

# Structure and Wear Resistance of Brush Plated Nickel

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## INTRODUCTION

The properties of engineering components are to a great extent determined by their surfaces. The surface constitutes the boundary between a part and its environment, and suffers especially from wear and corrosion. Surface layers can protect the component or, when damage has already happened, make it functional again. Methods for providing surface layers are numerous, and include techniques such as physical and chemical vapour deposition, nitriding, electron beam and laser treatment, spray metallizing as well as bath plating.

In recent times another technique, called selective plating or brush plating, has reached industrial maturity and is gaining more attention. A principle used for decades to repair defects on bath plated deposits, namely the localised application of a current through a electrolyte containing pad, has been developed into a practical metal application tool. Its combination of deposit and process characteristics makes it suitable for many applications where other techniques do not produce the desired results, are impractical or are simply too cost intensive.

## SELECTIVE PLATING

### Basic Principles

Selective plating, also known as brush plating or electrochemical metallizing, is a process similar to a combination of arc welding and bath plating in that the process is based on electrodeposition but its application is localised on a similar scale to the arc welding process.

The electrodeposition of a metal or alloy to a confined surface area is achieved by continuous movement ('brushing') of an anode, covered with an absorbent material (anode-wrap) soaked with the electrolyte, over the surface of the workpiece. The anode is connected to the positive and the workpiece to the negative outputs of a power pack rectifier modified for the needs of the process. When anode and workpiece are in contact, the electrical current permits the flow of metal ions from the solution in the anode wrap to the surface of the workpiece, thus creating a build up of metal in this area. Figure 1 shows a schematic diagram of this process.

The movement of the anode is necessary to get fresh solution to the contact area and to ensure an even deposition. Alternatively, the workpiece can be moved relative to a stationary anode, as practised when plating a round bar.

At regular intervals the anode is replenished with plating solution, in the simplest case by immersing it into the electrolyte. In the majority of industrial applications, however, the solution is supplied by a small pump, thus avoiding any interruption of the plating process ('flow through'-plating).

In order to plate only small areas, for instance in repair jobs, selective plating is relatively straightforward. Disassembling and masking of the component is hardly necessary, as the rest of its surface will not be affected by the plating solution and vice versa, and there is no limitation to the size of the workpiece. In addition, selective plating is a mobile process.

Hydrogen embrittlement is reported to be less severe in selectively plated deposits, the deposits tend to be denser, and adhesion is equally good as with conventional bath plating. On some metals, such as high alloy steels, chromium, and aluminium, better results have been achieved with selective plating<sup>1</sup>. It should be mentioned, however, that those results were obtained using relatively expensive proprietary equipment and solutions. Selective plating is also highly labour intensive, since, with few exceptions, all steps are carried out manually.

## MATERIALS AND EQUIPMENT

### (a) Solutions

Generally the solutions for selective plating can be divided into 3 classes, according to their purpose.

*Preparatory solutions* are cleaning and activating solutions, used to remove contaminants and to activate the surface in order to achieve good adhesion. Some of these solutions require the use of reverse direction current.

*Bonding solutions* are applied when the original bond strength between substrate and deposit would be insufficient. A thin layer of a bonding metal, usually less than 3 microns in thickness, is deposited for that purpose. It may also be necessary to prevent intermetallic diffusion between workpiece and deposit or, in some cases, corrosion of the work material by the plating solution.

Finally, *Build-up solutions* are used to obtain a deposit of the desired thickness of the chosen metal. In comparison with bath plating, the build-up solutions for selective plating contain a significantly higher concentration of metal salts. This permits the use of higher current densities

