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# ELECTROPLATING OF NI-CO ALLOY IN A SODIUM CITRATE BATH ON BRASS AND STUDYING SOME EFFECTS ON THE LAYER THICKNESS AND HARDNESS.

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**Abstract:**
A nickel sulfate solution with a Co suspension was used to electroplate Ni-Co alloy coatings onto a brass substrate. The impacts of the plating bath's pH, temperature, length of time, nanoparticle concentration, and current density on the coating's composition were examined. The best conditions were (C.D. 2A/dm$^2$, 55$^o$C, 60 min, and pH 8) deposit surfaces were examined by X-ray diffraction thin film and Vickers microhardness. The surface hardness peaked at 2 A/dm$^2$ (278 HV), which is the greatest value possible. It is evident that more cobalt is deposited as the current intensity increases, raising the bath's cobalt concentration by more than 15 g/l. According to the results, the rate of Ni-Co deposition is affected by pH, rising from 7 to 9.5 while falling Co% at pH values over 7.5. At 33 °C, the layer deposition rate was 30 mg/dm$^2$.min, rising to 40 mg/dm$^2$.min at 63 °C, then dropping to 35 mg/dm2.min as the bath temperature increased to 73 °C. Low deposition rate and temperature were observed in cathodic deposits.

**Keywords** A nickel sulfate; Vickers microhardness; Yellow Brass; in sodium citrate bath; surface hardness

## 1. INTRODUCTION:

Metallic coatings can be divided into two categories based on whether they are protective or aesthetic, however, protection is the coating's primary function; aesthetic appeal is an optional extra. [1] Given the emphasis on plating's significance, he presented research on the introduction of a new, affordable, and environmentally friendly alkaline bath for depositing Ni-Co alloy plating on copper with the benefit of improved hardness. A cell with an electrolyte bath, a sample of copper acting as the cathode, and a pure nickel anode with an effective area of 100 x 50 x 10 mm was selected. the necessary wattage is supplied via a DC power source.

Cu Zn alloy sheets measuring 0.6 mm x 30 mm x 30 mm were the specimens used in the investigation. The samples underwent a quantitative analysis utilizing. Table (1) indicates the quantitative chemical analysis for the specimens (C27200) Yellow Brass

Table (1) Chemical analysis of the specimen (base metal)

| Cu | Pb | Fe | Zn |
|---|---|---|---|
| 63.5% | 0.07% | 0.07% | 36.36% |

The specimen was firstly degreased in Alcohol, then rinsed with distilled water and finally, it was pickled in hydraulic acid of (10% conc.) for five seconds to remove oxides and corrosion product on the outer surfaces of the specimens and rinsed with distilled water. The specimen electropolished for 2 minutes at 7 Volt. The specimen was then rinsed and dried with hot air and there it was ready for the electroplating process.

The plating bath used in the study was a sulphate-citrate bath. Table (2) indicates the content of the plating bath. The hardness of the deposited layer was increased using a plating bath with different concentrations.

Table (2) Nickel-Cobalt plating bath chemical composition using sodium citrate

| Bath Chemical composition | Content |
|---|---|
| Nickel Sulphate | 30g/l |
| Cobalt Sulphate | 4g/l-15g/l |
| Ammonium Chloride | 5g/l |
| Sodium Citrate | 120g/l |

## 2. Steps of the experiment:

The pH of the solution was measured during the preparation of the plating bath using a pH meter type PH315i (Germany). pH meter was calibrated following the manufacturer's instructions. An ammonium hydroxide solution was used to maintain the desired pH value.

The accurate current density was calculated depending on the total surface area of the substrate. The current density was 2-6 Am/dm2. A digital multi-meter was used to measure the current during the experiments with an accuracy of ± 0.01 A.

The bath temperature was kept at 55oC ±1oC during the experiments. A mercury thermometer was used to measure the temperature of the bath.

During all experiments, a magnetic stirrer was used for agitation of 250-300 rpm.

The obtained coating thickness was measured by taking a cross-section of a plated specimen and the coated layer was measured by optical microscope (neophyte 21, Germany).

The chemical structure of different coated specimens was determined by XRD analysis. The periodicity by which atoms are arranged in the lattice is specific for each phase.

