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CEMS STUDY OF COMPOSITION MODULATED AMORPHOUS Fe_{78}B_{13}Si_{9}/Si FILMS

Liang-Mo Mei, Wei-Dong Li and Si-Sun Bi

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Abstract. – The characteristics of composition modulated amorphous Fe_{78}B_{13}Si_{9}/Si have been studied by using a technique of the interface sensitive conversion electron Mössbauer spectroscopy (CEMS). The composition profile in the interface transition region can be obtained by analysing the properties of conversion electron Mössbauer spectra.

Recently there has been a great interest in the study of various composition modulated films. For such films the atomic interdiffusion at the interface plays an important part in determination of their characteristics. In this paper we present some results of atomic interdiffusion at the interface of compositionally modulated amorphous films by measuring CEMS.

The composition modulated amorphous films used in the experiments were prepared by depositing Fe_{78}B_{13}Si_{9} and Si on 0.1 mm thick glass substrates by a two-source ac-sputtering method. Before the sputtering the vacuum chamber was evacuated to a pressure below 2 \times 10^{-6} Torr and sputtering was carried out at an argon pressure of 1.5 \times 10^{-2} Torr. During sputtering the substrate holder was cooled by cold water. The thickness of each layer was controlled by varying the deposition time at a constant deposition rate.

The amorphous structure of the modulated films was confirmed from X-ray diffraction and the modulation wavelengths were estimated from the peak positions in X-ray small angle diffraction. CEMS at room temperature were recorded by using a constant accelerated Mossbauer set-up with \textsuperscript{57}Co/Rh as the source. In order to obtain a best fit of the hyperfine parameters, computer fitting of the spectra was carried out using the standard MOSFUN program on PDP11/34 computer system, and a convolution of a Gaussian and a Lorentzian shape was used [1]. For the different period samples we denote as \((m/n)\), where \(m\) (Å) stands for the thickness of the Fe\textsubscript{78}B\textsubscript{13}Si\textsubscript{9} layer and \(n\) for Si layer. The number of the modulation wavelengths is 40 for all samples.

The CEMS of the various \((m/n)\) modulated films were shown in the figure 1 from which it can be seen that the spectra of all as-deposited samples consist of two components: a magnetically splitting amorphous sextet and a quadrupole doublet. Their ratio depends on both \(m\) and \(n\). The percentage of the intensity (area) of the paramagnetic component, as a function of the Si layer thickness, was shown in the figure 2. The paramagnetic component will not appear until the thickness of Si layer is beyong a certain value. Then with increasing Si layer thickness the percentage of the paramagnetic component increases and finally approaches to the saturation at a certain thickness. The computer fitting of the spectra gives out the average Mossbauer parameters and their intensity ratios, which are listed in the table I. The Mossbauer spectra of the magnetic component are still a typical amorphous spectrum, but comparing with the pure Fe\textsubscript{78}B\textsubscript{13}Si\textsubscript{9} film, the linewidths are broadened and the hyperfine fields reduced. However, the separations and linewidths 2-5 seem not to depend on the thickness of Si layer and only depend on the thickness of Fe\textsubscript{78}B\textsubscript{13}Si\textsubscript{9} layer.

