3.37 (Class 3)

Review:

The inherent strength of all bonds (even van der Waals) is extremely high
Primary (1-3eV) → 1,000,000 – 3,000,000 psi
van der Waals (0.1-0.2eV) → 100,000 – 200,000 psi

graph of energy vs. distance
graph of force vs. distance
interatomic distance
can get bulk compressibility, modulus, etc from these graphs

Today:

Question: What is the difference between "strength" and "toughness"?

- Strength is how much force to break something
- Toughness is how much energy something will absorb
  - Rubber is tough, glass is brittle
- If a brittle material has no defects it can be very strong, small defect makes it very weak
- Strength is a property of material in absence of defects

Metallurgists know that defects control properties

Two fundamental reasons why two materials don't stick together when brought in close contact:

- Contamination
- Surface Roughness

Science of welding is opposite the science of lubrication, tribology (from Gr. "surface")

Graphite as a lubricant:

- Early 60's space program used graphite as a lubricant, but up in space, in absence of oxygen graphite is no longer a lubricant
- Graphite: atoms line up in planes, hexagonal close-packed structure
- Oxygen in air lines up on basal planes of graphite, carbon-oxygen bond is a satisfied bond
- NASA became interested in surfaces and cold welding
- In lab carbon brushes in motor wear out very fast, change carbon brushes to aluminum disulfide
- 1967 conference book, research on cold welding, what does it take in a rarified atmosphere

- lubrication breaks down when you clean off the “contaminant”, in this case oxygen

Can think of surface energy as surface tension

- Surface energy
  - Units of J/m
- Surface tension
  - Units of N/m^2
- Can think of as either as energy or force

Cleaving a material in a vacuum, then if stick it back together (no contamination) will bond with much of its original strength

- Time to form a monolayer
- Langmuir on order of 10^-8 atm*sec
- In an ultrahigh vacuum, this time is much longer, then the only issue is surface roughness
  - Experiments with flat foils in vacuum, 20-30% of base material’s strength

Lubrication

- Lubrication book: draw ligands (sp?), stearates (sp?), oleyates (sp?), linate (sp?), number of carbons in the chain
- Polar on one side, non-polar on the other
- Stick to the surface, other side has no interest in forming a bond
- Lubrication is intentionally trying to contaminate the surface

Why is Teflon such a good lubricant?

- Covalently bonded structure, all bonds satisfied
- Adhesives don’t stick to Teflon (even eggs ☺: proteins as adhesives)

Question: How do they get the Teflon on pan?

- Mechanical interlocking
- abrade the surface to get a mechanical interlock
- Farberware:
  - Spray on porous surface, then melt Teflon into it

Eagle Scout Project to clean off peeling paint

- Acetic acid to roughen the surface of galvanized steel
- Then primer coat
- Then paint
- 15 years later paint is worn down, but not peeling

Pepsi better than Coke as a cleaning solution

Peter Holcroft chart in packet: one axis how to control contamination, other is how to control surface roughness

Handout: How much contact do I get when surfaces touch

- Asperity contact
- Squeeze it together: Can I get 100% contact? No
- Compressive yield strength (sigma-yield) of the material when two small pieces pushed together
- 3 times sigma-yield to indent a flat object with a punch since need to push aside material on sides (drawn as slip line flow field, volume is about 3 times)
- See handouts for formulas
  - Macroscopic (apparent area)
  - Microscopic (true area of contact)
  - Only get about 30% contact area
- Can't solve surface roughness by just squeezing things together (even in absence of contamination)

Why interested in cold welding? More of these types of welds, semiconductor industry

- Gold wires in semiconductors, gold wire squeezed into surface, mushrooms on bottom
- How many?
  - Say 100 bonds/chip (Pentium may have 300-400 bonds around perimeter, others not as complex)
  - Semiconductor industry approx $100 billion / year
  - Say average chip costs $10
  - This results in approximately 10^12 bonds/year
- Why gold? Use gold since it doesn't contaminate with oxygen (doesn't have a surface oxide problem
  - Still have water, oils in air
  - Can drive off this contamination with temperature
- "Thermal-compression bonding"
- Need shear to break down surface
- 2nd best material for this is aluminum, which has a tenacious oxide