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Temperature influence on field dependences of impedance of amorphous CoFeNbSiB wires

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Abstract. The effect of temperature on the field dependences of the amorphous Co\textsubscript{66}Fe\textsubscript{4}Nb\textsubscript{25}Si\textsubscript{12.5}B\textsubscript{15} wires impedance is investigated. The saturation induction \(B_s\) of the samples was 0.4 T, the biased magnetodynamics \(X\) was about \(10^{-7}\). The measurements of the impedance were carried out in a frequency range 0.5–10 MHz. The maximal value of the external magnetic field was 4 kA/m. The temperature varied in the range 290–440 K.

1. Introduction
The giant magnetoimpedance effect (GMI) is observed in amorphous soft magnetic alloys with a low magnetostriction constant [1,2]. It is of considerable interest for the scientists in connection with development of new high-sensitivity sensors of magnetic field and biosensors [2,3]. One of the important aspects of GMI-sensors development is the study of magnetoimpedance properties at various temperatures. These data allow determining the temperature limits of new sensors applicability. The results of experimental research of temperature effect on magnetoimpedance of amorphous soft magnetic wires are reported in the present work.

2. Experimental setup and technique of experiment
The automated measuring complex was made on the basis of apparatus developed before [4] for research of temperature influence on magnetoimpedance properties of amorphous soft magnetic wires. The samples holder was made of talc ceramics, which provides necessary heat stability and mechanical durability.

The holder was placed inside the duralumin airway. The sample was heated up to required temperature by air stream. The electric heater was placed in the shield of soft magnetic alloy instead of samples holder in order to prevent the influence of its electromagnetic fields on the sample impedance. The temperature of air stream was kept stable by means of heat-insulated airway walls from the heater to the sample holder. The electrical contacts with the sample were provided with mechanical connections. In order to prevent oxidation all contacts were made of silvered copper. The temperature and uniformity of sample heating was controlled by two thermocouples (chromel–copel). The thermocouples were placed near the ends of a sample.

The impedance of a sample was determined by the value of the voltage on a sample with the constant value of the high frequency driving current. The probe of high-frequency voltmeter was

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beyond of a heating zone to guard against influence of heat. The samples have the form of the pieces of amorphous Co$_{66}$Fe$_{4}$Nb$_{2.5}$Si$_{12.5}$B$_{15}$ wire with diameter of 150 and length of 30 mm. The saturation induction $B_s$ of the samples was 0.4 T, the biased magnetostriction $\lambda_s$ was about $10^{-7}$. The impedance was measured in a frequency range from 0.5 MHz to 10 MHz. The temperature was varied from 290 to 440 K. The maximal value of the external magnetic field within the sample position was 4 kA/m.

The temperature dependences of the initial impedance were measured as the temperature varied linearly from 290 to 440 K over 60 minutes. In the course of the field dependences measurement the temperature was kept constant.

### 3. Results

Figure 1 shows the temperature dependences of the reduced impedance $Z/Z_0$ at two frequencies of driving current: 0.5 and 10 MHz, where $Z_0$ is impedance of the wire at $T=290$ K and $H=0$.

![Figure 1](image)

**Figure 1.** Temperature dependences of reduced impedance $Z/Z_0$ at two frequencies of driving current: 0.5 MHz (a) and 10 MHz (b).

As one can see the changes of an impedance of the wire are insignificant in a range 290–400 K. The further increase of the temperature from $T_1$ up to $T_2 = 431$ K results in a sharp decrease of an impedance. At the temperatures higher than $T_2$ the impedance remains constant.

The nature of change of the impedance from the temperature depends on frequency of driving current. At a frequency 0.5 MHz on a curve $Z/Z_0(T)$ in points corresponding to temperatures $T_1$ and $T_2$, the sharp change of impedance is observed. At a frequency 10 MHz the given changes occur more slowly. The curves of field dependences of sample impedance $Z(H)$ for two frequencies of driving current (0.5 MHz and 10 MHz) with different temperatures are presented in figure 2. In a frequency range from 0.5–4 MHz the peak on field dependences of the impedance $Z(H)$ is observed in a zero magnetic field (figure 2a). With increasing the temperature the value of the maximal impedance $Z_{\text{max}}$ was decreasing and peak width on field dependence was decreasing too. At the temperatures higher than 431 K the impedance of sample does not depend on external magnetic field and temperature.

If the frequency of driving current is higher than 4 MHz the maximal value of impedance $Z_{\text{max}}$ on field dependences is observed at $|H| > 0$ (figure 2b). With increasing the temperature from 293 K up to 419 K the reduce of initial $Z_0$ and maximal $Z_{\text{max}}$ impedances is observed. At the same time the value ($Z_{\text{max}} - Z_0$) is decreasing. At the temperatures $T$ higher than 431 K the maximal and initial impedances are equals ($Z_{\text{max}}=Z_0$) and the impedance does not depend on an external magnetic field and temperature.
**4. Conclusions**

The following facts have been established:

- With increasing the temperature the decrease of wire impedance is observed in the investigated frequency range of driving current.
- It is possible to differentiate three parts in temperature dependences of reduced impedance with zero external magnetic fields: 1) region of weak dependence of impedance on temperature ($T < 400$ K); 2) region of significant fall of impedance with growth of temperature ($400$ K $< T < 431$ K); 3) region, where dependence of impedance on temperature is not observed ($T > 431$ K).
- If the temperature exceeds 431 K the impedance does not depend on external magnetic fields. It is probably because the Curie point is achieved for the given amorphous alloy.

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