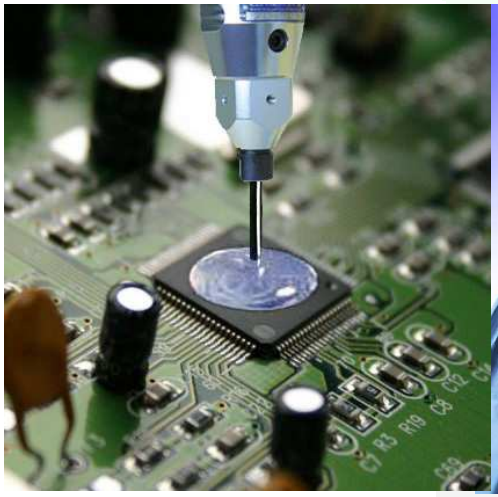
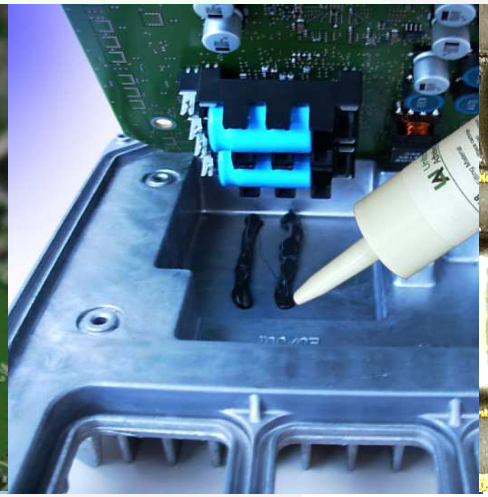
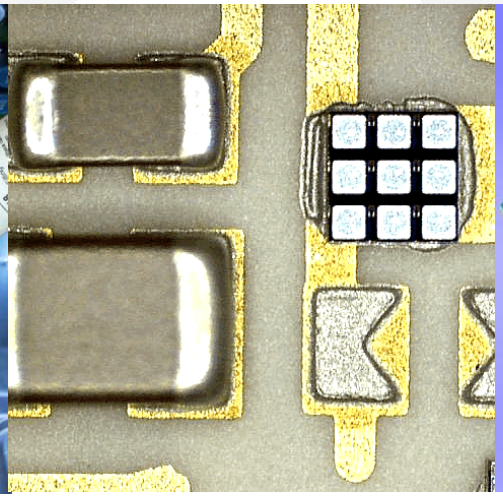
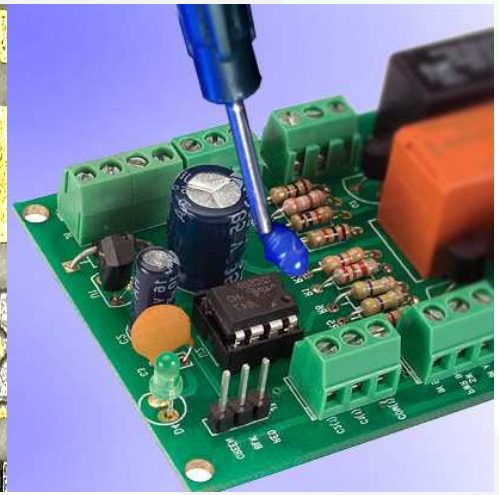
United Adhesives

