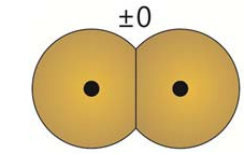
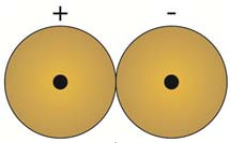
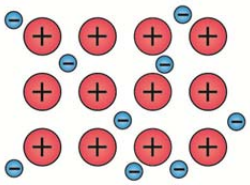
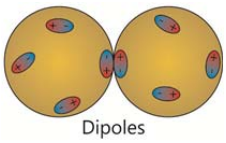
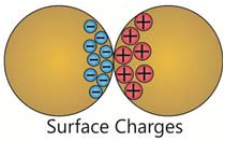
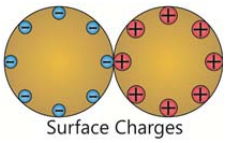
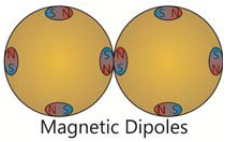
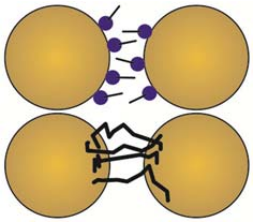
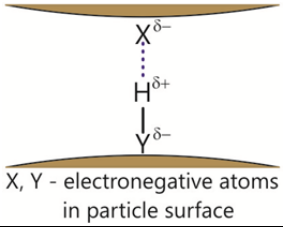
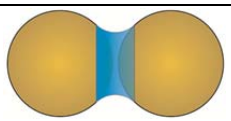
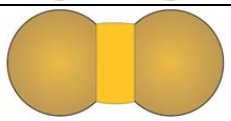
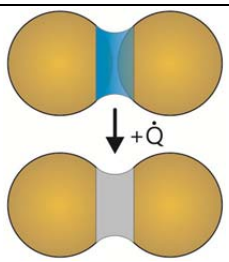
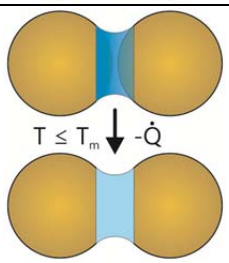
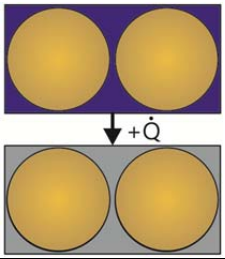
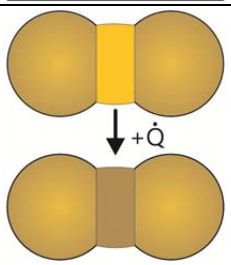
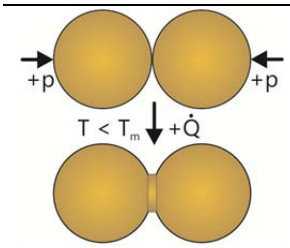
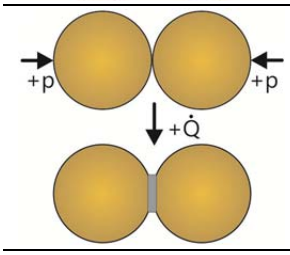
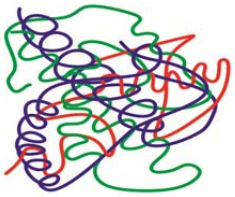
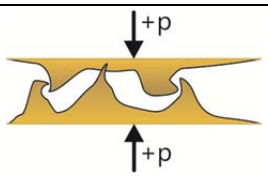
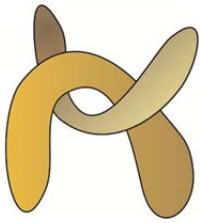
Essential Chemical Bonds and Mechanisms of Particle Adhesion as well as Micro-Processes of Inter-Particular Bonds

Scheme of operation principle	Mechanism	Physical operation principle	Example
Chemical bonds in solids			
	Covalent bond	Formation of shared electron pairs between atoms	Diamond
	Ionic bonding	Weakly electronegative atom loses valence electron/s to a strongly electronegative atom	Sodium chloride (NaCl)
	Metallic bonding	Electron cloud of delocalized electrons among the structure of cations (jellium)	Metals, alloys
Mechanisms of particle adhesion as well as micro-processes of inter-particular bonds			
• **Surface and field forces at direct contact of particles**			
	Van der Waals forces	Electric dipole moments (permanent, instantaneous, induced dipoles)	Adhesion of chalk on blackboard, gecko, crystal structure of the noble gases
	Electrostatic forces	between particles with different charges (Coulomb force)	
	→ electrical conductor	Contact electrification	Contact and separation of two different conductors
	→ electrical non-conductor/isolator	Triboelectric effect	Comb ←→ hair, rubbed amber
	Magnetic force	Magnetic dipole	Magnet
• **Inter-particular material bridges**			
	Short- and long-chain organic molecules	Flocculation in suspensions due to organic macro-molecules adhering on the particles	Flocculating agents (polyacrylamide, acrylate polymers)
	Hydrogen bonds	Between -OH, -NH_2 or similar groups in particle surfaces or in adsorbed surface layers of condensed water	In layered silicate minerals (e.g. kaolinite), stabilization of protein structures

	Liquid bridge bonds due to		
	→ lowly viscous wetting liquids	Capillary pressure, surface tension, wettability	Wet sand
	→ highly viscous liquid/bond agent	Cohesion inside the binder, adhesion between binder and particles; no formation of capillary radius/meniscus due to high viscosity	Resins, wax, honey
	Solid bridge bonds due to		
	→ crystallization	Crystallizing of dissolved substances during drying	Salt, sugar
	→ freezing of liquid bridges	Cooling up to or below freezing point ($T \leq T_m$)	frozen coal
	→ solidification of a binder by chemical reaction	Chemical reaction with adsorbed surface layers, carbonation, etc.	Lime, cement hydration → concrete
	→ solidification of a highly viscous bond agent	Drying of the solvent; cross-linking due to polymerization, -condensation, -addition under adding an accelerator, etc.	Solidifying glue, adhesive, resin, polyester resin
	→ sintering	Contact fusion under increased pressure and increased temperature slightly below melting point ($T < T_m$)	Ceramic, powder metallurgy
	→ chemical solid-solid reactions	Chemical reaction at the particle contacts	Cross-linking of particles due to polymerization, -condensation, -addition

- **Interlocking by macromolecular and particle shape effects**

	→ of macromolecular chains		Proteins
	→ of surface roughness	Overlaps and indentation at particle contacts	Wood pellets, briquetting of swarfs
	→ of particles of exceptional shape (hook-like)		Burdock, hook-and-loop fastener

In extension of the lectures:

„Schüttguttechnik“, Dr. P. Mueller, held at Magdeburg-Stendal University of Applied Sciences, 2009 – 2018

„Partikelmechanik und Schüttguttechnik“, Dr. P. Mueller, held at OvGU Magdeburg, 2018