Studies about Magneto-optic Kerr Effect on Electrodeposited Nickel Layers

VIOLETA VASILACHE[1] * SONIA GUTT[1], TRAIAN VASILACHE[2], GHEORGHE GUTT[1]
[1]University Stefan cel Mare of Suceava, Faculty of Food Engineering, 13 Universitatii Str.,720229, Suceava, Romania
[2]S.C. Daflog S.R.L Mediaş, 17 Garii Str., Medias, Sibiu, Romania

Magneto-optic properties of electrodeposited nickel layers were studied. Electrochemical parameters during electrodeposition were carefully measured and controlled. A MOKE magnetometer was used for advanced characterization of the layers. Hysteresis curves were recorded and studied to find properly conditions to obtain nickel layers with better magnetic properties, able to be used in practical applications.

Keywords: nickel electrodeposition, Kerr effect, MOKE, hysteresis curves

Kerr effect consists in rotation of light polarization plane when it is reflected by a surface situated in an electric field. Magneto-optic Kerr effect (MOKE) consists also in rotation of light polarization plane when the surface is situated in a magnetic field [1-3].

Both Kerr effect and MOKE may have important practical applications, like structure for memory devices in computer building technique. The idea is to write using a magnetic field and to read using an optic device, because it is faster. Also the growth of the crystals could be monitorized using MOKE.

It was reported that the magneto-optical Kerr rotation can be studied in hundreds metallic systems comprising alloys and inter-metallic compounds of 3d transition metals [4-6]. For all these materials the characteristics of crystal structure, lattice constants, room-temperature magnetization and Kerr rotation at different wavelengths haven been emphasized.

The changes produced in rotation of the polarization plane of the light by this effect are usually very small (< 0.1deg) and they are difficult to observe, even by means of modern laser sources. The achievement of Kerr is spectacular. It is sobering to realize that the effects discovered over 125 years ago by Kerr now form the basis of a substantial magneto-optic recording industry [7-10].

Experimental part

It was used a Watts bath with the next composition: $NiSO_4 \cdot 6H_2O$, 120 gL^{-1}; $NiCl_2 \cdot 6H_2O$, 35 gL^{-1} and H_3BO_3, 35 gL^{-1}, Merck trade mark. High purity water was used to prepare all solutions [11-14].

The experimental configuration used to carry out the electrodeposition of nickel consisted of a potentiostat-galvanostat VoltaLab with VoltaMaster 4 software, a thermostatic electrolysis cell, with a thermostat Lauda 003, a magnetic stirrer and a thermometer for temperature controlling. The conductivity of electrolytes was measured at room temperature with a conductivity measuring apparatus. The value of *p*H was 4.5±0.2 without additions.

As working electrode it was used an electrolytic nickel electrode; a saturated calomel electrode (SCE) was used as reference electrode. All potentials were shared after the reference electrode (SCE).

Small surface copper plates (approx. 2 cm^2) were cut and their thickness was measured with a micrometer. Their surfaces were mechanically polished with emery paper and felt. The copper plates were washed with hydrogen chloride 5% at 65°C, with water, dried and weighed.

The mass of the nickel deposed were calculated by a difference Δm between the weight of plates before and after process.

On the way to study the visual aspect for a large interval of current densities and the medium efficiency in current, the nickel layers were deposed on a copper substrate.

Optical inspection was performed with the optic microscope Zeiss DSM 982 Gemini.

In order to study the magneto-optic Kerr effect of the electrodeposited layers it was used a magnetometer which consists in two coils capable to generate a magnetic field up to 1 T and an optic system with a polarized source and an optic analyzer for measuring the deviation of the angle Kerr versus the magnetic induction of the applied magnetic field.

Results and discussions

In figure 1 there are represented the polarization curves, the chronopotentiogramme-charts of different experimental parameters characterizing this process [15].

