

Materials and Introduction to Manufacturing

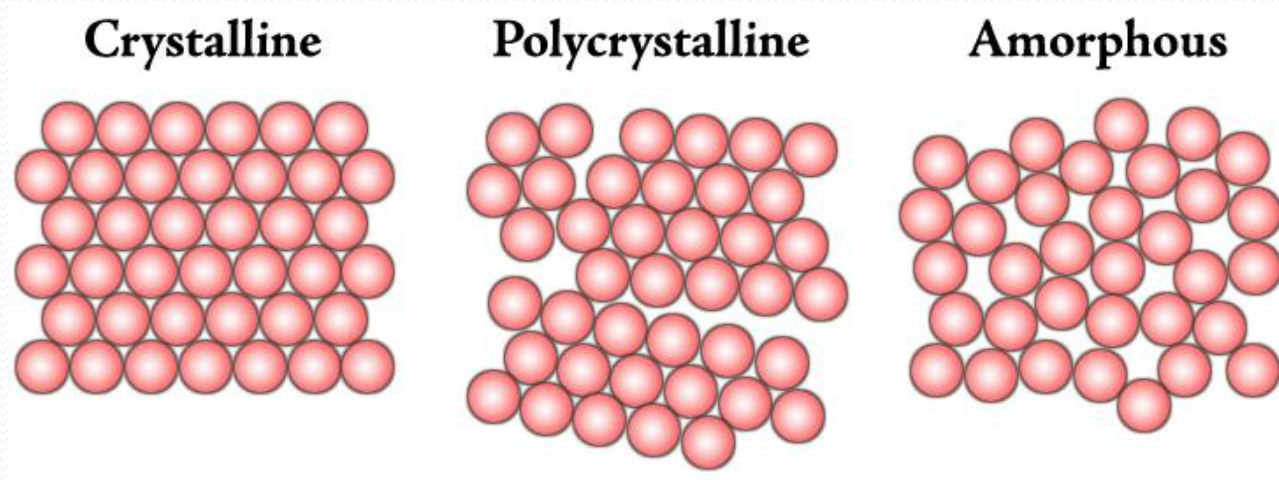
Glass Transition

Glass Transition Temperature

Polymers and glasses change from relatively hard or brittle materials into a soft viscous state when their temperatures are elevated

The temperature at which this occurs is known as the glass transition temperature and its symbol is T_g

Types of molecular structure



Crystalline materials have long range order.

Crystalline materials include ceramics, some metals and some polymers

Polycrystalline materials have some regions of order.

Alloys are common forms of polycrystalline material

Amorphous materials have no long range order

Glass and most plastics are amorphous

Crystalline materials

- When crystalline materials reach a high enough temperature the molecules within them have enough energy to break the bonds holding them within the crystalline structure. When this occurs the material melts i.e it turns from a solid into a liquid

Amorphous materials

Due to the lack of long range order within Amorphous materials there is a large amount of 'free volume'

This allows the molecules to move around when heated and yet retain some bonds with neighbouring molecules

It is the ability of the amorphous materials to maintain some of these bonds which gives them a viscous state rather than melt into a true liquid such as occurs in crystalline materials

T_g for common polymers

Material ♦	T _g (°C) ♦	T _g (°F) ♦	Commercial name ♦
Tire rubber	-70	-94 ^[20]	
Polyvinylidene fluoride (PVDF)	-35	-31 ^[21]	
Polypropylene (PP atactic)	-20	-4 ^[22]	
Polyvinyl fluoride (PVF)	-20	-4 ^[21]	
Polypropylene (PP isotactic)	0	32 ^[22]	
Poly-3-hydroxybutyrate (PHB)	15	59 ^[22]	
Poly(vinyl acetate) (PVAc)	30	86 ^[22]	
Polychlorotrifluoroethylene (PCTFE)	45	113 ^[21]	
Polyamide (PA)	47–60	117–140	Nylon-6,x
Poly(lactic acid) (PLA)	60–65	140–149	
Polyethylene terephthalate (PET)	70	158 ^[22]	
Poly(vinyl chloride) (PVC)	80	176 ^[22]	
Poly(vinyl alcohol) (PVA)	85	185 ^[22]	
Polystyrene (PS)	95	203 ^[22]	
Poly(methyl methacrylate) (PMMA atactic)	105	221 ^[22]	Plexiglas, Perspex
Acrylonitrile butadiene styrene (ABS)	105	221 ^[23]	
Polytetrafluoroethylene (PTFE)	115	239 ^[24]	Teflon
Poly(carbonate) (PC)	145	293 ^[22]	Lexan
Polysulfone	185	365	
Polynorbornene	215	419 ^[22]	

T_g for ceramics and glasses

Silicates and other covalent network glasses

Material	T_g (°C)	T_g (°F)
Chalcogenide GeSbTe	150	302 ^[29]
Chalcogenide AsGeSeTe	245	473
ZBLAN fluoride glass	235	455
Tellurium dioxide	280	536
Fluoroaluminate	400	752
Soda-lime glass	520–600	968–1,112
Fused quartz (approximate)	1,200	2,200 ^[30]

Cooling of materials past T_g

- The rate at which glass and some ceramic materials are cooled determine their properties
- Glass is cooled quickly to retain an amorphous structure
- If cooled slowly, glass will have more crystallinity which affects transparency due to grain boundaries reflecting light