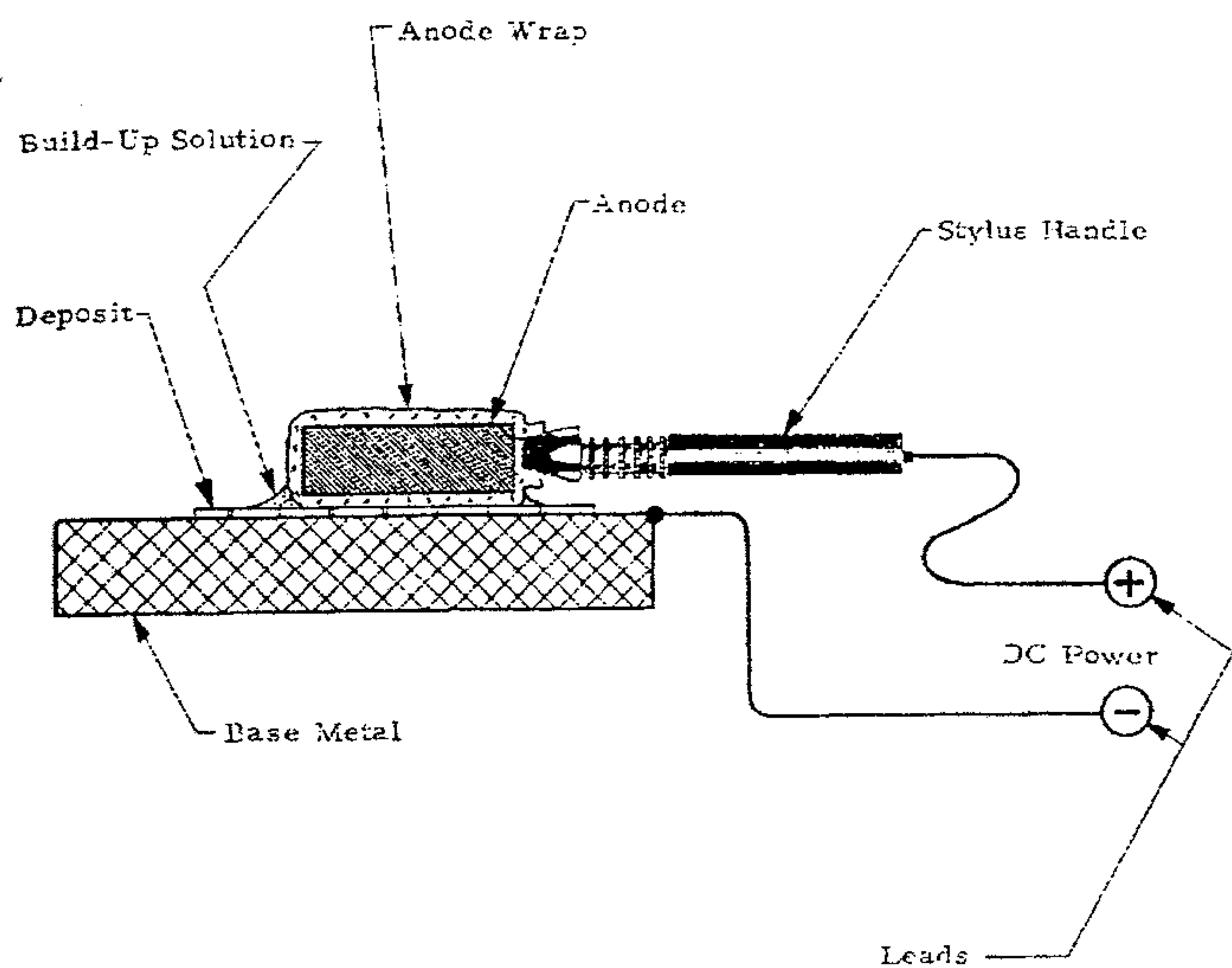


Figure 1. Brush Plating (schematic).