Introduction to Electronic Adhesives

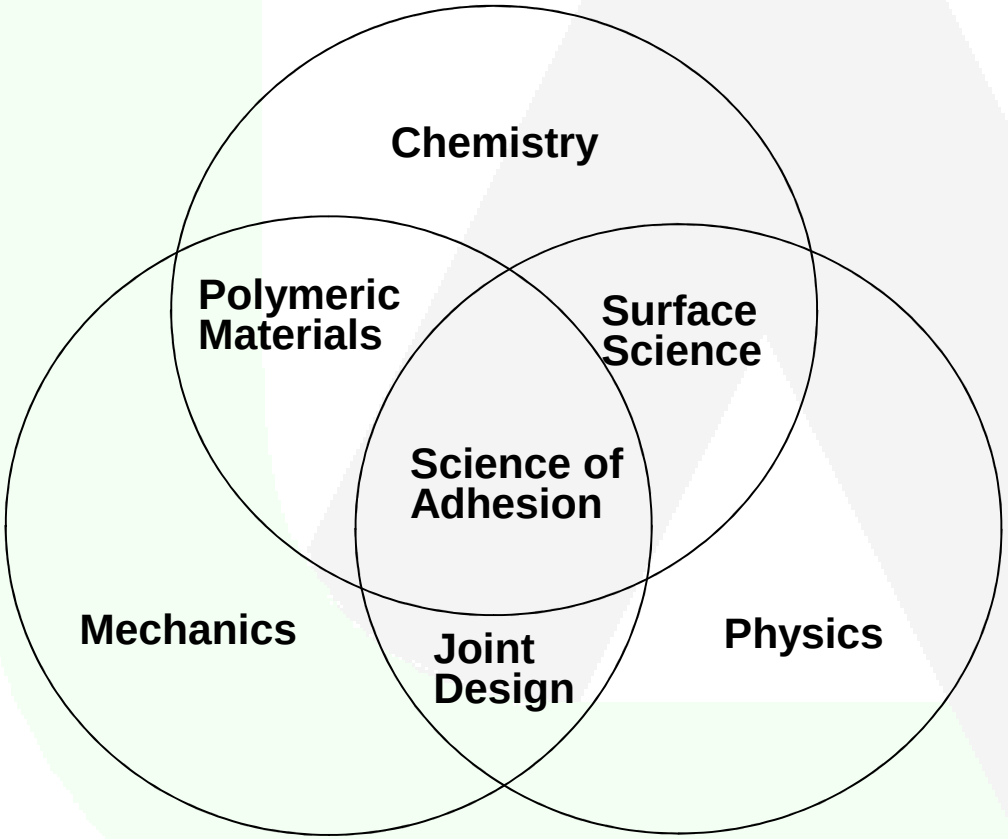
What is an Adhesive?

- Encyclopedia Britannica
  - **Any substance that is capable of holding materials together in a functional manner by surface attachment that resists separation.**

- "Adhesive", as most commonly referred to, is organic polymers
  - **Acrylic, epoxy, urethane, PVA, silicone, etc**
- "Adhesive" as a general term can also include following
  - Cement, mucilage, glue, and paste — terms that are often used interchangeably for any organic material that forms an adhesive bond.
  - Inorganic substances — such as Portland cements also can be considered adhesives, in the sense that they hold objects such as bricks and beams together through surface attachment.
  - Metalsolders — Joint metals objects such as steel, bronze, brass together at hot melt

Disciplines of Electronic Adhesives

Polymers
Crosslinkers
Resins
Additives
Fillers
Viscosity / Rheology
Flow behavior
Tg, Tc, Tm
Crosslink density
Degradation
Compatibility
Bonds
Surface cleanliness
Surface tension
Dielectric strength
Conductivity
Heat dissipation



Surface and Chemical Analyses -
ESCA / XPS, Auger, SEM/EDX, FTIR, AA
IC, GC-MS, NMR, GPC/HPLC, Karl-Fisher, SIMS

Strength
Stress-strain
Modulus
CTE
Elongation
Impact / shock
Tack
Yielding
Creep
Damping
Visco-elasticity
Peel adhesion
Shear adhesion
Tensile strength
Cohesive mode
Adhesive mode
DMA / TMA

Why do Adhesives Bond?

Intermolecular forces

Bond	Energy KJ/mole	Description
Ionic (electrostatic)	600 – 1000	Crystals, metals, rocks, cerment
Covalent	60 – 700	Crosslinked polymers, fibers
Hydrogen	up to 40	Sharing of Hydrogen with atoms, Having one pair of electrons, water
Dipole-dipole	4 – 20	Dipole-Dipole (Keesom Interaction) (decrease as 3^{th} power of distance)
van der Waals	0.1 – 40	Dipole-induced Dipole & London dispersion force (decrease as 6^{th} power of distance)

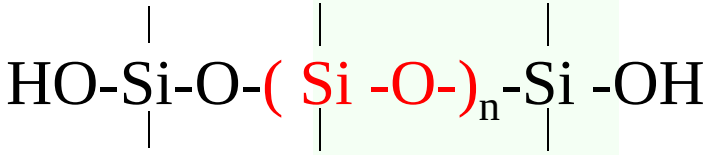
Adhesion = Intermolecular forces + mechanical Interlock