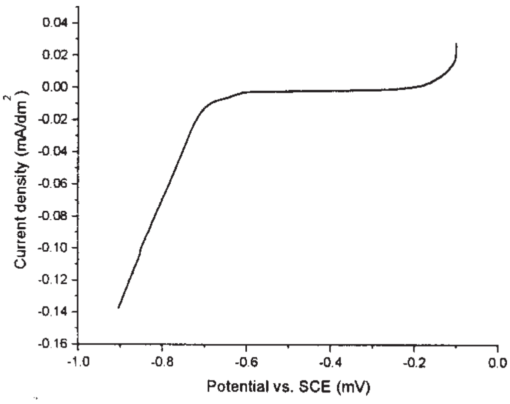
The polar Kerr effect is illustrated phenomenologically in figure 2, where linearly polarized light is normally (or obliquely) incident on a sample whose own magnetization was done perpendicular on surface. After reflection, in addition to the usual Fresnel amplitude component, a small orthogonal Kerr component appears that, in combination with, leads to elliptically polarized light with a complex Kerr rotation and ellipticity.

The Kerr effect could be positive (carbon sulfur) or negative (ether) depending if velocity of the polarized wave which is parallel with the lines of the electric field is superior or inferior relative to the velocity of the wave which is perpendicular on the lines of the electric field. The absolute phase difference Δ, between these two waves is proportional with the thickness *L* of the trespassed layer and with the quarter of electric field intensity *E*, according to the relationship:

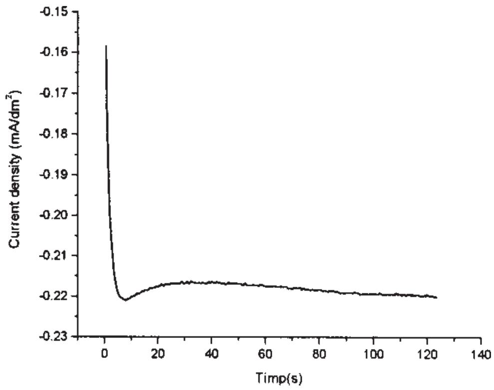
$$\Delta = KLE^2$$

where *K* is the Kerr constant, depending on incidental dielectric properties, temperature and frequency of the incident light.

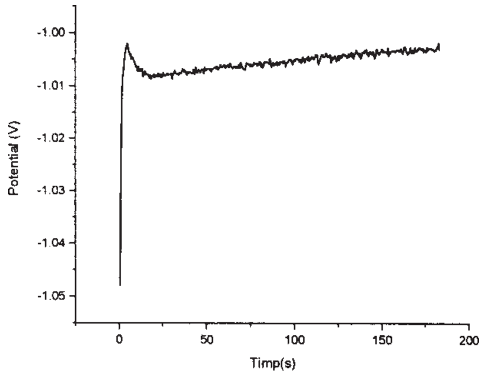
* email: violetav@usv.ro, violetaren@yahoo.com



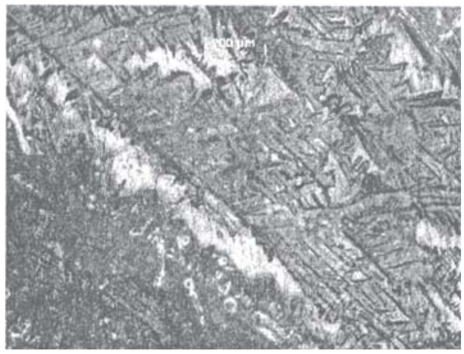
Polarization curve for the Watts bath, for the potentials interval from -100 mV to -1200 mV and 60°C temperature



Chronoamperogramme-chart recorded during nickel depositing for -900 mV potential, 60°C temperature with magnetic stirring of the electrolyte



Chrono-potential-chart recorded during nickel depositing for – 300 mA current intensity, 60°C temperature, with magnetic stirring of the electrolyte



The photo corresponding for nickel electrodepositing process without additives in Watts bath (optic magnitude 200X)

Fig. 1. Recorded data for nickel electrodepositing without additives and a photo of the electrodeposited nickel layer