XRD was performed in order to follow up on the surface structure and phase changes of the different specimens. Using an X-ray diffractometer with a copper target and nickel filter, selected specimens of each group were recorded.[2]

The composition of the deposited layer on the specimens was examined using the EDX technique. It is a method for determining the specimen's elemental composition or that of a specific part of it. Inside the scanning electron microscope, the specimen is subjected to an electron beam bombardment during EDX analysis.[3]

Fig 1. (XRD) Unit used measurement

Vickers microhardness test of the deposit was measured under load 10 grams for 15 seconds using Shimdsu Hardness tester see Fig 2. The average of the two-diameter length of the diagonal was measured and consequently, the microhardness value in HV was obtained automatically by the hardness tester.[4]

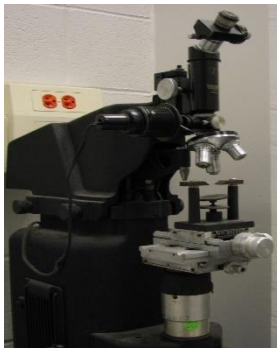

Fig 2. Vickers microhardness

## 3. RESULTS AND DISCUSSION:

### Effect of Change of deposition rate with current density in sodium citrate bath

The average deposition rate with a current density variation from 2 to 6 A/dm$^2$ in (mg/dm$^2$.min) is shown in Fig 3. Deposition rate values rose from 18 mg/dm$^2$/min at current density 2 A/dm$^2$ to 51 mg/dm$^2$/min at current density 6

A/dm$^2$, while bath temperature was maintained at 55 °C, pH 8, and time 60 min at 4 g/l Co. It is obvious that the deposited weight increased as the current density increased from 2 to 6 A/dm$^2$.

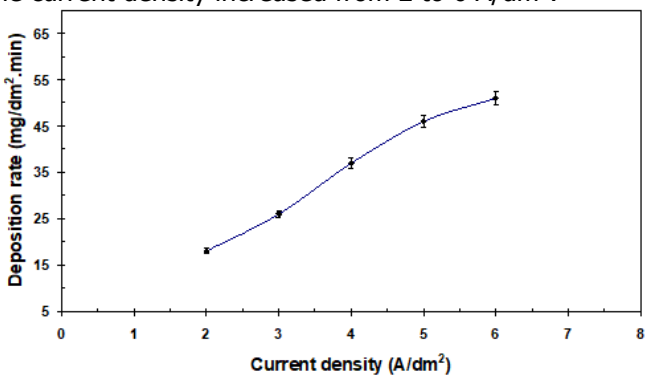


Fig 3. Current density's impact on the rate of sodium citrate bath deposition

## Effect of time on coating thickness in sodium citrate bath

Figure. 4 illustrates how the coating thickness changes over time. The bath temperature was held at 55°C, pH at 8, current density 4 A/dm$^2$, and the time change from 15 min. to 120 min. It is clear that the deposited film thickness increased as the time increased almost linearly. These results agree with the results according to Faraday laws.

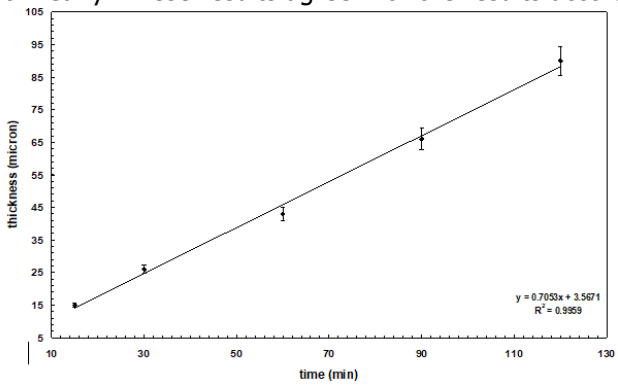


Fig 4. Coating variation Ni-Co coating thickness shown over time, pH = 8, current density = 4 A/dm$^2$, and temperature = 55 °C

## Effect of temperature on deposition rate in sodium citrate bath

Figure 5. illustrates how the rate of deposition changes as temperature rises. The bath's pH was maintained at 8, its 4A/dm$^2$ current density was applied for 60 minutes, and it went from 33°C to 73°C in temperature. The temperature increased. to 73°C, the rate of the deposited layer decreased to 35 mg/dm$^2$.min. Figure 5. shows the dependence of the alloy composition on bath temperature and electrolyte jet speed [5]. As the bath temperature rose, a slower rate of deposition in the cathodic deposit was noticed. According to Guiying et al.'s findings [6],

