The behaviour of the other two samples of ZrBNO is depicted in Figs. 7 and 8, and their extrapolation is shown in Figs. 9 and 10. The intersection point for Z1 is given 225 K, which is in reasonable agreement with Fig.6, but the abnormal low divergence of the lines of Z2 in Fig.8 places the intersection point in Fig.10 into the positive 1/T domain. It should be noted that the straight lines in Figs. 7 and 8 are parallel in the linear range at low voltages up to 5 V., and convergent at higher voltages, when the space charge limited current is gaining preponderance. Evaluation of Fig.9 with T = 225 K and I = 7.24 x 10^-10 A yields the mobility ν = 4.94 x 10^5 cm^2/V s, and the trap concentration 1.3 x 10^17 cm^-3, which seems reasonable. From Fig.10 only the existence of a high exponentially distributed trap concentration can be derived.

4. CONCLUSIONS

Investigation of the temperature dependence of the current at various voltages proved the oxide films of ZrBNO and ZrBNO:Fe to have a single trap level situated about 1 eV below the edge of the conduction band. The concentration of the free carriers was about 2 x 10^17 cm^-3 and did not depend on the temperature. The exponential temperature dependence of the resistivity was due only to the temperature dependence of the mobility, which was extremely low.

The samples of ZnB(NO)3/2 (ZrBNO), analyzed according to the theory of Lappert [4] and of Gould [5], showed signs of an exponential distribution of trapping centers below the edge of the conduction band, but the accuracy of the measurements did not give sufficiently reliable results because of the high error in assessing the intersection point due to the very sharp angle of the converging straight lines log I = α/1/T.

Acknowledgments

Support of this work by SKODA UIP, Prah, Company is highly appreciated. Special thanks are due to Ms. Vera Vrtilkova for providing the samples with specified thickness.

REFERENCES


THE EFFECT OF SUBSTITUTION OF Fe BY CO ON RAPIDLY QUENCHED (FECO)MO(Cu,B13) AMORPHOUS ALLOYS

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Summary: (Fe1-xCox)0.6Mo(Cu,B)13 amorphous alloys were prepared in the form of ribbons by rapid quenching for x=0, 0.25 and 0.5. The effect of variation of Co/Fe ratio is analyzed with respect to the formation of amorphous state and to transformation of the structure into nanocrystalline phases formed after subsequent thermal treatment. Selected properties and atomic structure in as-quenched state are studied by TEM, AFM, XRD and by measurements of magnetoresistance characteristics. The influence of heat treatment on transport and magnetic properties is shown on temperature dependencies of electrical resistivity and magnetization. It was found that while the increase of Co content leads to the increase of Curie temperature of as-quenched structure, transition to nanocrystalline state is not affected in a significant manner. The as-quenched state for alloy without Co was found to contain thin crystal-containing layer which, however, was observed, contrary to general behavior, at the side of the ribbon exposed to higher quenching rates.

1. INTRODUCTION

Formation and transformation behavior of amorphous Fe-Mo-B based alloys were studied recently [1] in form of thin films prepared by electrodeless plating. The effect of addition of small amount of Cu on structural and magnetic properties of rapidly quenched amorphous Fe1-xMoxCuB13 was investigated in detail by Mössbauer spectroscopy, differential scanning calorimetry (DSC), X-ray diffraction (XRD), transmission electron microscopy (TEM), high resolution electron microscopy (HREM) [2, 3]. The results obtained suggested a possibility to enhance significantly certain properties by substituting a suitable metallic element in place of Fe.

In this work we have studied the influence of the addition of cobalt into Fe-Mo-Cu-B system by using different measuring techniques and microscopic methods.

2. EXPERIMENTAL DETAILS

Amorphous (Fe1-xCox)0.6Mo(Cu,B)13 alloys for x=0, 0.25, 0.50 were prepared in the form of ribbons (6mm wide and ~20μm thick) by the method of planar flow casting. Sample composition was checked by induction-coupled plasma spectroscopy (ICP Jobin Yvon JY-70) to be within 1% of the nominal content of each element.