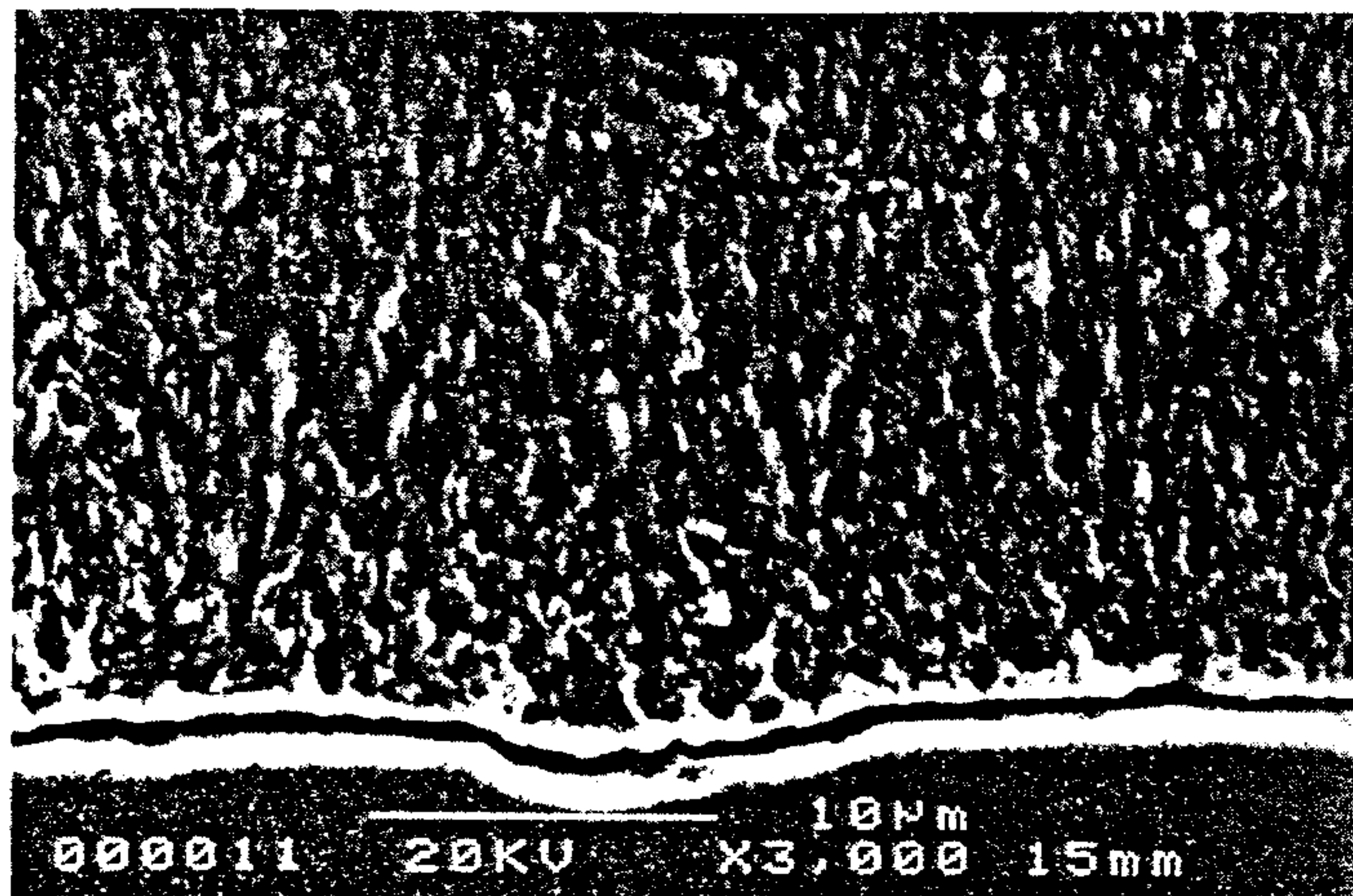


Figure 2. Nickel deposit plated with 100% anode coverage and 'flow through' (x1700, Etch: Kallings' Reagent).