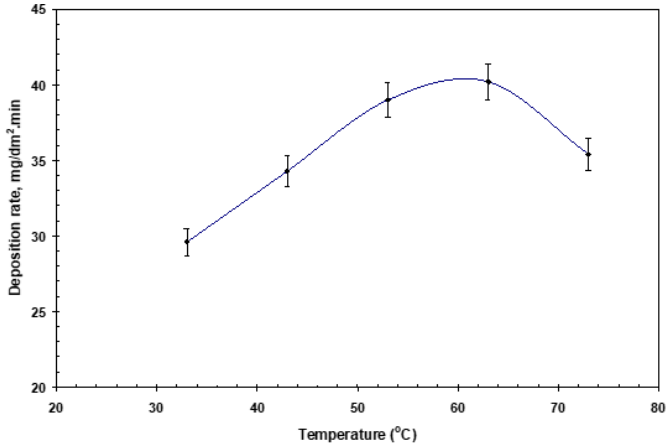


Fig 5. Effect of temperature on deposition rate wt % in (pH 8, C. D= 4A/dm$^2$, time=60min)

## Effect of the bath's Co content on the amount of Co deposited in the sodium citrate bath

The variation in Co content in Ni-Co alloy coating according to concentration is depicted in Fig 6. The bath was maintained at 55 °C, pH 8 for 60 minutes, and 2 A/dm$^2$ of current density. The fig displays how adding cobalt to the nickel bath affected the result. Cobalt content in the deposit rises as cobalt concentration does. based on the outcomes

discovered by D. Golodnitsky et al. [7]. The EDX study showed that the rise in Co percentages in the bath greater than 15 g/L resulted in practically constant Co content. This is connected to the idea that more particles are available for adsorption at the cathode as the bath is loaded up.

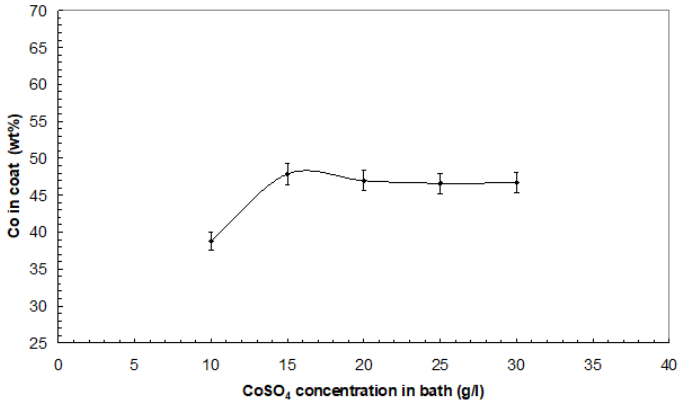


Fig 6. Relationship between particle concentration in the bath and Co in deposit.

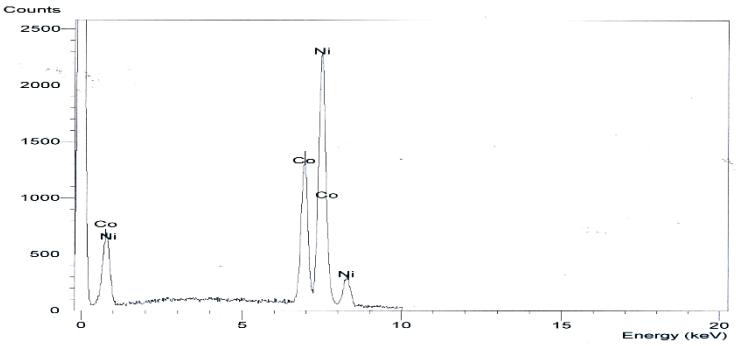


Fig 7. Chemical analysis using electron dispersive X-rays (EDX) for Co 10 g/l at 10 and 20 kV acceleration voltages

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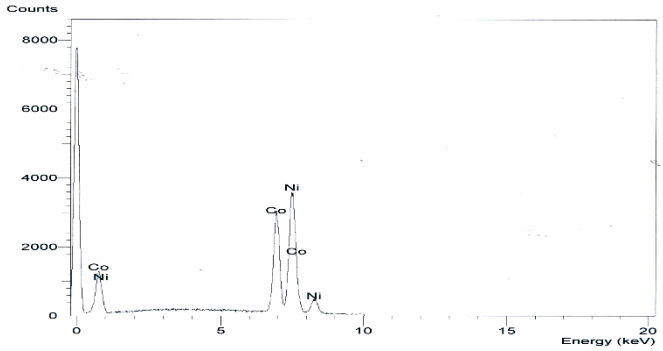


Fig 8. Chemical analysis using electron dispersive X-rays (EDX) for Co 15 g/l at 10 and 20 kV acceleration voltages.

