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ELECTRON-YIELD EXAFS STUDIES OF Tb/FeCo AND Tb/Fe MULTILAYERS

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ABSTRACT

By using the electron-yield detection technique, the EXAFS spectra for Tb/FeCo and Tb/Fe multilayers, as well as a TbFeCo alloy and some reference thin films, have been measured. These multilayers were prepared by sputtering onto float-glass substrates, and had the total thickness of 1000Å with various individual layer thickness or period values. An electron detector obtained from the EXAFS company of F.W. Lytle was used for the measurements and the high quality of data shows that the electron-yield detection technique is especially suitable for studies of multilayers. Preliminary analysis results show some qualitative tendencies which need to be checked with more careful analyses and, if possible, with some low temperature data.

INTRODUCTION

Rare earth-transition metal (RE-TM) amorphous alloy films are useful as magneto-optical recording device materials. Recently those of TbFe and TbFeCo have been found to be especially promising. The microscopic origin of perpendicular magnetic anisotropy in these amorphous RE-TM films is of great interest and various possible mechanisms have been postulated. A preferential oxidation along the boundaries of columnar structures[1], single ion anisotropy[2], atomic pair ordering[3], and exchange anisotropy[4] have been proposed as the possible origin of the perpendicular anisotropy. Egami et al.[5] noted that careful purging of oxygen does not reduce the anisotropy and inferred that bond-orientational anisotropy may be the possible origin. Lee et al.[6] recently found that Tb/FeCo multilayers have certain advantages as magneto-optical (MO) device materials compared with a homogeneous alloy layer of TbFeCo. The perpendicular magnetic anisotropy of the multilayer disk is also an order of magnitude greater than that of the alloy disk. In the present study, electron-yield extended x-ray absorption fine structure(EXAFS) measurements were made on the Tb/FeCo and Tb/Fe

multilayers of varying sublayer thicknesses. The data were taken on the X-11A beamline at the National Synchroron Light Source(NSLS). Electron yield techniques have the high surface sensitivity and therefore are suited for studies of thin films as well as surfaces of bulk samples[7]. When an atom is excited by absorbing the incident x-ray, the excited atom can decay either by emitting a characteristic x-ray or by emitting Auger electrons. The former is the radiative transition, and the characteristic x-rays are detected in conventional fluorescence EXAFS. The latter is the nonradiative transition process, and the Auger electrons are detected in electron-yield EXAFS. The electrons emitted from the x-ray absorption event can be detected by placing an electrode with a bias voltage in front of the sample and measuring the current between this electrode and the sample(sample current). This sample current corresponds to a signal from the electrons emitted by the sample and thus consists of both K and L Auger electrons, photoelectrons, and electrons excited by the Auger electrons(secondary electrons). Since one x-ray photon creates many electrons on the sample and the electrons with energy greater than the first ionization potential of the ambient gas creates more ionization, the signal level in the electron detection technique is much higher than that of a typical fluorescence measurement. A low Z fill gas such as He or H_2 can be used to create a constant environment and to minimize the absorption of fluorescent x-rays in the e-detector. At the beamline X-11A at NSLS, a helium-flow electron detector called Lytle detector is used. With the electron detector, the signal levels are very high, $\sim 10^2$-10^3 more than other detectors. The technique samples the top $\sim$1000Å of surface and can also sample mainly the top $\sim$50Å with proper energy selection[8].

