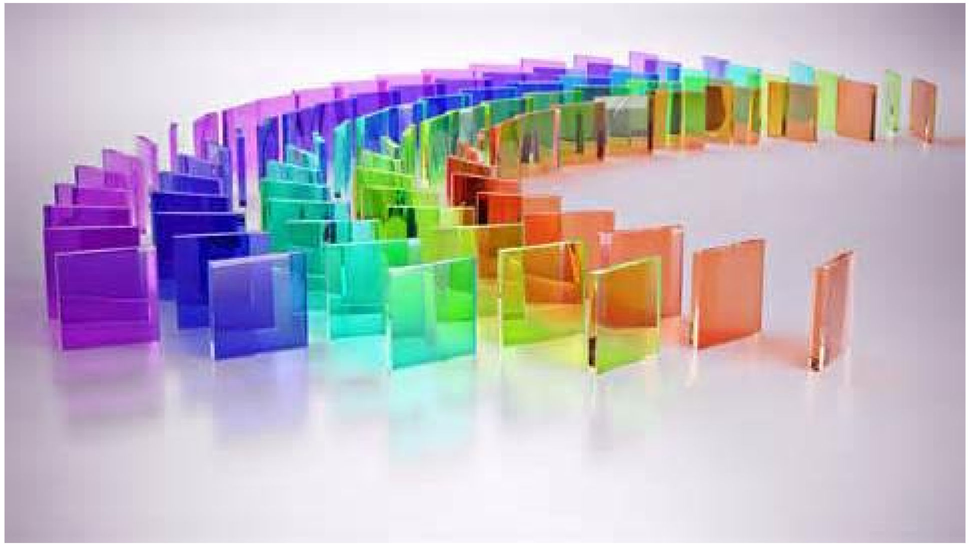
CERAMICS, GLASS AND REFRACTORIES

DR KASSIM AL-JOUBORY
UNIVERSITY OF TECHNOLOGY
BAGHDAD - IRAQ

3) Glass Constituents and Properties



Dr. Kassim Al-joubory - University of Technology - Baghdad - Iraq

CONSTITUENTS OF GLASSES

3 types of oxides

Glass Formers

SiO_2 and B_2O_3

- **SiO_2: Fundamental** sub-unit : **SiO_4^{4-} tetrahedra**
- **B_2O_3: Fundamental** Sub-unit : plane triangles BO_3^{3-} ⇨ triangles BO_3^{3-} become BO_4^{4-} tetrahedra when we add oxides of alkaline M and alkaline earths. The cations give electroneutrality. The glasses that are made only of B_2O_3 have little durability .
- Normally we add B_2O_3 to SiO_2: ***borosilicate glasses***

Glass modifiers

(Na_2O, K_2O) and (CaO and MgO)

- Are the oxides that **brake the silicate lattice**
- Alkaline (Na_2O, K_2O) alkaline earths (CaO y MgO)
- They are accommodated in interstitials (do not form part of the silicate lattice)
- ↓ **viscosity** ⇨ facilitates moulding and workability

Intermediates: Al_2O_3

DO NOT form glasses only by themselves.

They are incorporated in the silicate lattice

- **Al_2O_3** ⇨tetrahedra AlO_4^{4-} replacing SiO_4^{4-}
- **Charge defects** (Al^{3+}: Si^{4+}) compensating with alkaline cations and alkaline earths .

Improve special properties :

- **Al_2O_3** ⇨ ↑ strength at high T (***aluminosilicate glasses)***
- **PbO**
  - Modifies optical properties
  - ↓ T_f (glass soldering)
  - Radiation protection of ↑ E

CONSTITUENTS OF GLASSES

Substances constituents of glasses

COLOURS THAT METALLIC IONS GIVE TO GLASSES		
	M^+ as a MODIFIER	
ION	C. I.	COLOUR
Cr^{3+}	6	Blue
Cr^{6+}	6	Green
Cu^{2+}	8	Blue –green
Cu^{+}	6-8	Transparent
Co^{2+}	6-8	Rose
Ni^{2+}	8	Yellow –green
Mn^{2+}	6	Light orange
Mn^{3+}	6-8	
Fe^{2+}	6	Blue-green
Fe^{3+}	6-10	Light yellow
U^{6+}	6	Light yellow
V^{3+}	6	Green
V^{4+}		Blue

Type of Glasses and Applications

- Soda-lime Glass

70% SiO_2, 10% CaO, 15%Na_2O, 5% MgO / Al_2O_3:
Windows, bottles etc.
Low melting/softening point, easily formed

- Borosilicate Glass (Pyrex)

80% SiO_2, 13% B_2O_3, 4% Na_2O, 3% Al_2O_3:
Cooking and chemical glassware.
High temperature strength, low coefficient of thermal expansion (CTE), good thermal shock resistance

-**Glass-Ceramic**

The term mainly refers to a mix of lithium and aluminosilicates that yields an array of materials with interesting thermomechanical properties.

