Advice & Counsel

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The "Attractive" Side of Electroless Plating

Dear Advice & Counsel
We perform electroless nickel plating for an application requiring close control over magnetic properties. I've just been transferred into the plating department, and frankly, I don't have a clear understanding of what magnetism even is. Aside from heat treating, are there any other ways or methods for increasing or changing the magnetism in a high or mid-phos electroless nickel plating?

Signed,
Izzy Attractive

Dear Mr. Attractive,
Metals fall into three levels of magnetic properties:

a. Diamagnetic metals have feeble magnetic fields and are generally repulsed by the field. Examples are copper, silver, gold, and bismuth.
b. Paramagnetic metals have a small positive magnetic susceptibility, and most metals fall into this category, including, lithium, sodium, potassium, calcium, strontium, magnesium, molybdenum, and tantalum.
c. Ferromagnetic metals have a large positive susceptibility to magnetism. Included in this group are iron, cobalt, nickel and gadolinium. Iron alloys containing these metals or manganese or chromium are also ferromagnetic. A feature of ferromagnetic metals is that they retain some or all of their magnetism, after the magnetic field has been removed.

Magnetic Properties

The magnetic properties of electroless nickel deposits depend upon the crystal structure of the deposit, the alloy and to some degree the conditions under which plating occurred (pH, temperature, chemical composition etc.). Crystalline electroless nickel deposits are ferromagnetic, while amorphous (no structure) deposits are considered non-magnetic. Magnetic properties include coercivity, which is the external magnetic field that must be applied to demagnetize the deposit. Coercivity is measured in Oersteds. Electroless nickel deposits ranging from 0-80 Oersteds have been reported. Another magnetic property is referred to as the remnant flux density, which is the amount of magnetism remaining when an external magnetic field is removed. The remnant flux density is measured in gauss. For example, the remnant flux density of electroless nickel after heat treatment ranges from 1000 to 3000 gauss. Electroless deposits between 3-6% have coercivities between 20 and 80 Oersteds, and 7-9% have 1-2 Oersteds. Heat treatment increases coercivity (magnetism) to 100-300 Oersteds. There also is the saturation magnetization property of a metal, which is measured in gauss/cc, emu (electromagnetic units)/cc or emu/g.

Modified Levels

The level of magnetism can be reduced/modified by the incorporation of certain non-magnetic elements in the electroless deposit. These elements include phosphorus, molybdenum, boron, and thallium. Electroless nickel-phosphorus alloys become non-magnetic when the phosphorus content in the alloy is greater than 8%. Theoretically, the electroless deposit can be made non-magnetic at lower %P content, if another element (such as boron, molybdenum or thallium) that affects magnetism is alloyed into the deposit along with the phosphorus. In general, these tertiary alloying elements need to be present at concentrations much greater than 1% to affect the magnetic properties of the electroless nickel-phosphorus deposit.

The deposit can be made more magnetic, if a ferromagnetic alloy such as cobalt is plated in the alloy. For example, the level of magnetism can be controlled by plating specific cobalt-nickel-phosphorus alloys. Such alloys have been used in computer data storage devices (hard drives).

Other Data

In the AESF book, *Electroless Plating**, edited by Haydu & Mallory, page 265 indicates that "a variety of interesting and useful magnetic properties can be obtained by addition of other metal ions to the typical alkaline-ammoniacal electroless cobalt bath to form ternary alloy deposits. Addition of 10 g/L sodium tungstate dihydrate or 0.8 g/L potassium perrhenate to a typical bath at pH 8.9 and 98° C resulted in deposits containing 9% tungsten and 30% rhenium." No mention of impact on magnetism is made following these statements, but the implication is that these alloys (iron and zinc are also mentioned) have an impact on magnetic properties.

Safranek's book, *The Properties of Electrodeposited Metals and Alloys**, provides a table of coercivity of electroless nickel and nickel-cobalt alloys. The data reported includes "0" values for 10-17% phosphorus electroless nickel deposits. Safranek wrote: "Although several reports state that electroless nickel becomes non-magnetic when its phosphorus content reaches 9%, a field of 6,500 gauss showed slight magnetization for alloys containing <15% (less than 15%) phosphorus. Magnetization approached zero at 15% phosphorus."

The substrate plays no role in the magnetism of the EN deposit if it is a non-magnetic substrate such as aluminum. If the substrate is magnetic, then the substrate would have a magnetic field that can induce additional magnetism in the EN deposit. Stainless steel can be magnetic (400 series) or non-magnetic (300 series). P&SF

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