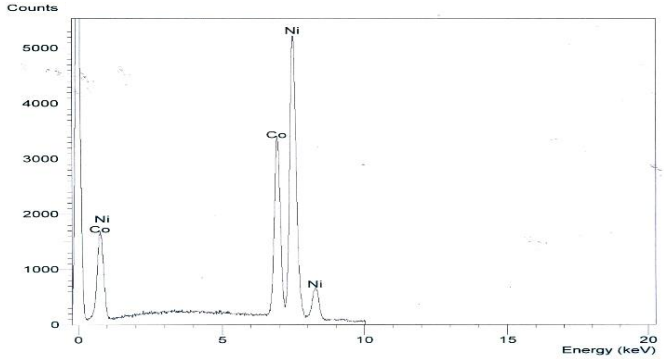


Fig 9. Chemical analysis using electron dispersive X-rays (EDX) for Co 20 g/l at 10 and 20 kV acceleration voltages.

## Effect of pH in sodium citrate bath

A key factor in the co-deposition process is the electrolyte's pH level. Figure 10. depicts how pH affects the rate of deposition. The findings showed that for a solution of 4 g/l Co, 55 °C, and a 4 A/dm$^2$ current density, the rate of Ni-Co deposition increased with rising pH from 7 to 9.5. As seen in Fig11., the Co% decreased as the pH was raised above 7.5.

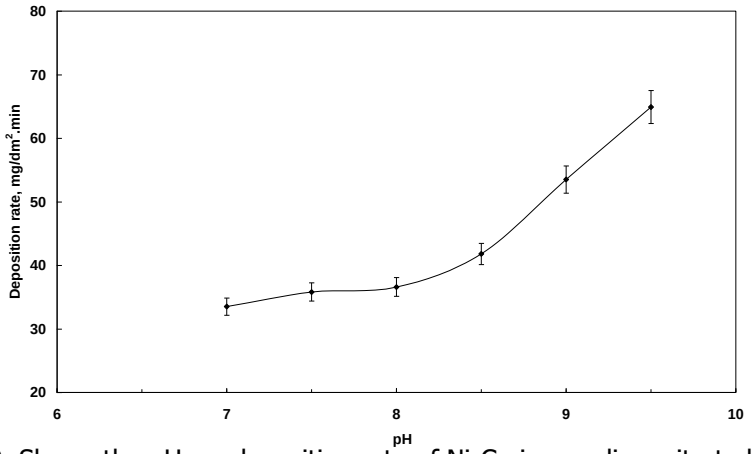


Fig.10. Shows the pH vs. deposition rate of Ni-Co in a sodium citrate bath. (C. D= 4A/dm$^2$, time = 60 min, and temp = 55°C).

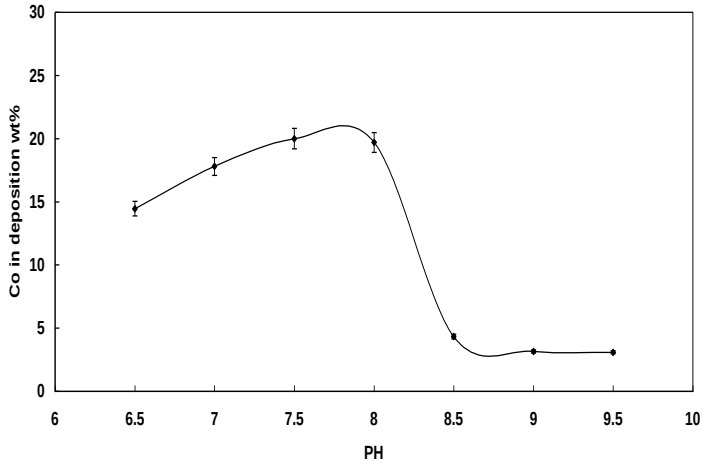


Fig 11. Shows the pH vs. Co% content in deposition (C.D = 4A/dm$^2$, time = 60 min., and temp = 55°C)

## Hardness measurements in sodium citrate bath

Fig.12. demonstrates how the microhardness varies. Of the coated samples with current density [8]. The bath temperature was held at 55°C, pH at 8, and time 60 min. and the current density change from 2 to 6 A/dm$^2$. The microhardness test was conducted on the surface and was taken as the average of 5 readings to represent the surface[9]. Coating the brass with Ni-Co has increased its surface hardness from 130 HV (brass substrate) to 278 HV. the same figure. indicates that the greater value of surface hardness was at the current density of 2 A/dm$^2$. It slightly decreases to 251 HV with increasing current density to 6 A/dm$^2$.

