

3.37 (Class 10)

Review

- Handout on joining of dissimilar materials: explains why can't go to larger die sizes in semiconductors, about 1cm is as large as can go.
- Adhesives vary widely in cost, water resistance, corrosion
- Adhesive joints are good in fatigue, variable in corrosion
 - Semiconductors, encapsulate joints on semiconductor chips
 - Significant problems with adhesives with moisture absorption
- Adhesives require large surface area for strength
 - Large surface to volume ratio
 - Need to bond sheets, fibers, powders, aggregates
 - Tend to fail in peeling, not in shear

Today

Diffusion Bonding

- Squeeze and add heat,
 - Heat helps deform surface asperities to get better than 1/3 surface contact,
 - Heat also helps diffuse away the surface contaminants in some cases
- Cold welding with heat, but usually don't have significant shear
- Pass around example: titanium sheets, test diffusion bond joint for F-22 fighter, hollow titanium air foils, diffusion bonded at interfaces
- Avoid brittle intermetallics that can form, Ni-Al, can use Ni-Cu-Al, interposing a foil in between
- Eliminate prior Thermal Mechanical Treatment (TMT), often have done special things to the metals to form certain precipitates
 - Bonding temperature is typically 0.6 to 0.8 of melting point T_m (Kelvin)
 - Want a high enough temperature to get deformation at bonding pressure
 - Bonding pressures 500-5000psi
 - Tradeoff: How to fixture these for 5000psi pressure?
 - Mitsubishi has a diffusion bonding pressure several meters in each dimension, used to make clad plate, 10,000-20,000 metric tons
 - Need a high enough pressure for the metal to creep, lower viscosity
 - Example melting point of lead is approx 600K
 - Iron melting point approx 1850K, at 300K room temp, far away from melting point, to fusion bond steel need to be at 900-1000K (600-700degC), 1200degF approx 600degC, loses about half of its yield strength (as in Trade Center disaster)
 - At higher ranges get grain growth which destroys the ability to get rid of the pores (diagram from welding handbook on overhead), trap pores inside

the grain, becomes a stable defect that heat will not eliminate, want to be in stage I and stage II where it is still possible to diffuse away the pores, don't want to get to stage III where the pore is trapped, so would like to be at low end of temperature range

- For fixturing want to be at low pressure range, requiring higher temperature range, so this creates a tradeoff
- Some materials (like aluminum and magnesium) are not diffusion bondable (unless interpose say a copper layer even then very difficult)
- Typical times, say at $0.6T_m$ say 6 hours in a furnace, cost of vacuum furnace approx \$1000/hour, so this is for high value parts, aerospace industry, not generally used in automotive industry, can go to transient liquid phase diffusion bonding to reduce these times (will cover tomorrow)
- Sometimes use thermal expansion mismatch to create the pressure, special steel and titanium, or say molybdenum
- Titanium diffusion bonds very well since titanium oxide diffuses away its own oxide layer at 900deg.
 - This sometimes is a problem in jet engines, can result in a titanium fire if pushed too high in temperature
 - Robert Sprague from GE Aircraft engines on carbon-carbon composite engines (can run at high temperatures, but will eventually burn, can use for missiles, Tomahawk cruise missile), called them “expensive coal”. These are lightweight and can operate at high temperatures, so can get better efficiencies (basic thermodynamics), 50degC operating increase is worth \$2billion/year to airlines in fuel

Transient Liquid Phase Bonding (TLP)

- Registered trademark of Pratt & Whitney from 1972, but have not been able to defend patents in court
- Other people in industry had been doing this prior
- Etruscans used this in 600BC to bond small gold beads to copper swords, oxidize surface of copper in fire, then put gold beads on
- King Tut's sword in 2000BC, think that this is diffusion bonded, not willing to cut it open to find out
- Most people think of this in aerospace alloys
- Used to think that this was more limited in scope, but over the last 10 years, have a tremendous increase in applications, many things that we thought were soldering or brazing are actually TLP
- Semiconductor bonding: bonding gold (or silver or copper) to gold (or silver or copper), and can interpose with tin, indium, lead, etc., can solder and hold with small force (say 2lb force) and hold on a hot plate for 1 hour and the indium or tin diffuse in, can't remelt until 600degC