60% SiO_2, 20% Al_2O_3, 20% Li_2O, + TiO_2 (nucleating agent): cooker tops, ceramic composites. Heat treatment causes glass to crystallize to form crystal/amorphous composite with greater creep resistance and very low CTE – hence excellent thermal shock resistance.


LAS glass ceramic system

Thermal Tempering of Glass

Glass can be significantly strengthened by a process referred to as *thermal tempering*, which introduces a state of compressive residual stresses on the surface.
The appropriate thermal process, involves heating the glass body to a temperature above its glass transition temperature, followed by a two-step quenching process

PROPERTIES OF GLASSES

Mechanical Properties

Brittle Materials (↑↑ elastic modulus) = f (composition, macroscopic (surface) imperfections, volume of material and T)

Low modulus of Weibull

Mechanical strength ↓ (presence of water/air + humidity)

Electrical Properties

Generally insulators ($\sigma \approx 10^{-10} - 10^{-20}\ \Omega cm^{-1}$)

σ↑↑ with Temperature

σ↑↑ with modifier (=f(size and amount of modifier))

Thermal Shock

$$\uparrow\uparrow\alpha = \downarrow R_{thermal\ shock}$$

Material	Thermal Expansion coeff. ($°C^{-1}$)	Thermal Shock failure (°C)
Soda-lime glass	10^{-5}	80
Sodium borosilicate (Pyrex ™ type)	10^{-4}	270
Fused silica	10^{-6}	1600
Lithia-alumina-silicate glass ceramic (Pyroceram ™ type)	10^{-6}	670
Transparent lithia-alumina-silicate glass ceramic (Visions ™ type)	10^{-6}	1330

Thermal shock resistance of common glasses and glass ceramics

NON CRYSTALLINE CERAMICS : GLASSES

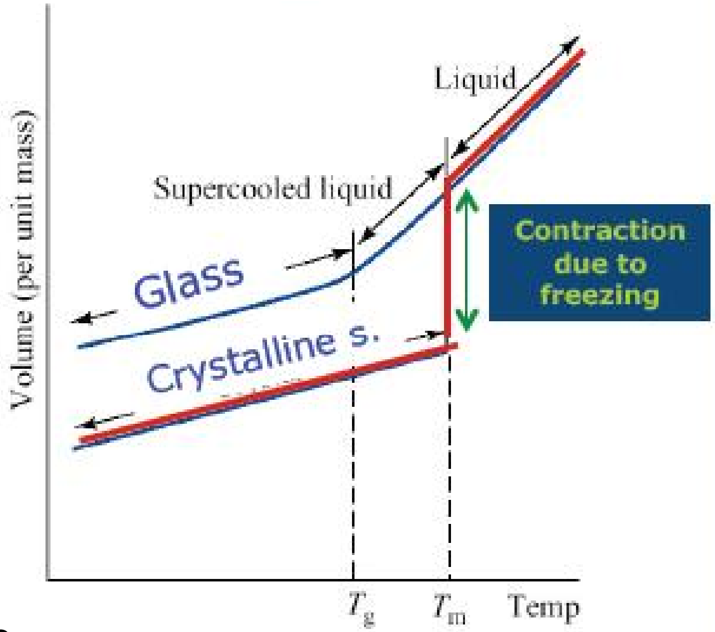
Behaviour of glass during solidification

Crystalline Solid

As ↓T crystallizes in T_m

GLASS

As ↓T: ↑viscosity
Plastic stage ⇔ Rigid stage



Glass transition temperature Tg : temperature at which a glass-forming liquid transforms from a rubbery, soft plastic state to a rigid, brittle, glassy state

Glasses:

Lack of long range order of constituent atoms
Do not have a sharp melting point and do not cleave like crystals
Solid at low temp, soften at intermediate temp and liquid at high temp
Show elasticity up to fracture (like crystal solid)

Cleavage of quartz crystal

CRYSTALLINE MATERIALS

CRYSTAL: Highly ordered two or three dimensional network of atoms or ions, the repeat pattern theoretically extend to infinity in all directions.

Crystal → Sharp melting point

SINGLE CRYSTAL: Have in theory continuous order throughout the material (can extend to over many cms)

POLYCRYSTALLINE MATERIAL: Consist of a collection of "welded" single crystals (grains)