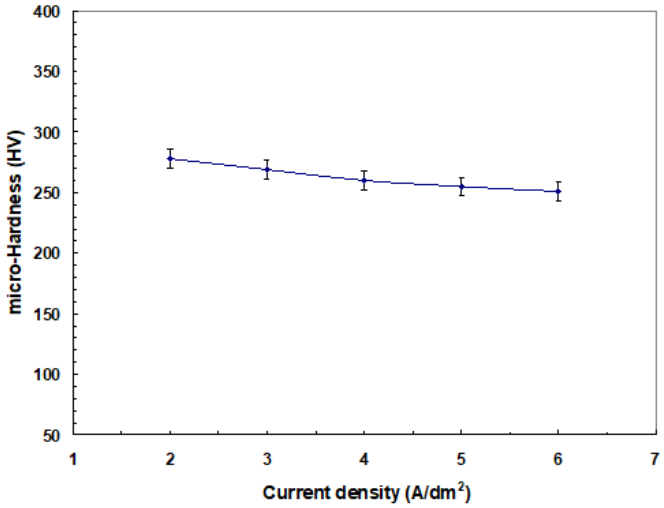


Fig 12. Current density's effect on the microhardness of a Ni-Co alloy coating

## 4. CONCLUSIONS

1. The deposition rate values increased from 18 mg/dm2/min at current density 2 A/dm$^2$ to 51 mg/dm$^2$/min at current density 6 A/dm2 when the bath temperature, pH, and time at 4 g/L Co were maintained at 55°C, 8°C, and 60 min, respectively. Evidently, greater weight was deposited as current density rose.
2. According to the EDX study, the amount of cobalt is nearly unchanged but the percentage of cobalt in the bath has increased by more than 15 g/L. This is connected to the fact that a rise in bath loading increases the quantity of particles available for cathode adsorption.
3. The results showed that for a solution of 4 g/l Co, 55°C, and 4 A/dm$^2$, the deposition rate of Ni-Co increases with increasing pH from 7 to 9.5 and that raising the pH over 7.5 decreased the Co%.
4. The brass substrate's surface hardness rose from 130 HV to 278 HV after obtaining a Ni-Co coating. At a current density was 2 A/dm$^2$, the surface hardness was higher. increasing the current density to 6 A/dm$^2$, it marginally decreases to 251 HV.

## REFERENCES


1. Arthur. A. Tracton, "Coatings Materials and Surface Coatings", CRC Press, (2007)
2. Mahmoud, S. S., & Ahmed, M. M. (2009). Electrocatalytic oxidation of phenol using
3. Ni–Al2O3 composite-coating electrodes. Journal of alloys and compounds,
4. 477(1-2) 570-575.
5. Olivella, M. A., Palacios, J. M., Vairavamurthy, A., Del Rıo, J. C., & De Las Heras, F. X. C. (2002). A study of sulfur functionalities in fossil fuels using destructive- (ASTM and Py–GC–MS) and non-destructive- (SEM–EDX, XANES, and XPS) techniques. Fuel, 81(4), 405-411.
6. Jönsson, B., & Hogmark, S. (1984). Hardness measurements of thin films. Thin solid films, 114(3), 257-269.
7. Qiao, G., Jing, T., Wang, N., Gao, Y., Zhao, X., Zhou, J., & Wang, W. (2005). High-speed jet electrodeposition and microstructure of nanocrystalline Ni–Co alloys. Electrochimica Acta, 51(1), 85-92.
8. Guiying Qiao, Tianfu Jing, Nan Wang, Yuwei Gao, Xin Zhao, Jifeng Zhou, and Wei Wang, "High-speed jet electrodeposition and microstructure of nanocrystalline Ni-Co alloys", Electrochimica Acta 51 (2005) 85-92.
9. D. Golodnitsky, Yu. Rosenberg and A. Ulus "The role of anion additives in the electrodeposition of nickel-cobalt alloys from sulfamate electrolyte", Electrochimica Acta 47 (2002) 2707-2714.
10. Zhang, Q., Tan, J., Meng, L., Xie, F., Zhao, H., & Yan, Z. (2019). Preparation of Co-Ni Alloy Coating with Stable Composition by Jet-Electrodeposition. Applied Sciences, 9(24), 5545.
11. Saleh, M. S., Fadiel, A. F. A., & Khalida, H. M. Corrosion Rate Study of AZ91C Magnesium Alloy in Sodium Chloride Solution of Different Concentrations Using Immersion Method for Coated and Uncoated Samples1.