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Short Communication

Effect of ultrasonic agitation on surface finish of electrodeposits

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Use of ultrasonics during electrodeposition has been carried out to obtain the smoother deposits and to improve its hardness. A comparison has been made between the deposits obtained from a still bath and an ultrasonically agitated bath. The surface finish of the deposited samples has been studied using a perthometer.

Conservation of materials is today receiving a great deal of attention from many industries. The field of surface finishing is no exception to this rule and the electroplater must constantly strive to increase output and reduce unnecessary costs. Although metallic coatings help conserve large quantities of steel and non-ferrous metals in a broad sense, present day plating processes also lead to a considerable wastage of metals. Since plating time is money involved, in direct proportion, any reduction in the processing time is advantageous. Many modern plating solutions use agitation in one form or another to improve the conditions of operation. Ultrasonic agitation of the plating solution is a more recent entrant to this field.

Ultrasonic waves when passed through an electrolyte produce rapidly alternating regions of high and low pressure. Since liquids generally have a low tensile strength, its particles are actually "pulled apart" or fractured into thousands of tiny cavities. These cavities explode with great force, concentrated over many small areas. The pressure developed could sometimes be as high as 1000 atm.[1], the net result is agitation of an extremely intense nature, much more thorough than is possible by any other agitation methods.

The beneficial effects of ultrasound during electroplating have been studied over the last few decades. Plating in an ultrasonic field has been found to increase the cathodic current efficiency in the plating of copper[2,3], chromium[4], gold[5] and zinc[6]. The hardness of copper deposits is found to increase in an ultrasonic field[7]. Residual stresses of nickel electrodeposits are lower when plated in an ultrasonically agitated bath[8]. The grain size is reduced and the limiting current density is increased for copper electrodeposition when the bath is agitated ultrasonically[9]. The beneficial effects of ultrasound during nickel electroplating are obtained even at room temperature though the temperature is to be raised upto 60°C in conventional methods of plating[2].

In the present work, nickel, tin and zinc were selected to study the improvement in the nature and quality of the respective deposits when plated in ultrasonically agitated bath.

Experimental procedure—Nickel, tin and zinc were electrodeposited on mild steel (0.18%C) using a Watts nickel bath, a tin fluoborate, bath and an acid zinc bath, respectively, in still and ultrasonically agitated conditions. The composition and operating conditions of these baths are shown in Tables 1-3, respectively.

Table 1—Composition and operating conditions of nickel plating bath

Nickel sulphate, $NiSO_4.7H_2O$	250 gL^{-1}
Nickel chloride, $NiCl_2.6H_2O$	50 gL^{-1}
Boric acid, H_3BO_3	45 gL^{-1}
Current density	40 $mAcm^{-2}$
Temperature for still bath	60°C
Temperature for ultrasonically agitated bath	25°C
*p*H	4.0

Table 2—Composition and operating conditions of tin plating bath

Tin fluoborate, $Sn(BF_4)_2$	200 gL^{-1}
Fluoboric acid, HBF_4	53 gL^{-1}
β-Naphthol, $C_{10}H_7OH$	1 gL^{-1}
Gelatin	6 gL^{-1}
*p*H	0.2
Current density	40 $mAcm^{-2}$
Temperature	25°C

Table 3—Composition and operating conditions of zinc plating bath

Zinc chloride, $ZnCl_2$	71 gL^{-1}
Potassium chloride, KCl	207 gL^{-1}
Boric acid	35 gL^{-1}
Dextrin	3 gL^{-1}
Current density	35 $mAcm^{-2}$
Temperature	25°C
*p*H	4.5

The samples were tested for microhardness in a Leitz microhardness tester using a 50 g load. At least six values were determined at different regions of the coated specimens and the average taken. Care was taken to ensure that the thickness was sufficient for the indentation produced during testing.

The characteristic surface roughness for each plated specimen was measured by a perthometer (Perthon S5P). It is an electromechanical device wherein a stylus passes across the surface and follows the contour of the surface to trace the irregularities. This is fed into an amplification system and then to a device that records the amplitude of the surface irregularities.

Table 4—Microhardness of electrodeposits

Deposits	Bath condition	Microhardness (VHN_{50})
Nickel	Still bath	247
Nickel	Ultrasonic bath	344
Zinc	Still bath	68
Zinc	Ultrasonic bath	72

Results and discussion

Microhardness—Table 4 shows the microhardness of electrodeposits. The microhardness of tin deposits alone was so low that it could not be measured with the available facilities. It is obseved that the use of ultrasonics during electroplating increased the microhardness. This increase in hardness is considered to be due to the cavitation that results in shock waves which deform and harden the metal surface[10]. A finer grain size as well as a reduced porosity in the plated surface due to ultrasonic agitation are also the likely reasons for the enhanced microhardness.

