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## Abstract

## Full Text

# PHYSICAL CHEMISTRY

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# ON THE TEMPERATURE DEPENDENCE OF THE SATURATION MAGNETIZATION AND ON THE MAGNETIC STRUCTURE OF NICKEL FILMS OBTAINED BY A CHEMICAL METHOD

*(Presented by Academician A. V. Shubnikov on October 20, 1961)*

The magnetic properties of nickel deposits obtained by the method of chemical nickel plating differ from the properties of nickel deposits obtained by electrolysis ([1]). It was found that the Curie point of nickel deposits obtained chemically lies considerably below the Curie point of pure nickel; the saturation magnetization, residual induction, and coercive force of the deposits depend linearly on temperature ([2]).

**Fig. 1.** Temperature dependence of the saturation magnetization of nickel films obtained by the method of chemical nickel plating.

In the present work, along with samples possessing a linear dependence of $I_s$ on temperature (Figs. 1, 2), samples with another character of dependence were obtained (Fig. 1, 1, 3). The curves correspond to samples obtained from a bath of one composition (in g/l): nickel sulfate 30, sodium hypophosphite 10, sodium acetate 10. The bath temperature during formation of the deposits was 87°. The difference in obtaining the samples consisted in the fact that the volume of the bath solution taken for one and the same coating surface area (12.5 $cm^2$) was different. As the investigations showed, the samples are complex in magnetic structure. They consist of ferromagnetic and nonferromagnetic layers, since from a freshly prepared solution a ferromagnetic deposit first forms, and then a nonferromagnetic one. In a bath of larger volume the thickness of the ferromagnetic layer is greater. To increase the accuracy of measurement, the bath solution was replaced several times with freshly prepared solution.

Fig. 2. Hysteresis loops of nickel films obtained in the same bath at different times

Figure 2: Fig. 2. Hysteresis loops of nickel films obtained in the same bath at different times

The shape of the samples, the procedure for preparing them, and the measurement of $I_s$ were analogous to those described in ([2]). Table 1 gives the data for the samples.

**Table 1**

| Sample No. | Deposition time, h | Solution volume, ml | How many times the solution was changed | Film thickness, $\mu$ | $I_s$ at 20°C |
|---|---|---|---|---|---|
| 1 | 6 | 15 | 24 | 65.5 | 54.8 |
| 2 | 6 | 70 | 18 | 61.8 | 48.5 |
| 3 | 6 | 500 | 3 | 76.8 | 65.5 |

The change in the ferromagnetic properties of the deposit during operation of the bath was investigated. In a freshly prepared solution of volume 500 $cm^3$, every 10 min of bath operation the finished sample was removed and, in its place, a copper substrate was introduced, on which further deposition proceeded.

In all, during 150 min of deposition, 15 samples were obtained; moreover, as the experiments showed, the last three samples do not possess ferromagnetic properties. Figure 2 gives the hysteresis loops of the first 12 samples.

**Fig. 2.** Hysteresis loops of nickel films obtained in the same bath at different times

in the order in which they were obtained. The loops were photographed from an EO-7 oscillograph. To amplify the signal, a three-stage amplifier with an integrator and a circuit for calibrating the applied signal was connected to the vertical-channel circuit. The remagnetization frequency was 50 Hz, the field amplitude 34 oersteds, and the temperature of the specimens 20°. From the hysteresis loops, graphs were constructed (from specimen to specimen) of the magnetization, the residual magnetization, and the coercive force of the specimens.

In Fig. 3 are shown graphs of the dependence of $I_s$ on $t$, respectively for specimens 1, 3, 5, and 8 of this series.

Thus, by the method of chemical nickel plating it is possible to obtain films having different temperature dependences of the magnetic properties (Figs. 1,

Fig. 3. Temperature behavior of the magnetization of specimens 1, 3, 5, and 8 in an alternating field with field amplitude 34 oersteds

Figure 3: Fig. 3. Temperature behavior of the magnetization of specimens 1, 3, 5, and 8 in an alternating field with field amplitude 34 oersteds

3); apparently, such films may find application as thermometric bodies. By a corresponding choice of the composition of the bath and of its operating conditions it is possible to obtain films needed in engineering with very different hysteresis loops. Thus, a loop analogous to loop 8 in Fig. 2 was obtained from a solution in which, instead of 30 g/l of nickel sulfate, 10 g/l was taken.

**Fig. 3.** Temperature behavior of the magnetization of specimens 1, 3, 5, and 8 in an alternating field with field amplitude 34 oersteds

It has been found that the magnetic properties of films obtained by the method of chemical nickel plating change

from layer to layer. Therefore, it must be considered that the data in the literature (for example, ([1],[2])) on $I_s$, $I_r$, and $H_c$ are an average value for the entire film as a whole, which may consist of both ferromagnetic and nonferromagnetic layers.

In view of the very high sensitivity of the magnetic properties of deposits to the composition of the bath (Fig. 2), which, unlike electrolytic solutions, changes as the deposit is formed, a magnetic method may be proposed for monitoring and correcting the bath during its operation.

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