Using the measurements of temperature dependencies of the electrical resistivity (R(T)) and magnetization (M(T)) we have obtained the most basic properties of the studied metallic system with respect to the magnetic state of as-cast systems. The complementary information has been obtained by the measurements of magnetoresistance.

TEM, atomic force microscopy (AFM) and XRD methods have provided information about structure and ordering of the constituent atoms in the bulk and on the surface of the investigated material.

The set of all experimental methods used has yielded a complex view of atomic and electronic structure of this nanocrystal-forming amorphous system. TEM was performed on a JEOL 1200EX; samples for TEM were polished by precision ion polishing system (Gatan PIPS). AFM was performed by a PICO scanner from Molecular Imaging, Inc. XRD was performed using a standard Bragg-Brentano geometry with Cu Kα radiation. R(T) and magnetoresistance measurements were performed by four-probe method with ultrastable current source and two Keithley nanovoltimeters controlled by PC. The R(T) measurements were performed in a special planar furnace controlled by EUROTERM 2416 controller. Heating rate was 10K/min.

Measurements of magnetoresistance were performed at 300 K using external magnetic fields in the range of 0 - 0.5 T under different mechanical loads on the sample, inducing σ-stresses between 0 and ~130MPa on the ribbon samples. Due to rather low values of magnetoresistance thermal stabilization of the magnet-sample setup was necessary to avoid temperature drifts during measurements.

M(T) measurements were performed on a Perkin-Elmer TGM 7700.

3. RESULTS AND DISCUSSION

3.1 Temperature dependent characterization

Transformation behavior in three samples with different Co/Fe ratio has been investigated by measurements of temperature dependence of magnetization M(T) and electrical resistivity R(T). Fig.1 shows the plots of these temperature dependencies for x=0, 0.25 and 0.5.

The sample without Co (x=0) in the range 300K - 700K exhibits a pronounced increase of
The effect of substitution of Fe by Co...
The effect of substitution of Fe by Co...

Tab. 1. Crystallization temperature (from R(T)) and M(T), quantification of decrease in resistivity by crystallization, Curie temperature. The values are deduced from Fig. 1.

<table>
<thead>
<tr>
<th>Sample</th>
<th>T&lt;sub&gt;1/2&lt;/sub&gt; (K)</th>
<th>T&lt;sub&gt;sub&lt;/sub&gt; (K)</th>
<th>ΔR/ΔR&lt;sub&gt;c&lt;/sub&gt; [%]</th>
<th>T&lt;sub&gt;Curie&lt;/sub&gt; (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>x=0</td>
<td>720</td>
<td>710</td>
<td>12</td>
<td>-200 (&lt;290)</td>
</tr>
<tr>
<td>x=0.25</td>
<td>690</td>
<td>680</td>
<td>18.2</td>
<td>600</td>
</tr>
<tr>
<td>x=0.5</td>
<td>660</td>
<td>670</td>
<td>22.6</td>
<td>-1000</td>
</tr>
</tbody>
</table>

R(T), which can be approximated by linear fit, yielding a temperature coefficient of electrical resistivity, TCR, of this sample in this range of TCR=1.8×10<sup>-3</sup>K<sup>-1</sup>, typical for amorphous Fe-based amorphous systems. Electrical resistivity for samples with x=0.25 and 0.5 exhibits approximately constant value in the temperature range 300K, 640K and 300K – 680K for x=0.25 and 0.5, respectively, the change of R(T) is in range 0.2%, hence TCR=0 for these alloys in amorphous state.

The resistivity plot shows a decrease for all compositions, starting at T<sub>1/2</sub>, T<sub>sub</sub>, T<sub>Curie</sub> for x=0, 0.25 and 0.5, respectively, as shown in Fig. 1. The deviation from linear behavior in R(T) indicates the beginning of crystallization; thus T<sub>1/2</sub>, T<sub>sub</sub>, T<sub>Curie</sub> are taken as the temperatures of the onset of this process. The values are in good agreement with those obtained from M(T). Crystallization terminates above ~950K and leads to fully crystallized state.

