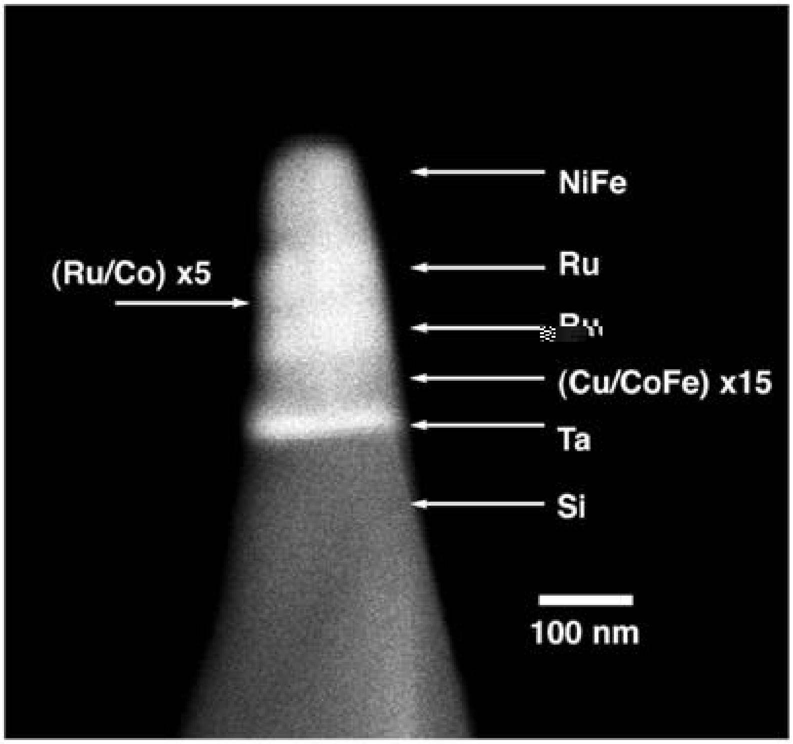

Fig. 1. Field ion specimen fabricated with multilayers normal to the specimen axis.

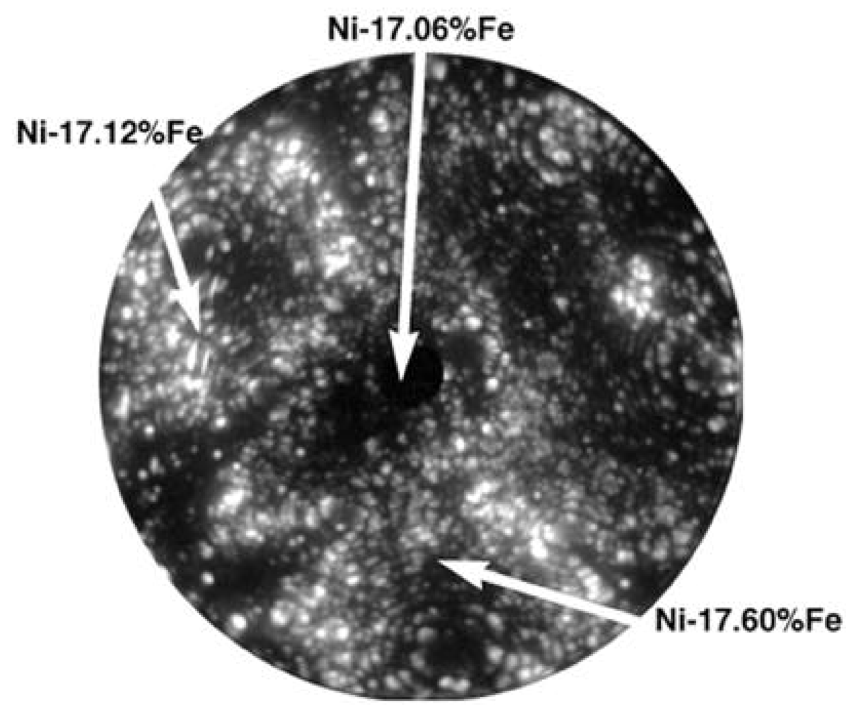

Fig. 1. Field ion image of the NiFe layer (plan view) which forms the top 150 nm of the multilayer structure shown in Fig. 1.