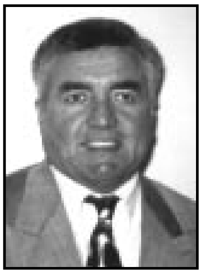

Design Engineering

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How Things "Stick"

In the past few months, we have discussed several steps that lead to successful finishing. Another important requirement for any functionally designed "thingamajig" is to have the coating adhere to the part. Adherence requirements depend on the design function (application) and basis material selected, as well as the type of coating used. You may not care that the coating is inseparable from the basis material, but you should design in some service duty. You may need to rely on standard data or specify a certain bond strength. There are many types of qualitative adhesion and quantitative tensile testing available. Some types of plating create an alloy of plate and basis material—not unlike welding penetration—so there will be *no* bond rupture up to the material's phase yield limits.

The work of adhesion is the sum of interfacial energies of the freshly prepared surfaces, less the interfacial energy of the two joined phases. The work of adhesion is also related to the force needed to break the bond. Any bonded surface adsorbate-induced restructuring or epitaxial growth works to restructure the interface. Atoms of similar size and interatomic distance provide for good adhesive bonding. The work of adhesion then equals the interface restructuring work *plus* the work of bond separation.

Nearly all types of electroplating adhere via chemisorption, so a micro-rough surface is mandatory. These are not true chemical (covalent) bonds. They are weaker associative intimate structures having some water, air, ions or organics "trapped" in between. In fact, most plated metals have these entrained in their structures at small percentages. Owing to this, each process and step—including cleaning and rinsing—gives characteristic potential plate-interface bond restructuring effects on the adhesion working range with time and temperature. The most notorious of these interface contaminants are basis material oxide, the presence of chloride and hydrogen. Here are some processing techniques developed by platers.

Processing Techniques

Electroless or electrolytic nickel plating of aluminum invariably involves zincating after cleaning. The zinc surface prevents oxidation until it dissolves in the nickel bath. Because there are always pores of unzincated aluminum surface present, "double" zincating is employed. This consists of stripping the zinc in nitric acid and then re-zincating. Certain aluminum alloys respond to this modification, wherein fewer large pores are present. There are, however, *always* surface pores trapped with caustic water at the interface. The degree of contamination determines ultimate bond strength, whereas corrosion and temperature limit service duty.

Carbon steel has graphite in it and oil on it. When treated by hydrochloric acid pickling, the iron removed exposes more graphite, which won't plate. Further, chloride—the world's best oxidation catalyst—can cause problems if not completely removed. To minimize and/or compensate the hydrochloric "activation" step, amphoteric surfactants are used in hot alkaline gluconate baths with surface impingement (if using thiosulfate as a chelate breaker won't work). More rigorously, some cycle between permanganate and chelate baths. The best—perchloroethylene, creosote and o-dichlorobenzene—can't be used anymore for environmental reasons. Even cleaning processes that work, won't. One process formerly cleaned parts effectively, but adhesion problems arose even after repeated cleaning. Although the parts appeared clean, a film that wiped a smut was observed, even though nothing else had changed. The metal manufacturer had received metal processed with a reformulated oil with different antioxidant ("oil" is not "oil").

Anodized aluminum is alloy-dependent. It requires different deoxidation because of the presence of silicon, manganese, zinc, etc. It sometimes requires annealing to have good grain size and distribution. Billets have differential compositions from center to periphery. Changing suppliers could leave a previously machined peripheral zinc-rich zone to affect adhesion. Don't rinse after etch; go with reverse current before forward in plating bath; enter bath with current on ("live" entry); let nickel-plated parts soak in chrome solution before plating; high or low initial current, etc.

There are many pre-plating processes designed to prevent interference from oxide formation, and there is one best for each application. Strong adhesion on anodized "valve metals" is provided by plating into the intimate hard-oxide pores. They are: U, Bi, W, Ta, Hf, Sb, Sn, Nb, Zr, Ge, Ti, Si, Al, Mg and Be. P&SF