The same qualitative transformation behaviour is observed on the M(T) dependencies where a transition from a paramagnetic amorphous state into a mixture of (paramagnetic) amorphous remains and growing ferromagnetic crystalline grains lead to a sharp increase of M(T) above 740K and above 700K for samples with x=0 and x=0.25, respectively. The sample with x=0.50 exhibits the Curie temperature above the onset of transformation, thus the increase of M(T) related to crystallization of amorphous ferromagnetic matrix is observed from values above zero. The extrapolation of M(T) towards higher temperatures allows to estimate roughly the value of T<sub>Curie</sub>, which may be as high as ~1000K. The increase of Curie temperature with increasing ratio of Co to Fe as well as the transformer temperatures are given in Tab. 1.

3.2 Characterization of as-quenched material

Fig. 2 shows the AFM and TEM image of ribbor sample without Co. It can be seen that at the surface imaged by AFM are "cell-like", yet amorphous objects detached from each other by trench (depth ~100Å). This effect is related to the rapid quenching process used to prepare amorphous samples and to the roughness of the quenching wheel. Inside these "cells" small crystalline grains are visible. TEM image of the sample polished from the top side of the ribbon ("air side" with respect to the rapid quenching with single roller technique) shows a view of the structure immediately below the surface. There can be seen large crystalline grains close to the surface of the "wheel" side which are replaced with increasing depth by thin nanocrystalline grains about ~5nm in size. Further inside the bulk or at the "air" side of the ribbon no presence of crystalline phase was detected.

The presence of crystalline phase in the sample without Co is proved also by XRD. Fig. 3 shows XRD diffraction patterns for the three investigated alloys in as-quenched state. Plots 2 and 3 confirm amorphous state of the material but plot 1 shows a presence of crystalline phases at surface of amorphous material.

Fig. 4 shows two series of magnetoresistance plots. These series differ in orientation of sample against magnetic field. It could be noticed, that the orientation with surface of ribbon perpendicular to vector of homogenous planar magnetic field, shows higher magnetization field needed to reach saturation, probably due to higher demagnetization factor for this configuration. However, the character and the resistivity changes of the dependencies are the same for both orientations. Similarly as the temperature dependencies of magnetization the plots of magnetoresistance exhibit strong dependence on the content of Fe and Co.

3.3 Discussion

The plot of R(H) for x=0 (Fig. 4) represents the dependence of magnetoresistance of a paramagnetic system. However, the XRD pattern from the as-quenched sample (curve 1 in Fig. 3) shows two rather narrow crystalline peaks at the positions which correspond to the (110) and (220) reflections of the bcc-Fe lattice. However, the reflections for (200) and (211), lying between these two, are missing. This may indicate formation of a bcc-Fe like structure which is yet not fully developed but which is the first crystalline phase formed during transformation from the amorphous state in the temperature regions as indicated by the drop of
electrical resistivity and rise of magnetization on Fig. 1. The size and morphology of the crystalline grains observed to be present in a thin surface layer suggests that these grains are not magnetically correlated, hence the magnetoresistance exhibits paramagnetic behavior, in accord with the M(T) measurements.

The ferromagnetic character of the samples with x=0.25 and 0.3 is evident; the electrical resistance after initial decrease reaches a saturation value for rather low applied fields, giving indication of a soft ferromagnetic system.

It is to be noted that, contrary to all previous experience, the presence of crystalline layer is observed at the bottom ("wheel") side of the ribbon, where the quenching rate is certainly higher that at the top ("air") side of the ribbon. The top side of the ribbon, however shows absolutely no presence of any crystalline layer. Thus, effect is still under investigation and it is expected that a partitioning of solutes in the precursor melt before rapid quenching or during the quenching process may be responsible for it. The effect of moving the crystalline layer present at the bottom side of the ribbon persists for compositions corresponding up to x=0.20, as shown in [4].

4. CONCLUSION

Substitution of iron by cobalt in Fe-Mo-Cu-B system leads to formation of fully amorphous ferromagnetic state. Increased Co content leads to increase of Curie temperature of the amorphous phase. The temperatures of transformation into nanocrystalline state, however, are not significantly affected, although the magnitude of changes of electrical resistivity increases with increasing Co content. Excellent correspondence between transformation behavior during linear heating regimes was observed for electrical resistivity and magnetization measurements. Magnetization behavior was correlated also with measurements of magnetoresistance, showing distinct differences between paramagnetic and ferromagnetic samples. Alloys with low or no cobalt content exhibit unusal effect, where partial crystallinity is observed in the sample layer with higher quenching rate.