Adhesive Family

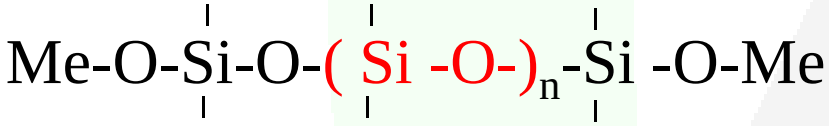
		Examples
Organic	Natural Products	Starch, tar, wax, natural rubber, sugar, egg, animal gel
	Synthetic Resins	Cellulose, PPO, PVA, PS, PMMA
	Silicone	United Adhesives' BS8460, Thermobond 3519
	Acrylic	Tapes, Crazy-Glue
	Polyurethane	Paint, Coating
	Epoxy	United Adhesives' EP1640, EP1239, UF1230
	Fluorinated Polymer	Sifel, Fluoro-silicone
	Hybrid	Epoxy-Silicone, Silicone-Acrylic
Inorganic	Minerals	Clay, Bentolite, Ceramic Precursors
	Salts	Sodium silicate (water glass), Sol-Gel, Magnesium Chloride
	Synthetic	Cement, Alumina, Calcium aluminate, low T glass
Metals	Solder (hot melt)	Fe, Sn, Cu, Ag, SnPb eutectic, SAC305, SMQ230 etc.

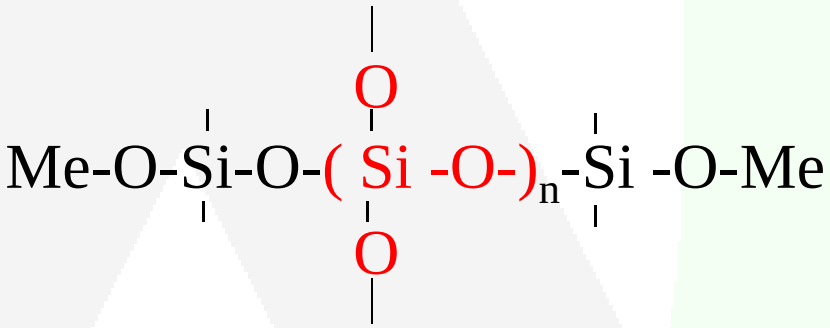
What is Polymer / Resin / Crosslinker?

- Polymer (e.g. OH-Polymer)