Surface topography—Figs 1-3 show the scanning electron micrographs of nickel, tin and zinc electrodeposits, respectively. There is a marked difference between a conventional plating and an ultrasonic plating. The grain refinement of nickel in an ultrasonically agitated bath gave a smooth finish to the plated surface. Electrodeposition of tin from a

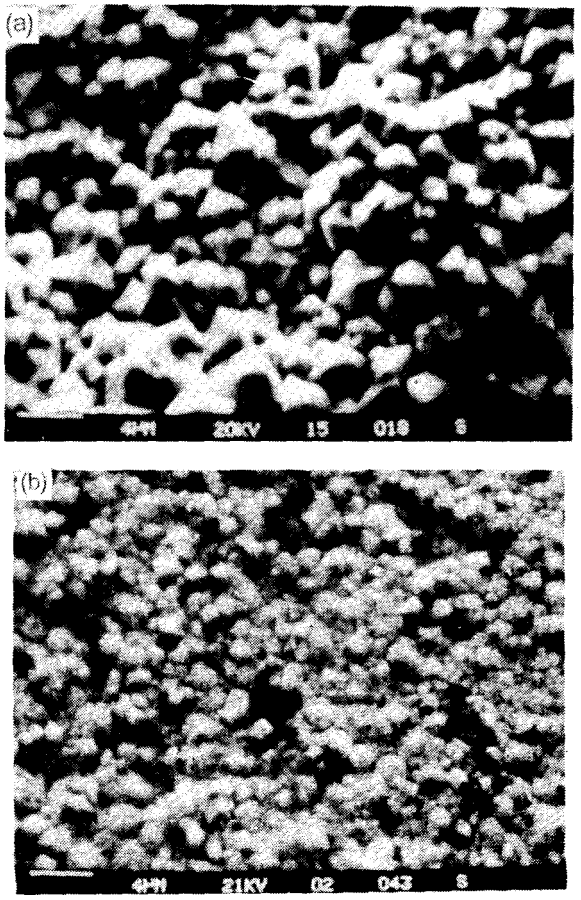

Fig. 1—Scanning electron micrographs of nickel electrodeposits (a) still bath, (b) ultrasonically agitated bath

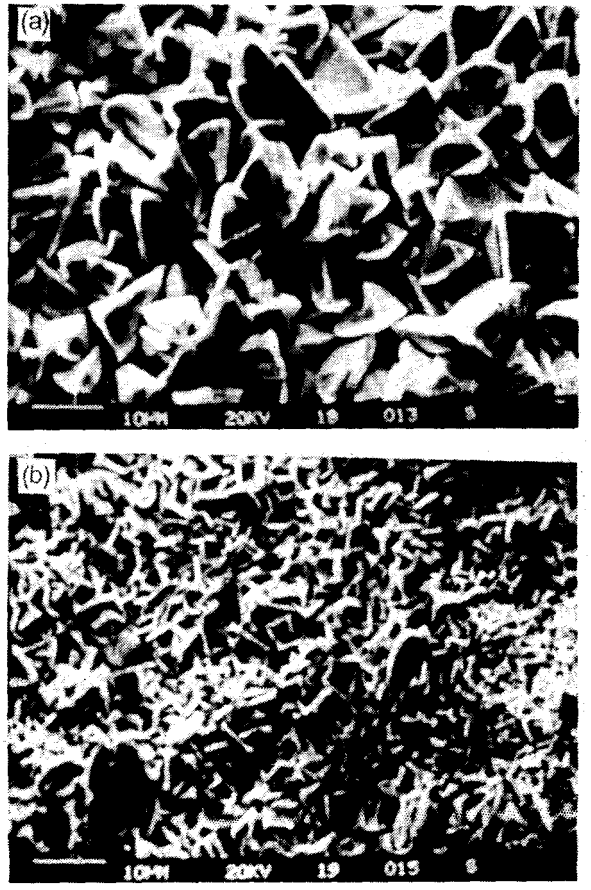

Fig. 2—Scanning electron micrographs of tin electrodeposits (a) still bath, (b) ultrasonically agitated bath

