

3.37 (Class 11)

Review

- Diffusion bonding can produce nearly perfect joints, but is limited in materials, cost, etc.
- Diffusion bonding using heat to dissolve, diffuse or evaporate contamination and soften asperities
- Al, Mg are difficult to bond, can't dissolve their oxides, need to add another layer
- Fe, Cu, Ti, Ni are relatively easy to bond
- DB is limited on low temp side by kinetics (days in the furnace, high pressures makes fixturing more expensive), on high temp side by grain growth

Today

Transient Liquid Phase Diffusion Bonding (TLP)

- Trademarked and patented (many declared invalid due to prior art)
- Phase diagrams (described by Chocolate/Milk diagram on board), phases and components
- In ice cream maker, adding salt to the ice, heat of fusion pulled out of the cream
- TLP joints start as a braze, solid-solid, interpose a liquid at some temperature
- Say Ni on either side, nickel-boron between, raise to temperature beyond the melting point of the braze alloy, hold at temperature, boron diffuses into the nickel, continues to diffuse and joint initially gets thicker and dissolves contamination, then get thinner and thinner as boron diffuses away
- TLP is iso-thermal solidification, go across the phase diagram in composition
- Pb-Sn solder (diagram on board) 60%, test temperature 200degC, were supposed to use 95-5, but used the 60-40, put it in conditioning furnace at 200degC and the wrong solder melted out, but in fact did tests to show that the joint did not break until about 300degC, tin had diffused away into the copper, leaving behind the lead, alloy moves across the phase diagram as the composition changes. Took very little pressure, only need about 5psi, so much cheaper since fixturing much simpler
- Quicker than solid-state diffusion bonding, TLP can occur in several hours
- Times down by factor of 2-3, pressures down by factors of 100, but need the correct metal combinations
- Another example: AEGIS cross-field amplifier for phased array radar system, way to amplify microwaves, electron beam shoots through hole, copper ring with slots, at the end want to braze a piece of molybdenum to prevent melting due to high heat fluxes. Problem, molybdenum would break off. Were using 82 Au – 18 Ni brazing alloy to braze the copper and molybdenum, created a brittle intermetallic so that would break when loaded. Wanted to know how to make a non-brittle joint. Suggested a TLP diffusion bond. They had tried 63 Cu – 35 Ag – 2 Ni joint that had worked well. They had stumbled into a TLP joint, not

enough nickel to form the brittle intermetallic, gold as the interstitial diffuser, braze alloy had diffused away, tremendous ductility. Initially Navy didn't like this because it was cheaper, wanted higher reliability, so had to write paper to justify the use.

- Side story: 1939 British physicists had invented the klystron but didn't have time to perfect, sent to MIT (to radiation lab, now where the welding lab is located)
- Typically when brought in as a consultant, management brings in because engineering hasn't been able to solve the problem, don't want to solve the problem right away. Many times have management that want the problem solved quickly, sometimes engineers don't give information quickly as they don't really want the problem solved quickly. What to do? Listen, then ask for tour of the plant, go up the foreman or machine operator, build them up (often large companies don't know how to treat blue-collar employees well), then ask them what the problem is, may need to translate, then go back to the conference room and tell them.
- Consulting example: Navy destroyer, weld Fe Cr-Mo tubing to stainless steel and hadn't been able to make these welds, EB (electric boat) inserts that get melted in, Navy spec called for stainless steel inserts and couldn't use a nickel-based alloy insert, go up to library, look in welding journal, good reason not to use nickel-based insert, but Navy wanted to use. Joint design was bevel with root pass, suggested a change in joint design (at this point didn't really know what the problem was, but wanted to try to get rid of stress), did this while wait, wrapped and needed to wait 45 minutes, cleaned and then spray with thin red lacquer to penetrate cracks, clean it off, then spray on white powder and red pulls out to the surface, no cracks! Didn't really know how to solve the problem, but did know that stress reduction was the only thing that could really try.
- Another consulting example: asst prof, low salary, plastic injection molding consulting problem, suggested plating the contact surface, no wear in the first two weeks of operation, but then fell apart in the next week, never did really solve the problem. Don't take consulting jobs when not an expert.

Activated Diffusion Bonding

- Coat a non-bondable surface with a bondable one
- Paper by O'Brien, Rice, Olsen in Welding Journal, Jan 1976
- Wanted to bond iron at low temperatures
- Plated surface with silver
- 10 min, 20,000 psi bonding pressure, 400degC
- achieved joint 100ksi tensile strength
- bonded silver to silver instead of iron to iron
- but yield strength of silver much less
- Contact Strengthening: get a very thin joint that is constrained by the hard non-yielding material on either side
- Refractory material, can't braze to it, how to join to it?, nickel plated it and now have a nickel surface to join to.
- Changing the composition of the surface to overcome some of the difficulties in joining

- Silver is good for this, don't have to get rid of oxide at 400degC
- Copper not bad for Al alloys
- Nickel is good for iron and many other cases, particularly in many electronic packaging applications.