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Influences of specimen shape and pulsed-laser condition on laser assisted atom probe tomography

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Laser-assisted atom-probe tomography (APT) analysis seems to be one of the most promising techniques to characterize local variation in chemical distribution across the interfaces of multilayer structures on a sub-nanometer spatial resolution. It is, however, difficult to perform reproducible evaluation of atom-probe data sets because of the thermal instability and sample fracture during measurements, affected by pulsed-laser power, laser wavelength, and evaporability of atoms, specimen shape, and specimen size. It is, therefore, important to investigate the influence factors contributing to optimum performance of the pulsed-laser atom probe. In this study, influences of specimen tip diameter and pulsed-laser power on a resolution of APT analysis were investigated.

A multilayer structure consisting of NiFe / CoFe / NiFe-capping were deposited on a Si substrate, which contains an array of Si micro-tip specimens. The needle-shaped specimens of approximately 60 nm, 80 nm, and 100 nm in tip diameter were, then, fabricated under the application of Focused Ion Beam (FIB) milling using 10 kV Ga^+ and lower energy Ar^+. After that the specimens were analyzed by using APT (IMAGO LEAP3000HR) as a function of laser power, ranges 0.4 -1.0 nJ, at 35K.

It was found that a decrease in the specimen tip-diameter resulted in a decrease in specimen voltage of field evaporation. Comparing atom-probe mass spectra obtained from each specimen, it was revealed that mass resolution and signal to noise ratio improved as the specimen tip diameter and laser power decreased. In particular, Co^+ peak could be clearly separated by Ni+ peaks in specimen with tip diameter of 60 nm. It was considered that the laser heating and heat release depends on mass resolution. Three-dimensional elemental maps and one dimensional concentration profiles demonstrated the nature of the each interface of layered structure. It was suggested that the optimum atom-probe conditions and idealized sample shape have a feasibility to improve atom-probe performance.

A multilayer system composed of Si substrate/Ta/NiFe/Ru/CoFeB/Ru/NiFe was studied using laser assisted atom probe tomography (APT) along different analysis directions. The distributions of atoms, which evaporate at higher field, were strongly influenced by the APT analysis direction. In particular, B in the CoFeB layer appeared near the interface between CoFeB layer and lower Ru layer with the measurement from standard direction to the film growth direction, while B atoms were observed the other side of the CoFeB layer with the measurement from backside direction.