The above experimental results can be explained by assuming at the interface there is a transition area in which Fe atomic concentration is gradually diluted from Fe\textsubscript{78}B\textsubscript{13}Si\textsubscript{9} to Si. It is due to atomic interdiffusion at the interface, and its thickness and compo-
Table I. - Some fitted Mossbauer spectral parameters.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Ferro. LW (mm/s)</th>
<th>Compo. 2-5 LW (mm/s)</th>
<th>Paramagnetic LW (mm/s)</th>
<th>Paramagnetic QS (mm/s)</th>
<th>Component IS (mm/s)</th>
<th>Percen. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FeBSi</td>
<td>0.48</td>
<td>4.91</td>
<td>(Fe\textsubscript{78}B\textsubscript{13}Si\textsubscript{9}) single layer film</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(55/90)</td>
<td>0.72</td>
<td>4.60</td>
<td>0.25</td>
<td>0.24</td>
<td>0.64</td>
<td>0.220</td>
</tr>
<tr>
<td>(50/63)</td>
<td>0.72</td>
<td>4.50</td>
<td>0.23</td>
<td>0.22</td>
<td>0.65</td>
<td>0.206</td>
</tr>
<tr>
<td>(56/48)</td>
<td>0.72</td>
<td>4.50</td>
<td>0.24</td>
<td>0.23</td>
<td>0.62</td>
<td>0.181</td>
</tr>
<tr>
<td>(50/22)</td>
<td>0.74</td>
<td>4.45</td>
<td>0.22</td>
<td>0.24</td>
<td>0.63</td>
<td>0.062</td>
</tr>
<tr>
<td>(53/15)</td>
<td>0.65</td>
<td>4.55</td>
<td>0.10</td>
<td>0.24</td>
<td>0.56</td>
<td>0.013</td>
</tr>
<tr>
<td>(36/58)</td>
<td>0.84</td>
<td>4.20</td>
<td>0.25</td>
<td>0.20</td>
<td>0.67</td>
<td>0.336</td>
</tr>
<tr>
<td>(36/45)</td>
<td>0.87</td>
<td>4.15</td>
<td>0.24</td>
<td>0.20</td>
<td>0.64</td>
<td>0.315</td>
</tr>
<tr>
<td>(37/30)</td>
<td>0.85</td>
<td>4.20</td>
<td>0.26</td>
<td>0.20</td>
<td>0.66</td>
<td>0.260</td>
</tr>
<tr>
<td>(36/15)</td>
<td>0.80</td>
<td>4.25</td>
<td>0.23</td>
<td>0.21</td>
<td>0.62</td>
<td>0.120</td>
</tr>
</tbody>
</table>

Note: The QS of the paramagnetic components is with respect to natural iron.

Fig. 2. - The fraction of the paramagnetic component as functions of Si layer thickness. The thickness of Fe\textsubscript{78}B\textsubscript{13}Si\textsubscript{9} layer is shown in figure.

position profile are mainly determined by the temperature of the substrate in depositing. When Fe concentration is diluted down a certain critical value, the formed Fe-Si glass phase becomes paramagnetic. In order to find out this critical concentration, we annealed all as-deposited samples at various temperatures in vacuum for several hours until the measured CEMS did not change, which shows that due to interdiffusion the composition modulated films have become homogeneous films. As a result, we found that the magnetic component in the Mossbauer spectrum of the film (50/63) just disappears, so we estimate Fe critical concentration to be about 0.4 which is consistent with the result obtained by other method [2].

For the modulated films whose $m$ and $n$ are both large, Fe atom composition profile in the transition area can be represented by a tanh-profile [3]:

$$C(x) = \frac{1}{2} \left[ 1 + \tanh \left( -\beta x \right) \right]$$

where $1/\beta$ is the diffusion-length. From the data given in the above (the percentage of the paramagnetic component and Fe atom critical concentration) the diffusion-length can be calculated and is of the order of $10^{-5}$ m, which is consistent with measured results in amorphous alloys. The diffusion coefficient $D$ calculated is of the order of $10^{-22}$ m$^2$ s$^{-1}$. Because the composition of the magnetic component in the transition area is inhomogeneous, the decreasing of the hyperfine field and broadening of the linewidths can be predicted. But when a paramagnetic component appears in the transition area, the magnetic component in it will not change with the thickness of Si layer again, so the hyperfine field and the linewidths of magnetic phase does not depend on the Si layer thickness. When the thickness of the Fe\textsubscript{78}B\textsubscript{13}Si\textsubscript{9} layer are different, the percentage of inhomogeneous part in the magnetic component are different. Thus their Mossbauer parameters do only depend on the thickness of Fe\textsubscript{78}B\textsubscript{13}Si\textsubscript{9} layer. Another fact that is worthy of note is that the Mossbauer parameters of the doublet are basically the same for almost all samples, which shows the Fe atoms in the paramagnetic phase have nearly the same local chemical and geometrical environment, i.e., chemical and geometrical short-range order.

Acknowledgments

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