EXPERIMENTAL DATA AND PRELIMINARY ANALYSIS RESULTS

In Fig.1, some raw data of electron detection EXAFS measurements, made on Tb/FeCo and Tb/Fe multilayers with various period values as well as on standard samples, are shown. Also shown is the raw data μx of transmission EXAFS measurement made on a 7.5 μ-thick pure Fe foil. Compared with the transmission EXAFS for the pure Fe foil, the electron-yield EXAFS for a standard pure Fe thin film shows smaller amplitude EXAFS oscillations. To account for this difference, some correction methods have been developed[9]. The raw data for the Tb/FeCo sample with 100 layers looks similar to that for the TbFeCo alloy sample, which looks mostly amorphous possibly with some nano-crystallites. But the raw data for the bilayer Tb/FeCo sample looks different. Because the Tb layer and the FeCo layer are separated by just one interface, they are mostly in the crystalline state except at the interface. The raw data for the bilayer Tb/Fe sample is also shown, which looks similar to the bilayer Tb/FeCo case but the Co edge is definitely missing. These and the rest of the data will be analyzed in time. For now, only a few qualitative aspects are presented. Figure 2 shows the comparison of the EXAFS data between some cases. The EXAFS for electron detection case shows quite similar features but smaller amplitude compared with the transmission measurement case for pure Fe. The EXAFS for the Tb/FeCo 100 layer sample was first measured with the polarization of x-ray parallel to the sample plane, and then measured again after being tilted by 50° so that the x-ray polarization will also probe any structural difference in the direction perpendicular to the sample plane. The EXAFS data for these two cases have been compared, and a slight shift and more rapid damping in the tilted case is observed. The EXAFS for the Tb/FeCo 100 layer sample and that for the TbFeCo alloy sample also show a similar difference in comparison. These differences are more clearly shown in Fig.3, where some radial structure functions obtained by Fourier transformation have been compared. The Fourier transform(FT) for the electron measurement case is similar to but smaller than that for the transmission measurement case. The Fourier transforms for the bilayer cases look more crystalline, while those for the multilayer cases look more amorphous. In the 100 layer cases, the addition of Co makes difference mainly in higher shells rather than in the first shell, probably because there is only small amount of Co in the $Tb_{24}Fe_{68}Co_8$ alloy composition used in the present study. When the Tb/FeCo 100 layer case is compared with the TbFeCo alloy case, the first FT peak for the alloy is slightly greater meaning that the multilayer case may have more disorder in the nearest neighbor distance. The alloy case shows more rapid damping of higher shell peak magnitude, which shows that in the multilayer case there is a little more crystalline order in the sample plane. Most importantly, when the FT for the Tb/FeCo 100 layer case is compared with that of the tilted case, the major peak in the FT of the tilted case is slightly shifted to lower r, though the magnitude is slightly bigger, and the higher shell peak magnitude shows more rapid damping. Thus in the direction perpendicular to the sample plane, the structure is more disordered like an amorphous alloy. If the nearest neighbor distance is really smaller in the perpendicular direction, this may provide a clue as to the origin of the perpendicular magnetic anisortropy. But only a preliminary analysis of a few data cases has been done so far, and more careful analyses of many other cases as well as more careful measurements at low temperature need to be carried out before a definitive conclusion can be made.

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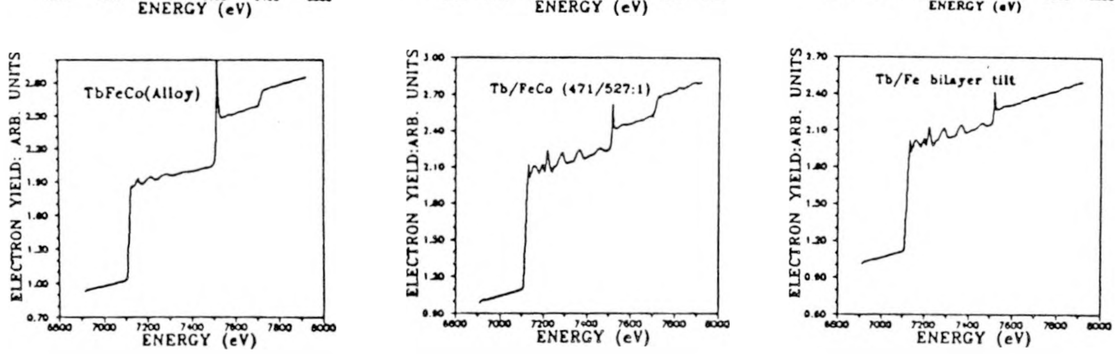

FIG.1. Raw data of electron-yield EXAFS measurements and a transmission EXAFS measurement.