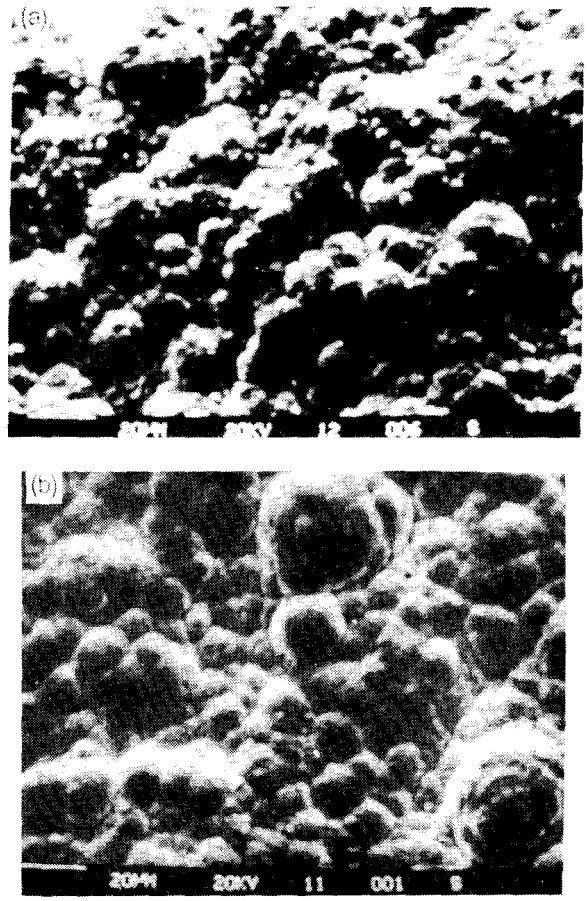

Fig. 3—Scanning electron micrographs of zinc electrodeposits (a) still bath, (b) ultrasonically agitated bath

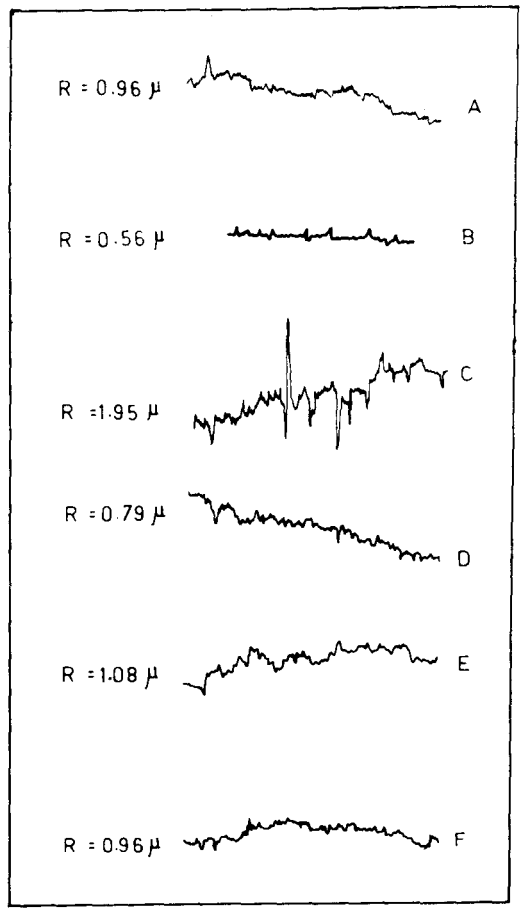

Fig. 4—Perthometer traces for electrodeposits (A) nickel plating-still bath, (b) nickel plating-ultrasonically agitated bath, (C) tin plating-still bath, (D) tin plating-ultrasonically agitated bath, (E) zinc plating-still bath, (F) zinc plating-ultrasonically agitated bath

fluoborate bath in a still bath gave a porous deposit. It is apparent that there is a change in morphology showing needle-like structure. A smoother surface is also observed in case of zinc plated from an ultrasonic field.

Fig. 4 shows the pethometer traces of various electrodeposits. The paramter R_a gives an idea of surface roughness of deposits, a higher R_a indicating a greater surface roughness. Here again an ultrasonically agitated bath gave smoother deposits. However, this effect is not pronounced in the case of zinc plating.

Ultrasound is considered to be instrumental in the removal or inhibition of the growth perpendicular to the growing deposit surface thus encouraging a lateral or a two-dimentional rather than a three-dimentional growth.

Conclusion—The use of ultrasonic agitation during electrodeposition leads to smoother and harder deposits.

References

1 Kenneth S Suslick, *Sci Am*, 260 (1989) 62.
2 Vasudevan R, Devanathan R & Chidambaram K G, *Met Finish*, 90 (1992) 23.
3 Upsensky S I & Shluger M A, *Electrokhimiya*, 2 (1966) 243.
4 Ginberg A M, Nudga V N & Perrov Yu N, *Sov Electrochem*, 3 (1967) 698.
5 Urdsel L, *Trans Inst Met Finish*, 44 (1966) 161.
6 Anon, *Met Ind*, 103 (1963) 622.
7 Walker C T & Walker R, *J Electrochem Soc*, 124 (1977) 661.
8 Prasad P B S N V, Vasudevan R & Seshadri S K, *J Mater Sci Lett*, 11 (1992) 1223.
9 Chiba A & Wu W C, *Plat Surf Finish*, 79 (1992) 62.
10 Walker R, *Trans Inst Met Finish*, 53 (1975) 40.