Resistivity and Magnetoresistance of Fe$_{80}$B$_{20}$ and Fe$_{78}$B$_{13}$Si$_{9}$ Amorphous Glasses.

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Summary. — The electrical resistivity of Fe$_{80}$B$_{20}$ and Fe$_{78}$B$_{13}$Si$_{9}$ amorphous glasses as a function of temperature from 293 K down to 15 K was measured, and it was found to fit quite well with the model given by Cote and Meisel. Comparison between our resistivity measurements of Fe$_{80}$B$_{20}$ and others was made, where some differences were found. These resistivity differences are evidence for a variety of amorphous atomic arrangements of the samples. The longitudinal magnetoresistance of Fe$_{80}$B$_{20}$ and Fe$_{78}$B$_{13}$Si$_{9}$ at 293 K and 77 K was measured in a low magnetic field. The observed magnetoresistance shows a typical field dependence known for ferromagnetic materials.

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1. – Introduction.

During the late 1960’s, it was shown that it is experimentally feasible to make amorphous metallic solids which lack crystalline periodicity[1, 2]. Amorphous systems often exhibit markedly different behaviour than those observed in crystalline solids[3]. Amorphous metallic glasses have been the subject of considerable investigations since alloys in ribbon forms were developed by continuous rapid quenching from the melt[4].

Metallic glasses made by the liquid-quench method are generally metal-metalloid systems in the form M$_{1-x}$G$_x$, where M is a transition element and G is a glass former. The concentration X is near the eutectic, where the glass-forming tendency and stability are dramatically increased[5, 6].

Fe-B amorphous metallic alloys have been studied extensively because they have many technological applications as well as they have great commercial value. The binary Fe$_{80}$B$_{20}$ amorphous alloy represents the simplest alloy to study. Measurements made on Fe$_{80}$B$_{20}$ are compared with that made on Fe$_{78}$B$_{13}$Si$_{9}$. In particular, the temperature dependence of the electrical resistivity (in the temperature range from 293 K down to 15 K) was measured for both alloys. Also the longitudinal magneto-resistance up to a field of about 5 kG at temperature 293 K and 77 K was measured.
2. - Experimental.

$\text{Fe}_{80}\text{B}_{20}$ and $\text{Fe}_{78}\text{B}_{13}\text{Si}_{9}$ amorphous glasses in the form of ribbons were obtained from 3M company (USA). These iron-base glasses were prepared by rapid quenching from the melt. Cross-sectional dimensions of the ribbons were typically $40 \mu\text{m} \times 1.3 \text{ mm}$ for $\text{Fe}_{80}\text{B}_{20}$ and $60 \mu\text{m} \times 5.48 \text{ mm}$ for $\text{Fe}_{78}\text{B}_{13}\text{Si}_{9}$. The thickness was measured with an accuracy of $1 \mu\text{m}$ using a micrometer. X-ray diffractometer measurements (using CuK$_\alpha$ radiation) confirmed that the samples were in the amorphous state.

The electrical resistivity was measured by using the usual four-probe d.c. method. The resistivity was measured in the temperature range 293 K down to 15 K. A closed cycle refrigeration system (model CS-202 from Air Products) was used for cooling. The electrical contacts between the sample and lead wires were made by using silver paste.

The sample current was kept low in order to prevent heating the sample. A typical value for the current used for our measurements was 10 mA. The sample temperature was measured with a calibrated $\text{kp-Au 0.07 at. % Fe}$ thermocouple and stabilized with the aid of a temperature controller. The current source provides both positive and negative current, hence the average value of the voltage was taken. The resistivity measurements were taken during cooling as well as during heating of the samples.

The longitudinal magnetoresistance was measured at 293 K and 77 K up to a magnetic field of about 5 kG in an electromagnet with flat pole faces. The magnetic field was applied parallel to the current direction as well as to the ribbon axis.

3. - Results.

The electrical resistivity at a given temperature normalized to room temperature resistivity ($\rho / \rho_{293}$) of $\text{Fe}_{80}\text{B}_{20}$ and $\text{Fe}_{78}\text{B}_{13}\text{Si}_{9}$ amorphous glasses between 15 K and 293 K is shown in fig. 1. It was found that the temperature dependence of resistivity has a linear $T$-dependence in the high-temperature region ($150 \text{ K} < T < 293 \text{ K}$), for both $\text{Fe}_{80}\text{B}_{20}$ and $\text{Fe}_{78}\text{B}_{13}\text{Si}_{9}$ alloys as shown in fig. 2. On the other hand, fig. 3. shows the normalized electrical resistivity ($\rho / \rho_{293}$) of $\text{Fe}_{80}\text{B}_{20}$ ($\Box$) and $\text{Fe}_{78}\text{B}_{13}\text{Si}_{9}$ ($\bigcirc$) as a function of temperature.

Fig. 1. - The normalized electrical resistivity ($\rho / \rho_{293}$) of $\text{Fe}_{80}\text{B}_{20}$ ($\Box$) and $\text{Fe}_{78}\text{B}_{13}\text{Si}_{9}$ ($\bigcirc$) as a function of temperature.