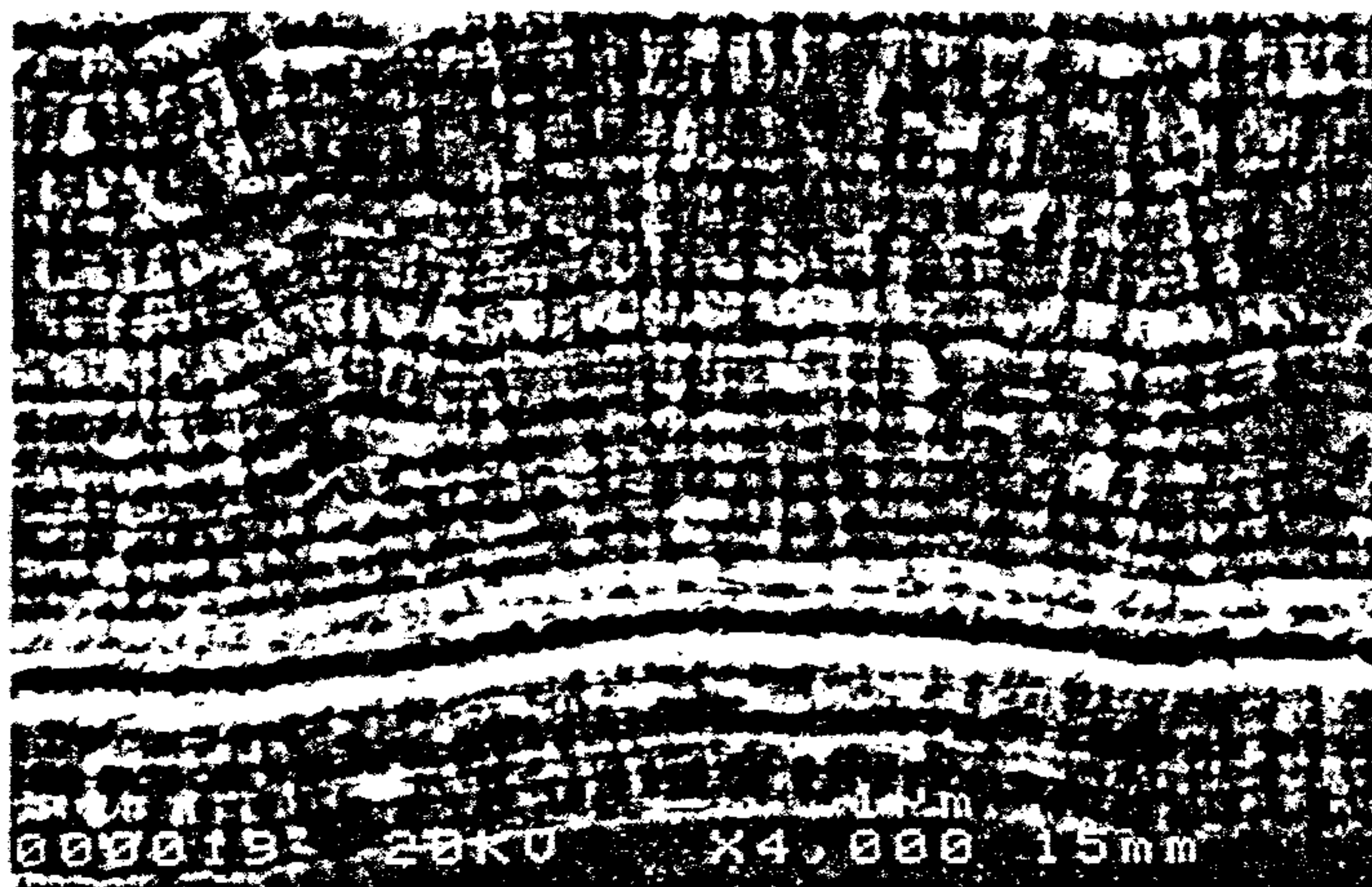


Figure 3. Nickel deposit plated with 100% anode coverage and manual dipping (x2400, Etch: Kallings' Reagent).