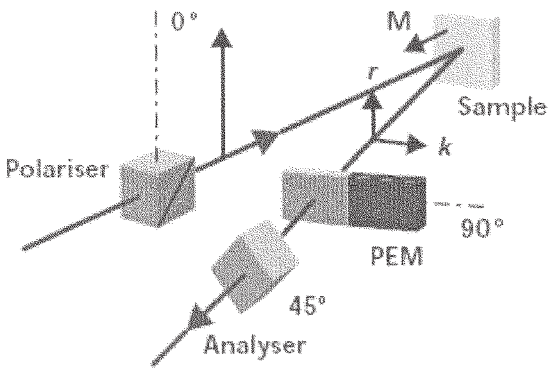


Fig.2. The polar Kerr effect – a phenomenological illustration

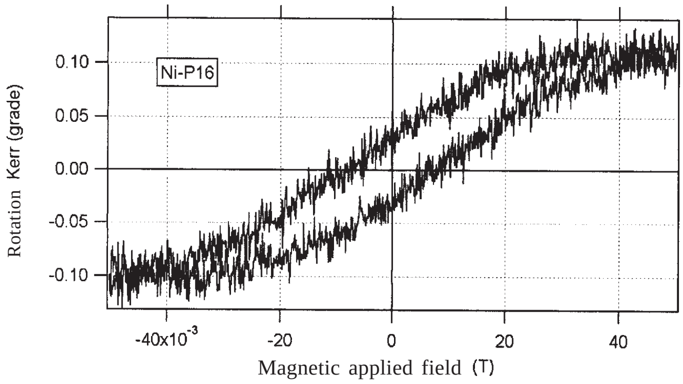


Fig.4. Magneto-optic hysteresis curve for a sample of nickel electrodeposited on copper substrate at -850 mV and 65°C temperature

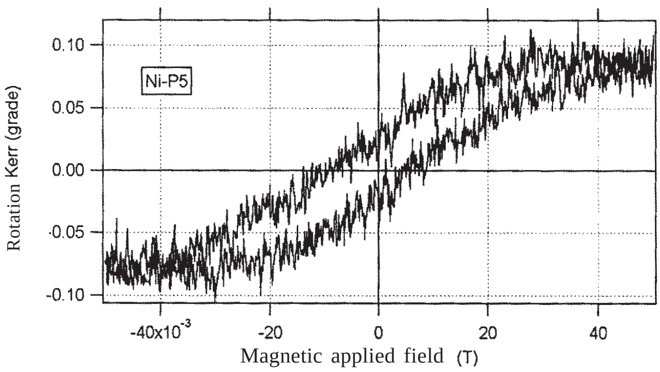


Fig.3. Magneto-optic hysteresis curve for a sample of nickel electrodeposited on copper substrate at -850 mV and 60°C temperature

The magneto-optic Kerr effect (MOKE) consists in a gentle rotation of the polarized light plane when this beam is reflected on a magnetized material (situated under the action of magnetic field). Both optic Kerr effect and MOKE have important practical applications, especially in memory devices building.

In figure 3 a magneto-optic hysteresis curve for a sample of nickel electrodeposited on copper substrate at -850 mV and 60°C is presented. The magnetic field was scanned between -0.05 T and +0.05 T. A maximum rotation of the plane of the polarized light of 0.09 degrees was achieved. When magnetic field is downing to 0 T , it was measured a remanence which imposes a plane rotation of 0.02 degrees.

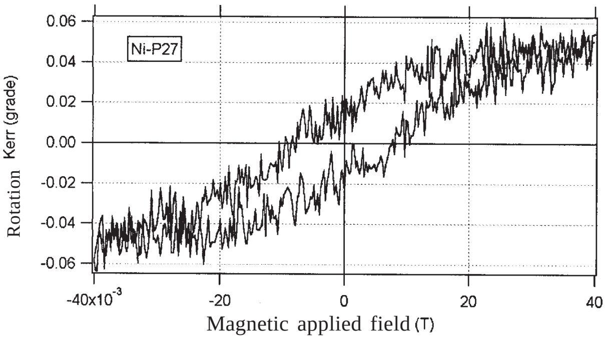


Fig.5. Magneto-optic hysteresis curve for a sample of nickel electrodeposited on copper substrate at -750 mV and 60°C temperature

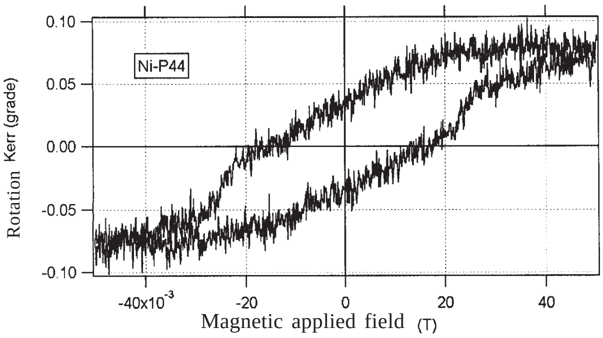


Fig.6. Magneto-optic hysteresis curve for a sample of nickel electrodeposited on copper substrate at -900 mV and 50°C temperature

