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Laser and Resistance Weldability Issues, Part I – Bulk Material Properties

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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 I of this microTip covers bulk material issues while Part II reviews the effect of surface properties on weldability.

Bulk Material Properties

The chemistry, crystalline structures, and microstructures determine the bulk material properties of each metal or alloy, hence their weldability and bond type. Properties controlled by the chemistry include melting temperature, thermal conductivity, and electrical conductivity. Properties determined by the crystalline and microstructures include hardness and brittleness.

Why Do Metals Bond?

Metals bond because the atoms from one metal chemically or metallurgically interact with the atoms from another metal. Take two metals, similar or dissimilar, completely clean the oxide off their surfaces, place them in intimate contact and a metal bond will form. The resulting bond type depends on the bulk material properties of both metals.

Metal Bond Types

Metal bond types fall into four general categories. Fusion bonds involve the complete melting and mixing of both metals. Diffusion bonding can be viewed as a form of fusion bonding but with reduced mixing of both metals. With Solid State bonding, there are very limited atomic bond layers between the two metals. Finally, Reflow brazing or soldering utilizes a low temperature interface alloy to join two higher melting point metals.

Important - The laser welding process is limited to those metals that can form a fusion bond. For more detailed information on bond types, retrieve the microTip: *Laser & Resistance Welding – Metal Bond Types* at www.microjoining.com.

Ideal Welding Characteristics

Ignoring low temperature reflow soldering or brazing, the desired metal welding combination would have the following bulk material properties:

- Same or very close melting point temperature
- Low thermal conductivity
- Low electrical conductivity for resistance welding
- High ductility

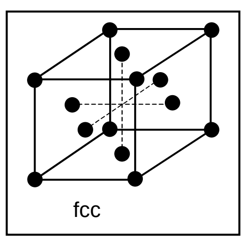
Nickel-to-nickel welding is close to ideal and can be easily welded by both laser and resistance welding processes. The melting temperature is 1,452ºC, the thermal and electrical conductivity are low, and the ductility is high. The resultant bond type can be a fusion, diffusion, or solid state bond, depending on the parts geometry and weld heat profile.

Real World of Laser and Resistance Welding

In the real world of resistance and laser welding, ideal metal combinations rarely exist. Materials that have high thermal and electrical conductivity are difficult to weld because the weld heat tends to dissipate away from the weld, preventing the metals at the weld from reaching melting temperature.

Materials that are hard or brittle generally have a very narrow plastic range and therefore have a tendency to crack or fracture during the welding and cooling process. The metal's ductility at welding temperature is also important. Metals with poor high temperature ductility will "hot crack" upon cooling.

Group 1 Bulk Material Properties



Group 1 metals include aluminum, gold, silver, copper, and brass and bronze alloys. These materials have a "Face Centered Cubic (fcc)" crystalline structure. Fcc metals and alloys are generally ductile due to the high number of dislocation slip systems in the fcc cubic structure. Group 1 metals can be very hard to weld because of their high thermal and electrical conductivity. Group 1 metals always form a solid state bond with Groups 1, 2, and 3. Note that a solid state bond can still produce a "nugget" or metal button when tensile tested. This phenomenon has sometimes been misinterpreted as a fusion weld.

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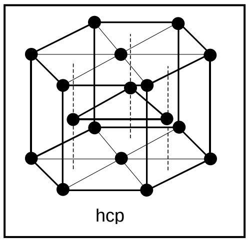
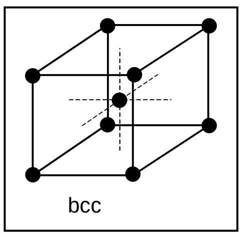
Group 2 Bulk Material Properties



Group 2 pure metals include: nickel (Ni), titanium (Ti), and platinum (Pt). Group 2 alloys include 304 and 316 stainless steel. These materials have a fcc crystalline structure, except for titanium which has a "Hexagonal Close Packed Cubic (hcp)" crystalline structure. Group 2 metals form fusion, diffusion, or solid state bonds with other Group 2 metals and solid state bonds with Groups 1 and 3.

Group 3 Bulk Material Properties



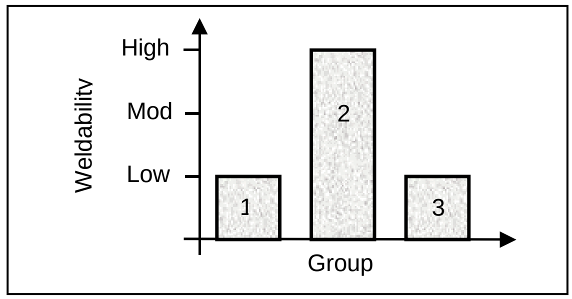
Group 3 pure metals include: chromium (Cr), iron (Fe), molybdenum (Mo), niobium (Nb), tantalum (Ta), and tungsten (W). Group 3 alloys include 416 and 430 stainless steel. These materials have a "Body Centered Cubic (bcc)" crystalline structure. Group 3 metals and alloys have high melting temperatures (1,500 to 3,500ºC), are very hard and brittle due to the low number of dislocation slip systems, and have moderate thermal and electrical conductivity. Group 3 metals always form a solid state bond with Groups 1, 2, and 3.

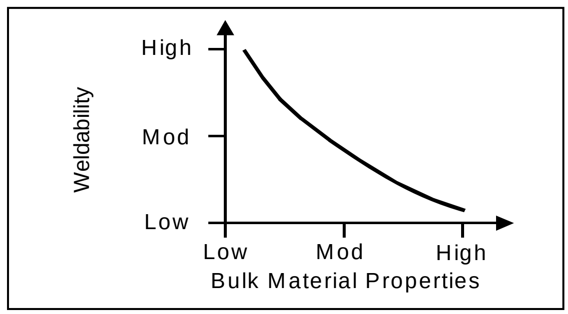
Table 1 contains the most common metals and alloys used to make a variety of aerospace, automotive, electronic, and medical product parts.

	Group 1	Group 2	Group 3
TABLE 1	Al, Ag, Cu, Brass, Bronze	Fe-Austenite, Ni, Pt, Pt-Ir Ti, 304, 316	Cr, Ir, Fe-Martensite, Mo, Nb, Ta, W
Al, Ag, Cu, Brass, Bronze	Solid State	Solid State	Solid State
Fe-Austenite, Ni, Pt, Pt-Ir Ti, 304, 316		Solid State, Fusion, Diffusion	Solid State
Cr, Ir, Fe-Martensite Mo, Nb, Ta, W			Solid State

Atomic symbols used in Table 1:
Ag = Silver, Al = Aluminum, Cr = Chromium, Cu = Copper, Fe = Iron, Ir = Iridium, Mo = Molybdenum, Ni = Nickel, Nb = Niobium, Pt = Platinum, Ta = Tantalum, Ti = Titanium, W = Tungsten

The two figures below summarize weldability by group type and the bulk material properties of melting temperature, thermal conductivity, electrical conductivity, hardness and brittleness.





Conclusion
Understanding how the bulk material properties of common metals affect laser and resistance weldability at the beginning of a new product design can significantly reduce future manufacturing problems.

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