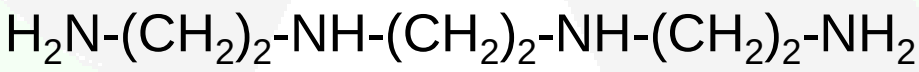


- Resin

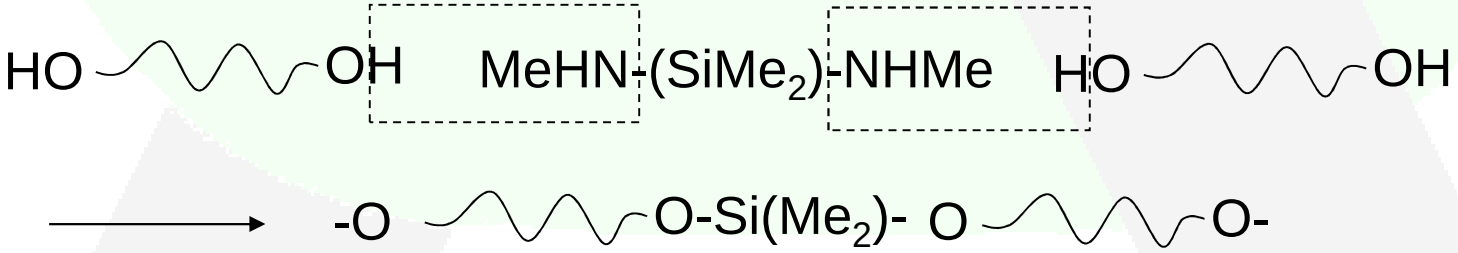




- Cross-linker

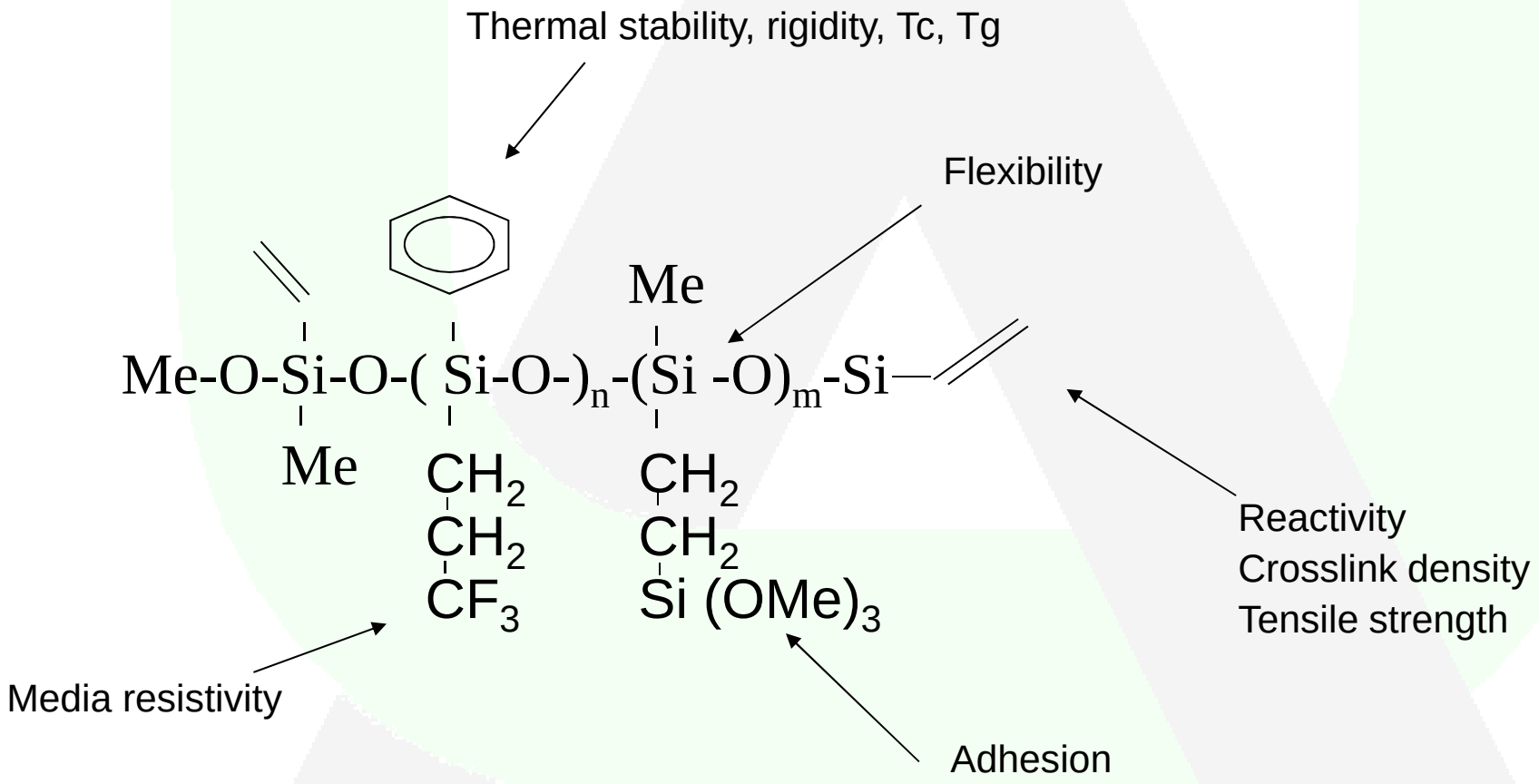


- **Cross-linking**



Modification of Polymer Chain

- Polymer (e.g. Vinyl-terminated PDMS Polymer)



How to Cure an Adhesive?

- Solvent Dry-out
  - Water based → Protein Glue, Starch, PVA, emulsion EVA (Ethylene Vinyl Acetate)
  - Solvent based → Acrylic
- Hot melt
  - Polyurethane, Acrylic, Wax
- Heat cure
  - Silicone, Polyurethane, acrylic, epoxy. One part or two parts
- Moisture
  - Polyurethane, silicone, Cyanoacrylate (acrylic crazy glue)
- UV cure (free radical reaction)
  - One part acrylic, epoxy, silicone
- Anaerobic
  - Thread glue (no oxygen)
- No-cure
  - Low Mw resins, PSA tape

Any other cure Options?
Microwave, Laser, X-Ray …

What is a Typical Electronic Adhesive Made Up?