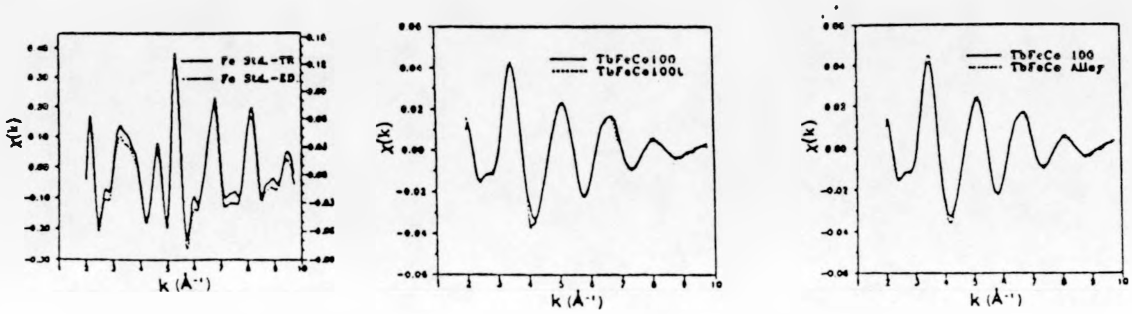

FIG.2. Comparison of the normalized EXAFS.

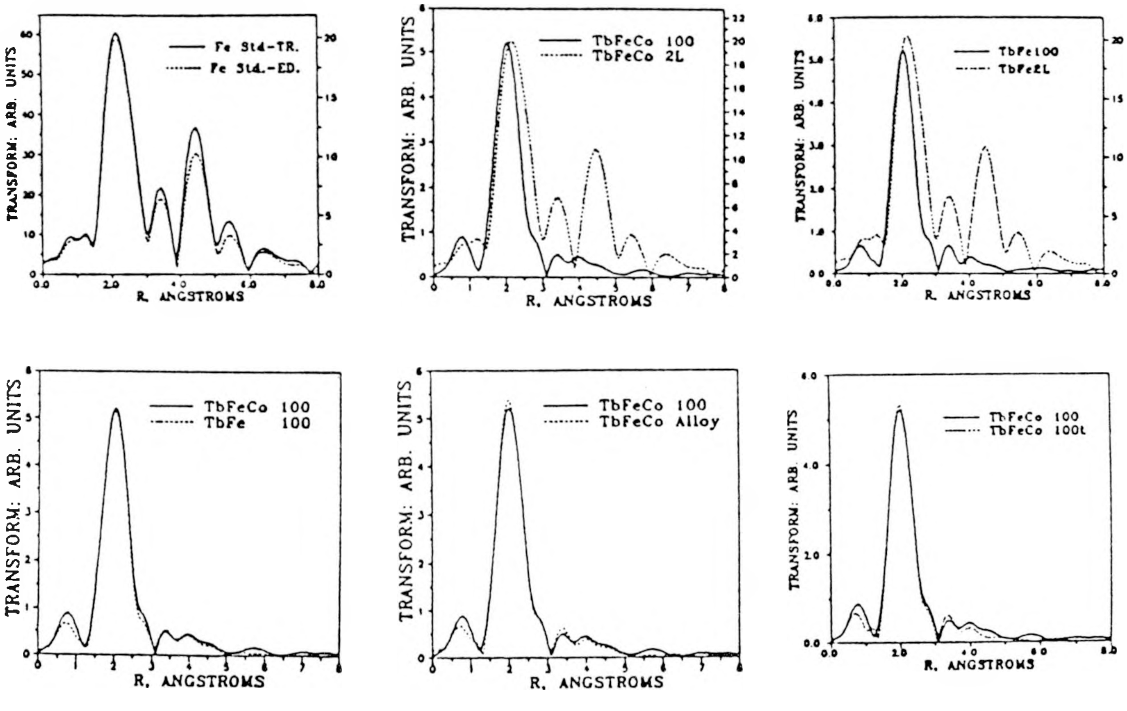

FIG.3. Comparison of Fourier transforms.