microJoining Solutions – microTips™
5563 Hallowell Avenue • Arcadia, CA 91007
Phone: 626-444-9606 • Fax: 626-279-7450 • Email: mjs@microjoining.com • Web: www.microjoining.com

Laser and Resistance Weldability Issues, Part II – Material Surface Properties

David Steinmeier

Metal Weldability

Why do some metals weld more easily than other metals? The answer can be found by examining the bulk material and surface properties associated with each pure metal or alloy. Part II of this microTip reviews the effect of material surface properties on weldability. Part I of this microTip covered bulk material issues of the weld parts and can be retrieved at: www.microjoining.com.

Material Surface Properties

Material surface properties include surface texture, natural oxide layers that depend on the chemical properties of each pure metal or alloy, contaminants due to processing and handling such as oil and dirt, and applied coatings such as plating. Each surface property affects the weldability in a different way.

Surface Texture– Laser Welding

Laser welding is sensitive to the surface reflection of the top part. Surface reflection depends upon both the surface texture and the material. All materials reflect and absorb incident energy at different wavelengths. Copper and aluminum are highly reflective compared to iron. To complicate matters, the degree of absorption changes as the material heats up. Surprisingly, some molten materials are more absorbent than solid, cool materials.

The smaller the peak-to-peak variations in surface texture, as seen at a specific laser wavelength, the more weld energy will be reflected. Surface reflection problems become more pronounced when using shorter wavelength 1-micron Nd YAG lasers as compared to 10-micron CO_2 lasers.

To overcome the reflection barrier when using pulsed Nd: YAG lasers, use a high peak power pulse to begin the melting process, followed by lower peak power pulses to complete the weld.

Surface Texture – Resistance Welding

Resistance welding is also sensitive to the surface texture of both parts being welded. Surface texture affects how the weld current is distributed across the part surface. Parts possessing a rougher surface texture will experience more weld splash and “unexplained blowouts”, as shown in Figure 1, Left Side, because the weld current is forced to flow through fewer contact points on the material surfaces. This weld current restriction dramatically increases the weld heat density, resulting in violent weld material vaporization or weld splash. Use of a pre-heat or an upslope weld heat profile to slowly collapse the surface peaks before applying the final weld pulse can prevent weld splash.

Figure 1 - Surface texture effect on weld current density. Left – Uneven, concentrated weld heat. Right – Evenly distributed weld heat.

Oxides

Many metals form a chemical bond with oxygen, creating an oxide. Most oxides are not electrically conductive and thus represent a barrier to resistance welding. Oxides trapped in a laser or resistance welded joint can cause weld stresses that ultimately result in a weld joint failure.

There are several methods to deal with oxides. One, plate the weld parts to prevent unwanted oxidation. However, this solution can create its own set of problems to be described later in this microTip. Two, mechanically remove the oxides before welding. Note: mechanical cleaning can also damage parts and in the case of aluminum oxide, the oxide reforms as quickly as it is removed. Three, protect the immediate area surrounding the cleaned weld parts with an inert cover gas such as Argon.

Contaminants

Contaminants include: dirt, grease, moisture, and oil. At best, dirt trapped in the weld joint reduces the weld strength. At the worst, dirt can carry traces of chemicals that can produce a latent weld failure.

Hydrogen contained in grease, moisture, and oil also presents a welding problem. When rapidly heated, the hydrogen contained in these chemicals dissolves into the molten weld material. Over time, the hydrogen atoms congregate at the weld material grain boundaries or inclusions, creating high internal stress points. If the weld metals are low in ductility, the weld joint can crack.

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This phenomenon is known as "hydrogen cracking". To prevent hydrogen cracking from occurring, remove all traces of dirt, grease, moisture, or oil from the weld metals before laser or resistance welding.

Applied Coatings

Applied coatings include: polymers, aluminum anodizing, nickel plating, and all other types of plating. Neither laser nor resistance welding can be used to weld anodized parts.

Polymer Coatings

Polymers are organic compounds typically used to provide electrical insulation on products such as magnet wire. Polymer coatings must be chemically or mechanically removed before laser welding.

For resistance welding, polymers block the flow of weld current and quickly become embedded in the electrode tip. For more information on magnet wire bonding, retrieve the microTip on this subject at: www.microjoining.com.

Plating

Typical plating materials include cadmium, gold, lead, nickel, silver, tin, tin/lead solders, and zinc. Plating provides corrosion resistance, wear resistance, enhanced electrical conductivity in some cases, and a more uniform appearance.

Nickel plating can cause a variety of welding problems. Electrolytic nickel plating is superior to electroless nickel plating for both laser and resistance welding. Electroless plating contains phosphorous, which contaminates the weld joint.

Brighteners introduced during electrolytic nickel plating enhance the appearance of the plated parts, but contain polymers that vaporize when exposed to laser energy. Brighteners also cause problems with resistance welding since the brightener impedes weld current flow. Use a high electrode force in conjunction with a pre-heat or upslope weld heat profile to displace the brightener.

Low temperature metals such as cadmium, lead, tin, tin/lead solders, and zinc vaporize readily before reaching the melting temperatures of the weld materials. Laser welding is very difficult due to the high peak weld energy profiles produced by Nd YAG lasers. When using resistance welding techniques, employ a low energy pre-heat pulse to displace most of the plating before the high energy weld pulse occurs. In all cases, these low temperature plating materials tend to form brittle intermetallics in the weld joint that can easily fracture under mechanical and temperature cycling stresses. The thinner the intermetallic layer between both parts, the stronger the weld joint.

Figure 2 shows a resistance weld failure with excessive tin plating remaining on the pin. The mating terminal broke off during temperature cycling.

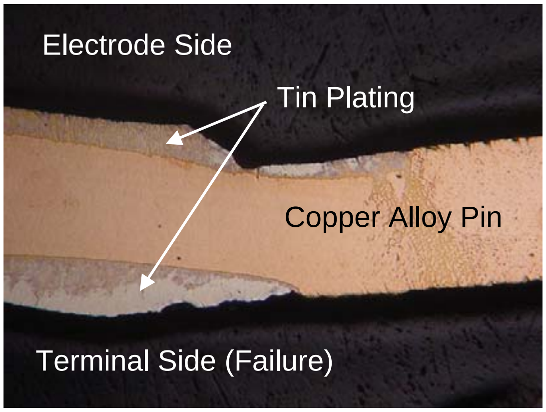

Figure 2 - Weld failure.

Figure 3 shows a good resistance weld joint (diffusion weld) with a trace of Cu_6Sn_5 intermetallic between the square pin and the bottom terminal.

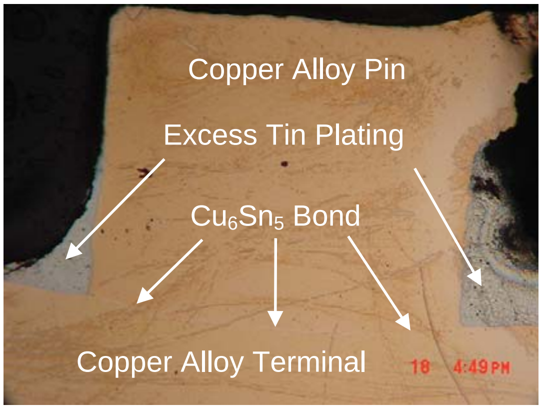

Figure 3 - Excellent diffusion weld.

Conclusion

Understanding how the material surface properties of common metals affect laser and resistance weldability at the beginning of a new product design can significantly increase future manufacturing yields.