RECTANGULAR WAVE CURRENT EFFECT ON PLATED NICKEL HARDNESS

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Abstract— **Effects of frequency, average current density and duty cycle on hardness of electroplated nickel were studied in Watts and sulphamate solutions by mean of direct and rectangular pulse current. The results in Watts solutions show high hardness values at low duty cycles, high average current density and high frequency of the pulse current. Hardness in nickel sulphamate solutions shows a low variation with duty cycle and frequency changes. Hardness values obtained in the Watts bath with rectangular pulse current are higher than those achieved with direct current at the same average current density. In the sulphamate bath this difference has not significance.**

Keywords— **Pulse current, Hardness, electroplating, Nickel.**

I. INTRODUCTION

Nickel is a metal with good abrasion and corrosion resistance. This characteristic allows its electro-deposits to have applications in the engineering field where the functional behavior, rather than the appearance, is the main required attribute

Early, nickel deposits applications were associated with works of art replicas manufacture, but at the present time they are used in the aerospace industry, in the manufacture of intricate guides, in production of compact and video disks and micro-components for the electronics industry.

Recently, research has begun to focus over these electro-deposits hardness and grain size. It is broadly accepted that the hardness is a parameter that provides an appropriate indication of the material strength, wear and abrasion resistance.

One recently proposed way to increase the nickel deposits hardness is the use of pulse current waveforms. This has driven remarkable improvements in properties like internal stress, elongation, corrosion resistance and hardness, among others. Additionally, it was been found that this technique decreases the energy costs as well as the raw material quantity needed to improve the deposits hardness (Chen and Wan, 1989).

It is known that the waveform, frequency, duty cycle and the peak current density produce remarkable changes in the electro deposits properties (Durney, 1984).

Most of the published works with pulse current waves for nickel electro deposits have been made using nickel sulphate baths (commonly referred as Watts baths) and in nickel sulphamate baths. Initially, Ping *et al.* (1979), established that with higher peak current densities, greater over potentials are generated, which favors the new nuclei formation, instead of the crystals growth, therefore producing deposits with finer grain size in nickel sulphamate baths when using pulse waves. They also report increases in the hardness when increasing the frequency in Watts baths.

Later on, El-Sherik *et al.* (1996) obtained nickel deposits with grain size below 100 nanometers obtained from Watts solutions free of organic additives using pulse current.

Devaraj and Seshadri (1996) report that using rectangular pulse current in nickel sulphate baths, deposits with soft surfaces that contain smaller pores, free of fractures, with decreased grain size and reduced tension stress are obtained with the hardness improvement at low duty cycles (10%) and low frequencies (smaller than 10Hz).

Improvements in the hardness of nickel electrodeposits were obtained in sulphamate solutions using several types of current waveforms: rectangular, rampup, ramp-down and triangular (Wong *et al.*, 2000), being achieved the highest hardness values with the ramp-down waveform and the lowest with continuous current.

It has also been reported that the deposits hardness using pulse current is significantly higher than the one obtained with direct current, at the same average current density (Qu *et al.*, 2003).

Tang *et al.* (2004) found that electrodeposition with pulse current produces deposits with more fine, more compact grain sizes, of lower porosity and with better substrate adherence. Additionally they show an increase in the plating rate and in the current efficiency with this technique. These experimentations in Watts baths showed an improvement in the hardness with the use of pulse current with frequencies above 40 Hz.

It is interesting to note that although there is an agreement about the benefit of using pulse current, there is not a clear conclusion about whether the hardness of deposits improves with high frequencies or not. Some propose low frequency (smaller than 10 Hz) and others propose high frequency (greater than 40Hz).

This article aims to study the effect of the rectangular current waveform on the nickel deposits hardness. Specifically, the article seeks to determine the effects associated to the pulse frequency, the average current