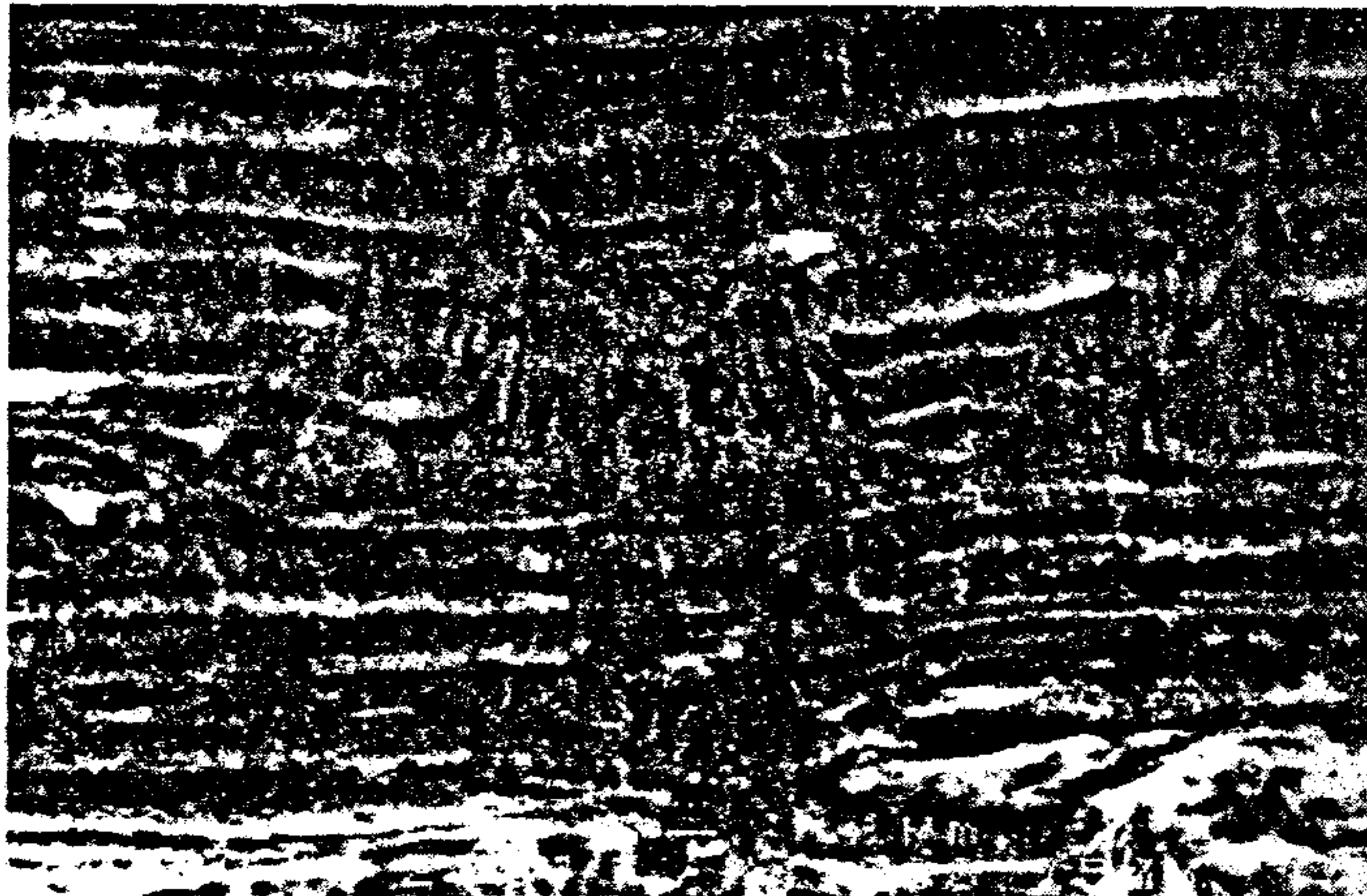


Figure 4. Nickel deposit plated with 100% anode coverage and 'flow through' (x2400, Etch: Kallings' Reagent).

and a therefore faster deposition. Most additives used in bath plating, such as brighteners and grain refiners, cannot be used for selective plating, since the high current density diminishes their effect considerably.<sup>1</sup>

#### (b) Anodes

For selective plating inert anodes are used, as soluble anodes can cause contamination of the solution and the deposit. The material most widely used for anodes is very pure graphite, which can easily be machined to the shapes and sizes of anodes appropriate for different workpieces.

Due to the brittleness of the graphite, it is not used for very small size anodes. Instead such anodes are often made of a 90% platinum 10% iridium alloy or platinumized titanium.

#### (c) Anode wraps

Apart from absorbing the plating solution the anode wrap also fulfils a second task by separating the anode and the workpiece.

Commonly used materials are polyester felt for deposits up to a thickness of about 25 microns, and more abrasive nylon-based wraps for thicker deposits.