- **Typical Organic Adhesives (e.g. heat cure silicone, epoxy)**
  - Main Polymers (main reaction functional matrix). e.g. OH-PDMS, Vinyl-PDMS, DGEBA
  - Resins (polymer modifier) → Control flexibility viscosity
  - Chain Extenders (di-functional reaction regent, to make longer chain → To get high elongation
  - Cross-linkers (tri, or multi- functional reaction regents, to make cross-linked matrix) → to form crosslinked net work (thermal set) for high mechanical strength
    - E.g. multifunctional amine, multifunctional hydrogenated silane, TETA
  - Adhesion Promoters → One end linked to matrix, and another end attached to bonding surface
  - Catalyst (e.g. imidozal for epoxy, Hg for urethane, Pt for heat cure silicone, Sn for RTV, etc)
  - Plasticizers (for flexibility, control of Tg, etc)
  - Impact resistance modifiers (rubber)
  - Fillers (for rheological control, mechanical reinforcement, thermal or electrical conducting)
  - Viscosity modifiers
  - Defoamer (mfg to remove bubbles)
  - Solvents (for dispersion, wetting, as carrier etc)
  - Other additives (Dye, anti-gem, moisture control agent etc)

How to Select an Electronic Adhesive?

- For Typical Organic Adhesive used in Electronics
  - Rheological Property
    - Sprayable, Dispensable, Printable
  - Cure Mechanism / Methods
    - Solvent (including water) evaporation, hot melt, Heat cure, UV (free radical), Anaerobic, moisture, No-cure (PSA tape)
  - Easy of use
    - Two part mixing, one part, bubble removal, high volume dispensing/printing feasibility
  - Compatibility with other materials
    - Plastics, metals, solders, PCB, coatings, adhesives
  - Adhesion
    - Tensile (mechanical loading), Shear (thermal stress), Peel (tape)
    - Substances / Surfaces to bond to (plastics To metals)
    - Heat and moisture stability
    - Media resistance (chemicals, oil, solvent, corrosion) stability

How to Select an Electronic Adhesive? (contn'd)

- Mechanical properties
  - Flexibility / rigidity (Modulus, Shore A, D)
  - Strength (tensile at 1%, at break)
  - Elongation
  - CTE
- Thermal Stability (thermal aging, temperature rating)
- Thermal Conductivity / Resistivity
- Dielectricity / Voltage breakdown
  - Purity level; high voltage feasibility; etc
- Package (drum, pail, jar, bottle, cartridge, syringe)
- Shipping and storage (-40C, -14C, 4C, 24C)
- Cost
- Safety (toxicity, flammability, solvent VOL)
- Chemical and biological compatibility (REACH, RoHS)
- Disposability

Comparison of Several Typical Organic Adhesives

	Polyurethane	Acylic	Epoxy	Silicone
Max. Operation Temperature (C)	115	125	180	260
Rigidity (Modulus)	3	2	5	1
Flexibility	2	4	1	5
% Elongation	2	5	0	5
Low CTE	3	1	5	2
Adhesion	4	4	5	2
Bonding Strength	3	2	5	3
Moisture Resistance	4	1	3	5
Chemical Resistance	2	1	5	4
Dielectricity / Voltage breakdown	5	4	5	5
Cost	2	3	3	5

How does a Bonding Surface Affect Adhesion?

- Plastics
  - Relatively easier surfaces: PBT, PET, PVC, PC, Nylon (PA), Epoxy, Acrylic (PMMA)
    - Surface has polar functional groups such as: -CO-O-, -CO-NH-
    - Form covalent bonds, hydrogen bond, and VDW bonds
  - Relatively difficult surfaces: PPS, PI, ABS, PEEK, PPE
    - -C-S-C
    - Form hydrogen bond, and VDW bonds
  - Extremely difficult surfaes:PE, PP, Telfon (PTFE)
    - -C-C, -CF2-CF2-
- Metals
  - Al (Surface forming high density polar Al2O3 layer)
  - Steel (Chromate coatings), SS, SnPb
  - Gold (difficult surface to bond since no functional or polar groups)
  - How about SnO / SnO2?