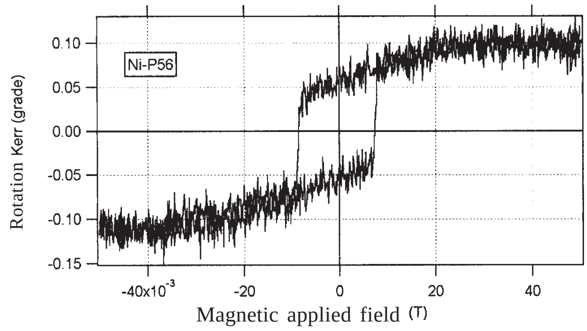


Fig.7. Magneto-optic hysteresis curve for a sample of nickel electrodeposited on copper substrate at -900 mV and 65°C temperature

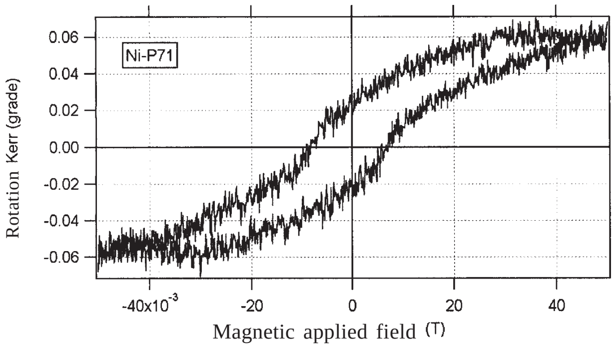


Fig.8. Magneto-optic hysteresis curve for a sample of nickel electrodeposited on copper substrate at -900 mV and 60°C

For a nickel sample electrodeposited on copper substrate at -850 mV and 65°C it was recorded the hysteresis curve presented in figure 4.

The magnetic field was scanned between -0.05 T and +0.05 T. It was achieved a maximum rotation of the polarized plane light of 0.10 degrees and a value of 0.03 degrees remanence when magnetic field is downing to 0 T.

For a sample prepared at -750 mV and 60°C, the magnetic field was scanned between -0.04 T and +0.04 T and it was obtained a maximum rotation of the polarization plane of 0.05 degrees with a remanence magnetization which imposes a rotation of 0.017 degrees when the magnetic field is downing to 0 T (fig. 5).

In figure 6 a magneto-optic hysteresis curve for a sample of nickel electrodeposited on copper substrate at -900 mV and 50°C is presented. The magnetic field was scanned between -0.05 T and +0.05 T. A maximum rotation of polarized light plane of 0.08 degrees was achieved. When magnetic field lacks (0 T), a remanence which imposes a rotation of the plane of 0.03 degrees was measured.

For the sample deposited at -900 mV potential at 65°C temperature it was recorded the graph chart presented in figure 7. For this part of investigation the induction of magnetic field was between -0.05 T and 0.05 T. A maximum rotation of polarized light plane of 0.10 degrees, with remanence magnetization at 0 T which produces a rotation of 0.05 degrees (fig. 7) was obtained.

The layer obtained under these conditions exhibits the marked magnetic properties.

For obtaining other kind of Ni layer, this metallic covering was deposited at -900 mV and 60°C. The figure 8 presents the dependence Kerr deflection on applied magnetic field B. The induction of magnetic field was between -0.05 T and 0.05 T consequently, and a maximum rotation of polarized light plane of 0.06 degrees, with remanence magnetization at 0 T which produce a rotation of 0.02 degrees was obtained.

Conclusions

The obtained nickel layers proved light magnetic properties so that further experiments will achieve better properties. The sample obtained at -900 mV and 65°C has better magneto-optic properties and the notable MOKE characteristics.In order to obtain nichel layers with magneto-optic usable properties, it is mandatory to work at the highest potentials and temperatures, as possible. A possible explanation is the higher orientation range of the microcrystallines structure which is produced in these conditions.

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