#### (d) Styli

In order to keep the operator isolated the

anode is attached to an insulated handle called a stylus, which in turn is connected by a lead to the power pack. For plating small inside diameters a rotating work tool called a Rotostylus is used to take up the anode, allowing constant motion between anode and workpiece.

### EXPERIMENTAL

Dry Ball-on-Disc tests were carried out on steel discs (709M40) plated with different nickel and nickel-alloy deposits of 30 microns thickness. The solutions used were proprietary brush plating solutions, according to manufacturers instructions. Table 1 gives some information about the solutions. Original steel bearing balls were used as counterbody, the test speed was 0.1m/s and the distance 1000m. Scanning electron microscopy was employed to

obtain information of the structure of the coatings, and their composition was analysed by EDX and GDS. The hardness of the deposits was measured on cross sections using a Leitz miniload hardness tester and a load of 25g.

### RESULTS

#### Composition

No hydrogen was found in any of the deposits, while the contents of oxygen and phosphorus were generally low. The content of sulphur, however, varied and reached values of up to 0.15% in Nickel Aero. The Nickel Tungsten deposit contained 3% tungsten and 0.10% sulphur. The other alloy, Nickel Cobalt, consisted of 86.5% cobalt and 13.5% nickel, while no significant amounts of other elements were found.

#### Ball-on-Disc tests

The examination of the wear scars revealed that none of the layers had been worn through, while the Nickel Cobalt deposit was worn to a much lesser extent than any of the others. The coatings exhibited coefficients of friction in the range of 0.55 to 0.75 under a load of 5N (Table 2). Additional tests carried out under a load of 15N and 25N on Nickel

Table 1. Solution Characteristics

| Solution        | Metal Contents (g l <sup>-1</sup> ) | pH  |
|-----------------|-------------------------------------|-----|
| Nickel Acid     | 112                                 | 2.3 |
| Nickel Aero     | 97                                  | 1.4 |
| Nickel Tungsten | 85                                  | 1.6 |
| Nickel Cobalt   | 100                                 | 2.0 |

**Table 2. Deposit Characteristics**

| Deposit         | HV <sub>0.025</sub> | Coefficient of friction (Load 5N) | Composition (%)                           |
|-----------------|---------------------|-----------------------------------|---|
| Nickel Acid     | 570                 | 0.70                              | O 0.04; P 0.02; Ni balance                |
| Nickel Aero     | 640                 | 0.70                              | O 0.04; P 0.02; S 0.15; Ni balance        |
| Nickel Tungsten | 630                 | 0.75                              | O 0.03; P 0.02; S 0.10; W 3.0; Ni balance |
| Nickel Cobalt   | 600                 | 0.55                              | P,S 0.00; Co 86.5; Ni balance             |

Cobalt showed average coefficients of friction of 0.45 and 0.40 respectively.

#### Hardness

All deposits reached high hardness values in the range of 570HV to 630HV.

#### Structure

The Nickel Acid deposit exhibited varying structures depending on the plating procedure. Figure 2 shows a layer plated with flow through solution supply and an anode coverage of 100%. The structure is

columnar with no banding.

If, however, the anode is dipped manually to replenish the solution in the anode wrap, thus effectively interrupting the plating, the same 100% anode coverage produces a completely different structure (Figure 3). Instead of a columnar structure, one consisting of several broader bands and numerous finer bands was observed. Finally, Figure 4 shows a deposit on a round nickel bar, which was plated with flow through solution supply,

but whose shape allowed only an anode coverage of 30%. This time the structure turned out to be predominantly banded, but with columnar parts, in fact a mixture of the structures found on the other two specimens.

#### CONCLUSIONS

- 1) Selective plating can produce dense and adherent deposits, as shown using nickel and nickel alloy solutions.
- 2) The deposits are relatively pure and their microhardness is around 600HV
- 3) For dry sliding against steel a cobalt-nickel alloy outperformed the nickel deposits in terms of coefficient of friction and wear resistance.
- 4) The structure of selectively plated nickel was found to be dependent on the plating conditions.

#### REFERENCE

1. M. Rubinstein, *Electrochemical Metalizing*, Vinmar Press, New York, 1986.