

# Case Report on Development of A Novel Surface Activation for Electroless Nickel Plating of Aluminum

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## Prior Achievements and Our Novel Approach

Electroless nickel deposition together with several novel versions of it like composite and nano-coatings have been widely studied and discussed [1,2] still recently, and, for example, Sudagar J et al. [1] even presented a critical review on this topic. However, they did not discuss the very important role of the substrates, which otherwise does have a vital role in being able to deposit really sound and well adherent nickel base coatings via electroless plating. In those cases, when the substrates like ours, i.e. an aluminium alloy as well as many other metallic and non-metallic materials do not have the proper surface catalytic activity, one always has to face the rather challenging task of finding and applying a suitable pre-treatment in order to modify the substrate surface before immersing it into the electroless plating bath. As both polymers and ceramic materials are electrically non-conductive, their surfaces can be made catalytic via, for example, a very thin-layer metallization by palladium as described in [3] for Polyimide film, or by some other means as, for instance, in the case of SiC ceramic powders pre-treatment [4], where a special aqueous mixture of hydrofluoric acid, nitric acid and benzotriazole was used in an ultrasonic bath for 20-30min to activate the surface before electroless nickel deposition in an aqueous nickel sulphate, sodium hypophosphite, sodium citrate containing bath buffered with boric acid.

For the surface activation of aluminium the conventional process consists of

- i) degreasing,
- ii) alkaline cleaning,
- iii) acid etching,
- iv) zincating,
- v) stripping of zinc,
- vi) re-zincating,
- vii) copper striking and
- viii) electroless nickel-phosphorous /Ni-P/ plating when hypophosphite reducing agent is used in the coating bath.

Some proprietary processes employ immersion tin instead of Zn from a stannate bath and electroless brass/bronze before Ni-P plating [5]. This latter example clearly shows the complexity of the whole process in the case of working with aluminium and aluminium alloys, and actually it was an important impetus for us to start working on such systems with the aim of developing a somewhat simpler and environmentally also less hazardous pre-treatment process for aluminium [6]. In short, it applies a hot (~85 °C) acidic (lactic acid containing) sodium hypophosphite solution for surface activation of the previously properly degreased aluminium parts (in an alkaline solution containing sodium phosphate as well), and after such a two-step pre-treatment procedure the still wet aluminium specimens/parts are immersed

in the Ni-P plating bath which contains a nickel salt ( $\text{NiSO}_4$ ) and sodium acetate in addition to the two main components of the pre-treating lactic acid-sodium hypophosphite solution. As the major surface activating agent of it is the hypophosphite, its surface adsorption had to be checked and monitored by a sensitive enough surface analytical technique, for which the HAXPES-XAES (Hard X-ray Photoelectron Spectroscopy-X-ray induces Auger Electron Spectroscopy) was chosen and applied successfully [7].

### On the Mechanism of the Novel Surface Pre-Treatment Process

After proper cleaning (degreasing) and effective activation of the aluminium substrate the key/crucial element of the whole lactic acid-hypophosphite type pre-treatment is the final surface condition of the so modified surface of the substrate. In order to decrease the otherwise rather high probability of a direct contact type reduction of  $\text{Ni}^{2+}(\text{aq})$  cations by the active metallic surface of Al(s) at the beginning of immersion in the electroless nickel plating bath, the pre-treating solution should temporarily reduce the high chemical activity of aluminium in these aqueous solutions. In our novel pre-treatment process this special requirement (i.e. slight passivation-like surface conditioning) is attained by the surface adsorption of the hypophosphite anions of the reducing agent that is also the most important component of the electroless nickel plating solution. In this way the reduction of the  $\text{Ni}^{2+}$  cations can start right at the surface of the aluminium by the weakly adsorbed hypophosphite anions relatively undisturbed by some unpleasant side reactions like the two fast direct (electron exchange) reduction between the metallic Al(s) and the directly reducible  $\text{Ni}^{2+}(\text{aq})$  and/or  $\text{H}_3\text{O}^+(\text{aq})$  cations both present in an acid-type electroless nickel

bath. This very first initial stage of the electroless nickel deposition will then decisively determine the final adherence strength of the nickel-phosphorous (Ni-P) deposit layer on the aluminium (or any aluminium alloy) substrates. If during this initial deposition phase the Ni-P layer is developing well all over the substrate surface, then one can expect to produce a sound Ni-P layer with the necessary thickness as the electroless nickel deposition onto nickel (or Ni-P) layer is progressing almost undisturbed in any proprietary electroless nickel bath available in the market today.

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