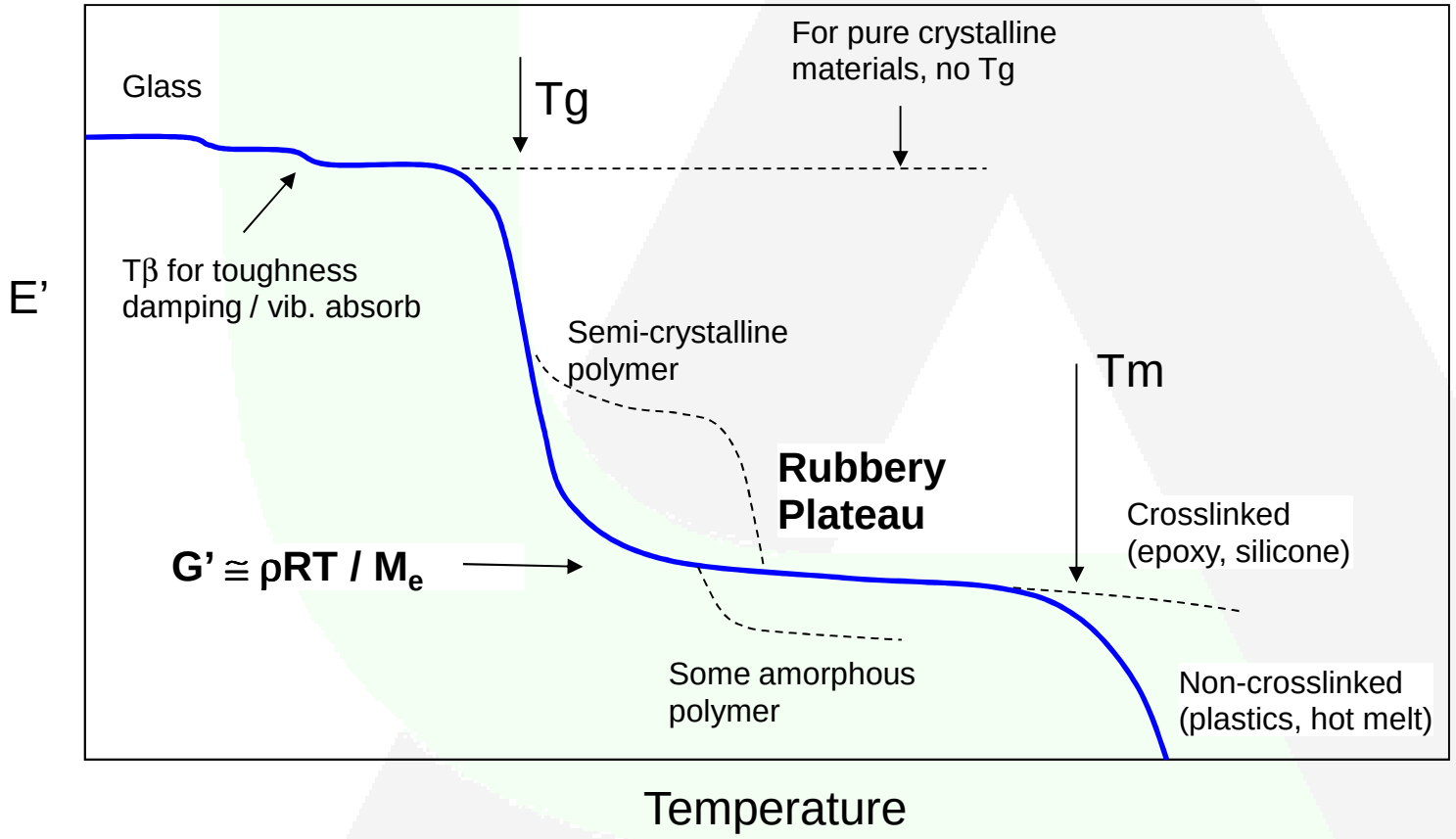
How to Prepare a Bonding Surface?

- Surface Cleaning
  - Detergent wash
  - Solvent wiping
  - Ultra Sonic
  - IPA, toluene, dichloromethane, trichloroenthane
- Radiation (UV, Laser, Ion Beams sputtering, etc)
- Plasma / Ion Beam
  - Ionize the surface molecular (generate functional bonding groups such as –OH, C=O, -COO-)
  - Clean of contaminations
- Chemical Etch (PE, PP, Teflon)
  - Generate functional bonding groups (-OH, -NH, C-O-C, etc)
  - Create mechanical interlock
- Mechanical Interlock
  - Sand blasting to make a rough surface
- Adhesion Promoters
  - Generate functional bonding groups, e.g. –Si-OH

Performance Window – Thermo Mechanical Properties

- Temperature Scan of Modulus of Polymer (DMA)

Bending / Stretching (Tγ) → Side Group (Tβ) → Main Chain Orientation (Tg, Tc) → Mina China Motion (Tm)