Acknowledgement

Support of the Slovak Grant Agencies for science (VEGA 5/09625, APVT-51-05270, APVT-51-021102 and SO 51038 (06 03) and SAS Centre of Excellence "Nanosmat" is acknowledged.

REFERENCES


PERFORMANCE OF AlGaN/GaN HETEROSTRUCTURE FIELD-EFFECT TRANSISTORS FOR HIGH-FREQUENCY AND HIGH-POWER ELECTRONICS

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Summary Preparation and properties of GaN-based heterostructure field-effect transistors (HFETs) for high-frequency and high-power applications are studied in this work. Performance of unpassivated and SiO2-passivated AlGaN/GaN HFETs, as well as passivated SiO2/AlGaN/GaN MOSFETs (metal–oxide–semiconductor HFETs) is compared. It is found that MOSFETs exhibit better DC and RF properties than simple n-FET counterparts. Deposited SiO2 yield an increase of the sheet carrier density from 7×1018 cm-2 to 9.2×1018 cm-2 and subsequent increase of the static drain saturation current from 0.75 A/mm to 1.09 A/mm. Small-signal RF charactarisation of MOSFETs showed an extrinsic current gain cut-off frequency fT of 24 GHz and a maximum frequency of oscillation fmax of 40 GHz. These are fully comparable values with state-of-the-art AlGaN/GaN HFETs. Finally, microwave power measurements confirmed excellent performance of MOSFETs; the output power measured at 7 GHz is about two-times larger than that of simple unpassivated HFET. Thus, a great potential in application of GaN-based MOSFETs is documented.

1. INTRODUCTION

It is well known that future devices used in new communication systems need to operate simultaneously at higher frequencies (higher speed, larger bandwidth) and higher powers. Unfortunately, Si-based and GaAs-based devices cannot fulfill this requirement, as it follows from their fundamental material and electronic transport parameters. Schematic frequency vs power diagram for devices using various semiconductor materials is shown in Fig. 1 [1]. Materials with higher bardslag, such as SiC and GaN (3.4 eV), clearly dominate. However, the natural advantage of GaN over SiC is the possibility of making heterostructures using AlGaN, InGaN or InAlN. Since recently GaN-based transistors are under systematic study by various academic and industry research groups. An expresive progress concerning the preparation and performance of AlGaN/GaN heterostructure field-effect transistors (HFET) can be observed [2]. This can be demonstrated by recently reported total output power of 179 W at 2 GHz on 48 mm wide (i.e. 3.7 W/mm power density), single chip HFET by Device Research Labs of NEC Corp. [3]. In spite of these record power data they are still some material and device issues, which need to be solved concerning mass production of AlGaN/GaN HFET devices. One key problem at the preparation of GaN-based devices is the lack of native substrates [4]. The material structure needs to be grown as lattice-mismatched to the substrate such as sapphire, Si or SiC. High gate leakage currents and DC/RF drain current dispersion, which limit microwave output power, as well as performance degradation belong to the main questions concerning the device preparation. Various tasks such as material structure optimisation [5], electric passivation [6] and field-modulating gate plate [7] are used to suppress or eliminate these effects. Recently an application of gate insulator, i.e. preparation of MISHFET devices, has been shown as a perspective alternative for the preparation of reliable GaN-based transistors [8].

In this paper, an influence of a SiO2 insulator, deposited on the un gated surface access region as well as below the gate, on the performance of AlGaN/GaN HFETs is investigated. The DC and RF performance of unpassivated and passivated HFETs and passivated MOSFETs, prepared on the same material structure, is compared. It is shown that SiO2 passivated MOSFETs exhibit higher output power than simultaneously prepared Schottky-gate HFET counterparts.

Fig. 1. Schematic frequency vs power diagram for devices on various semiconductor materials [1]