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Abstract

Full Text

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STUDY OF THE HALL EFFECT AND THE GALVANOMAGNETIC EFFECT IN THIN FILMS OF THE NICKEL-COPPER ALLOY SYSTEM

A study of the change in the electrical resistance of single-crystal films of the nickel-copper alloy system in a magnetic field (the galvanomagnetic effect) was carried out in work (1). The single-crystal films were obtained by the authors of that work by vacuum deposition of nickel and copper from separate sources onto a polished cleavage face [100] of a rock-salt single crystal. Studies of the galvanomagnetic effect and the Hall effect in polycrystalline films of the nickel-copper alloy system, as far as we know, have not been carried out by anyone. It is also known that in thin-film electronics and, in particular, for measuring the Hall effect and the galvanomagnetic effect in thin films, it is important to create reliable ohmic contacts, especially for high temperatures at the junctions of thermoelements.

Fig. 1. Schematic representation of the sequence for producing temperature-stable ohmic contacts on thin-film materials

The authors of the present work set themselves the following goals:

1. To develop a new method for creating reliable ohmic contacts on films.
2. Using these contacts, to study the galvanomagnetic effect and the Hall effect in thin polycrystalline films of the nickel-copper alloy system at room temperature.

Many researchers use the method of depositing contacts of silver, copper, platinum, etc., followed by soldering of leads with various alloys (2), mainly with

Figure 2

Figure 2: Figure 2

Figure 3

Figure 3: Figure 3

silver paste. R. G. Annaev proposed a new method for producing ohmic contacts in thin-film materials (metallic and semiconducting), published for the first time in this article. The sequence of the process of creating contacts is shown schematically in Fig. 1: *a*—cutting and polishing of glass, mica, or a single-crystal substrate; *b*—gluing thin multistrand conductors with fan-shaped ends using BF-2 adhesive and cleaning the upper part in order to create good contacts with evaporated film contacts; *v*—application, by vacuum evaporation, of contact films of silver, platinum, gold, copper, etc.; *g*—application, by vacuum evaporation, of the film under investigation, followed by coating in vacuum with a quartz or porcelain film, and at atmospheric pressure—with Bake-

with lithol varnish*. The contacts for measuring the Hall effect, made according to the method of Fig. 1, proved to be reliable, strong, and temperature-resistant. When film contacts 0.01–0.1 mm thick are deposited, these contacts withstand a temperature of 400°. As is known, the electrical and magnetic properties of thin ferromagnetic films are substantially affected by the temperature of the substrate, the nature of the substrate, the evaporation rate, and mechanical factors. In the present work the Hall effect and the galvanomagnetic effect were investigated on thin nickel-copper films obtained under specified conditions. Consideration of the influence of the substrate material and the deposition conditions is the aim of subsequent work.

Fig. 2. Dependence of the Hall e.m.f. on the external magnetic field for films of various thicknesses with 30 wt.% copper on a nickel base.
1 —600 Å, 2 —720 Å, 3 —850 Å, 4 —900 Å, 5 —1050 Å, 6 —1200 Å.

The films, of rectangular shape 7.5×15 mm^2 and with thickness from 400 to 1200 Å, were obtained by thermal evaporation in a vacuum of $5 \cdot 10^{-5}$ mm Hg onto cover glasses for a microscope, 0.1 mm thick, heated to 200°**. The alloys were evaporated from a tungsten crucible. The substrate temperature during evaporation was measured with a copper–constantan thermocouple; the film thickness, with an MF-2 microphotometer. The Hall effect was measured with an unbalanced potentiometer of R. G. Annaev ([3]), and the galvanomagnetic effect with an unbalanced double bridge ([4]). A galvanometer was used with voltage sensitivity $C_u = 2.6–1.2 \cdot 10^{-7}$ V/mm · m. Measurements of the effects were carried out at room temperature with an accuracy of up to 5%. Films obtained by evaporation of alloys containing 5; 10; 15; 20; 25; 30; 35 wt.% copper on a nickel base were investigated.

Fig. 3. Dependence of the longitudinal $(\Delta R/R)_\parallel$ and transverse $(\Delta R/R)_\perp$

galvanomagnetic effects on the external magnetic field for films of various thicknesses with 20 wt.% copper (a) and 15 wt.% copper (b) on a nickel base.
1 –1200 Å, 2 –1050 Å, 3 –900 Å, 4 –780 Å, 5 –430 Å, 6 –300 Å.

* M. Roziev and N. Annataghanov took part in the development of this method.

** In the opinion of the authors of the present article, investigations on thin films at high vacuum (10^{-8}–10^{-9} mm Hg) are mainly of theoretical significance. In practice these investigations are not profitable, since producing such high vacua is difficult and makes the apparatus cumbersome. It is expedient to study films at atmospheric pressure while isolating them from oxidation with a layer of heat-resistant material (varnish, porcelain, quartz, etc.).

The results of measurements of the Hall effect for films of different thicknesses with 30 wt.% copper on a nickel base are presented in Fig. 2. It is evident from the figure that the magnitude of the Hall effect increases as the film thickness decreases. A similar regularity is also observed for all the other alloys, which agrees with the data of other authors. As the copper content in the nickel-copper alloy increases, the saturation-field value of the Hall effect decreases.

Figure 3a gives the results of an investigation of the longitudinal $(\Delta R/R)_{\parallel}$ and transverse $(\Delta R/R)_{\perp}$ galvanomagnetic effect as a function of the external magnetic field for films of different thicknesses with 20 wt.% copper on a nickel base. It is evident from the figure that the longitudinal galvanomagnetic effect increases with increasing film thickness. For the transverse galvanomagnetic effect, no clear dependence of the effect on film thickness was found.

Figure 3b presents the dependence of the longitudinal $(\Delta R/R)_{\parallel}$ and transverse $(\Delta R/R)_{\perp}$ galvanomagnetic effect on the external magnetic field for films less than 500 Å thick with 15 wt.% copper.

It is evident from Fig. 3 that saturation of the longitudinal effect occurs earlier than that of the transverse effect, for films of different thickness and different composition. Deviations from the second rule of even effects are observed, which is explained by the presence in the films of magnetic texture and anisotropy, which form during deposition.

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Note: Figure translations are in progress. See original paper for figures.