Surface Tension

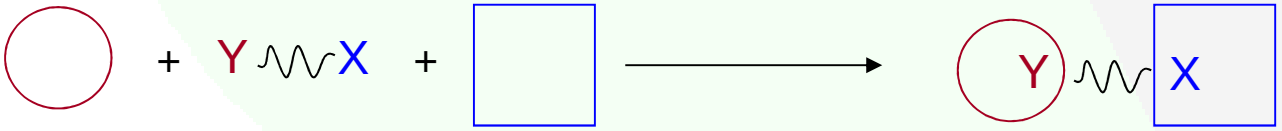
Materials	Surface tension (dyne/cm)
PTFE (Polytetrafluoroenthene)	18
Silicone	19
Polyethylene	31
Polypropylene	31
Acrylic Adhesive	35
PVC (polyvinylchloride)	39
PA (Nylon)	43
PET (polyethylene terephthalate)	43
Natural rubber	43

- Plasma treated PET/PBT → 60 to 70 dyne /cm
- Dyne Pen test on surface

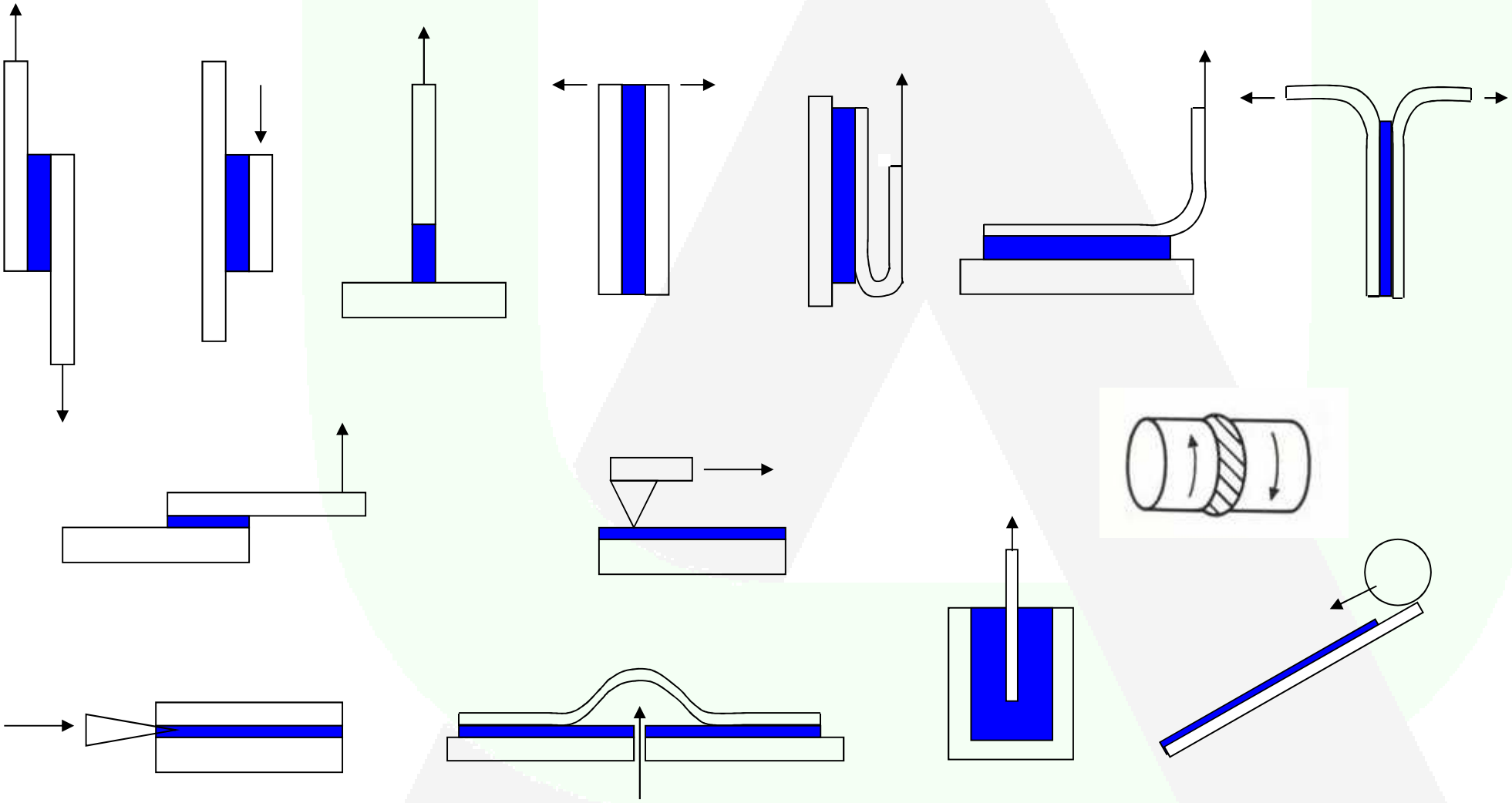
Bonding Process

- Adhesive must “wet” the substrate
- The surface energy of the adhesive must be lower than substrate
- Surface roughness and contaminations affect the adhesion
- After wetting, the adhesive must flow over the surface of the substrate
- Strength of bond depends upon the “chemistry” at the interface and the proximity for bond formation
- Any formation of Dipole-Dipole, Vader Waal, ionic and hydrogen bonds, and mechanical “lock” increases bond strength

- Adhesion Promoter / Primer (adhesion + protective)



Adhesion Test

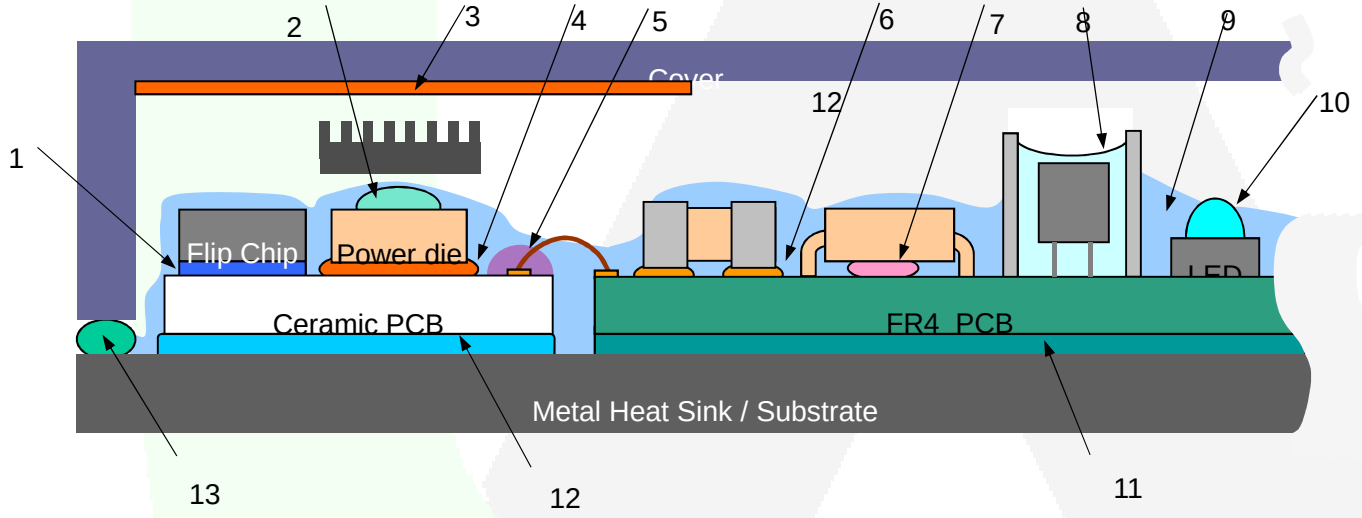


Adhesives and Sealants

- Functions
  - Sealant → Sealing / filling function to prevent the penetration of liquid (water), gas (air), dust, from getting through
  - Adhesive → Bonding function to keep object together to resistance thermal / mechanical variations
- Performance
  - Sealant → Can have lower strength and higher elongation
  - Adhesive → Need to have high bonding strength
- Life Time
  - Sealant → Maintains sealing properties for the expected lifetime, service conditions and environments without a signal defect (leaking)
  - Adhesive → Maintains bonding properties for the expected lifetime, service conditions and environments even with limited defects (delamination)

Applications

- A Typical Application on an Electronic Module



1. Underfills and Encapsulants)
2. Thermally Conductive Adhesives
3. EMI Shielding and Coating
4. Electrically or Thermally Conductive Adhesives
5. Non-Sag Adhesives or Gels
6. Electrically Conductive Adhesives
7. High Performance Epoxy or Low CTE Epoxy
8. Low CTE Adhesives)
9. Conformal Coating or Perfluoro coating or Encapsulation)
10. Epoxy Adhesives for Special Applications)
11. Thermal Gap Filling Materials)
12. Thermally Conductive Adhesives)
13. RTV or Heat Cure Adhesives & Sealants)