trusion will grow under spherical diffusion control resulting in a needle deposit. The growth of needles is possible only if r_c is reached before the overlap of growing grains begins. After the beginning of the overlap of growing grains diffusion to the macroelectrode becomes the rate determining step, and considerable changes in morphology are not expected during the establishment of steady-state conditions [6]. At the same time the maximum difference in the height of points on the electrode surface will be lower than the grain tip radius and deposition to the grain will be controlled by linear diffusion because

$$\frac{nFDC_0}{\delta} > \frac{nFDC_0}{r}\frac{h}{\delta} \qquad (25)$$

In this way the conditions suitable for dendritic growth initiation are established [7] which results in dendrite formation as illustrated by Figs. 1c, d.

Hence, the minimum overpotential at which needles can still be formed is determined from the relationship

$$N_0\,[1 - \exp(-At_i)] \leqslant \frac{1}{(2r_c)^2} \qquad (26)$$

At lower overpotentials (not lower than η_1) dendrites will be formed. It is to be noted that the same situation appears in deposition on a cadmium substrate [2, 3]. This is probably due to the same reasons as in the deposition on foreign substrates, because the deposit does not replicate the original substrate as can be seen from Figs. 4, 11 and 13 in Reference 3.

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SHORT COMMUNICATION

Scanning electron microscopic study of some nickel electroplates

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1. Introduction

Electrodeposition of bright nickel using organic brighteners has been the subject of much research [1–4]. Some of the recent publications correlate the surface irregularities and surface roughness to brightness of electroplate. For example Weil and Paquin [1] and Weil [4] have reported that the bright electroplates do not have extensive irregularities or well-developed facets on their surface. The investigations carried out in our laboratory also show that the bright electroplates are smooth [5]. The present investigation was undertaken to study the surface topography of nickel electroplates obtained in the presence and absence of combination of brighteners using both standard SEM and a Y-modulation technique [6] to show the difference in the information provided by the two types of display.

2. Experimental details

The composition and pH of the Watts bath used and the other experimental conditions were the same as reported earlier [5]. Sodium benzene sulphonate was prepared and purified by the method of Vogel [7]. Acrylamide (SD, LR) was purified by recrystallization from chloro-

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form. The nickel electroplates of thickness about 32 μm, obtained at 55° C and a current density of 5.2 A dm^{-2} were examined by a Philips (Holland) 500, Scanning Electron Microscope.

3. Results and discussion

The SEM pictures of the electroplates obtained in the absence of brighteners and in the presence of a combination of brighteners are presented in Fig. 1. In the absence of any brightener, the electroplate obtained from the Watts bath has a rough surface (Fig. 1a). The Y-modulation picture of such electroplate leads to a better appraisal of the roughness (Fig. 1b). It is well known that the difference in the rates of growth of different crystallographic faces leads to the formation of texture and roughening of the electroplates [8]. It has also been reported by us [5] that the electroplate obtained from the Watts bath in the absence of any brightener, at 55° C and a current density of 5.2 A dm^{-2} had a preferred orientation. From Fig. 1b it is clear that the electroplate obtained from the Watts bath has roughness greater than the wavelength of visible light. Hence such electroplates scatter more light and appear dull.

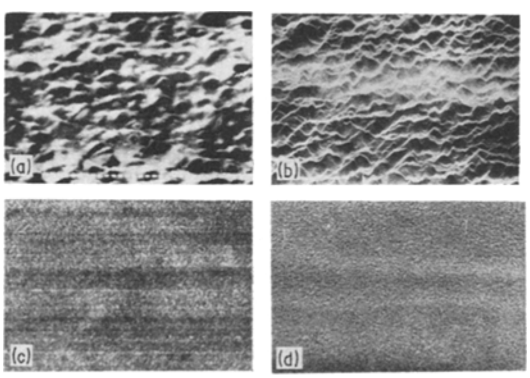

Fig. 1. Scanning electron micrographs of electroplates obtained from the Watts bath in the presence and absence of brighteners: (a) the electroplate from the Watts bath with no brightener at an angle of tilt, 60° (X 800); (b) the Y-modulation picture of Fig. 1a; (c) the electroplate from the Watts bath with 24 g l^{-1} of sodium benzene sulphonate and 1.5 g l^{-1} of acrylamide at an angle of tilt, 60° (X 1600); (d) the Y-modulation picture of Fig. 1c.

However, the very bright nickel electroplate obtained in the presence of the combination of acrylamide with sodium benzene sulphonate has a very smooth surface (Fig. 1c). The Y-modulation picture of such electroplate does not show any surface irregularity (Fig. 1d). This observation suggests that the presence of acrylamide along with a Class I brightener through a synergetic effect promotes the adsorption of Class I brightener on quickly growing crystal faces of the deposit and equalizes the growth rates of different crystal faces. Because of this, the electroplate is also free from preferred orientation [9] and is very smooth and free from surface irregularities.

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