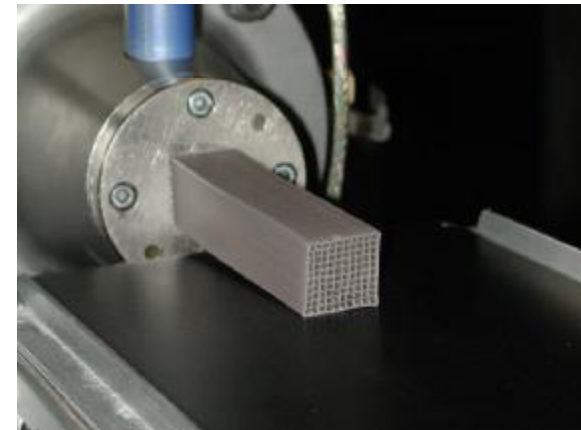


# **INTRODUCTION TO CERAMICS, GLASS AND REFRACTORIES**

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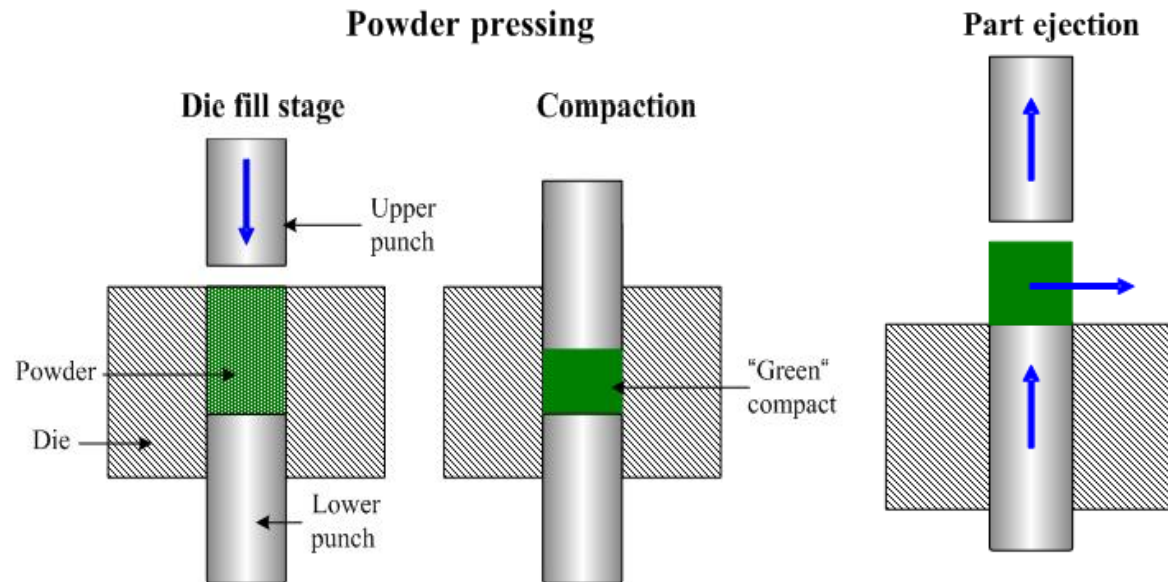
# 7) Shape Forming Processes



## Uniaxial (Die) Pressing

Involve the compaction of powder into rigid die by applying pressure along a single axial direction through a rigid punch, plunger or piston. Often required a binder and lubricant to increase the flowability of the powder and to give the pressed part enough strength for handling and or machining.

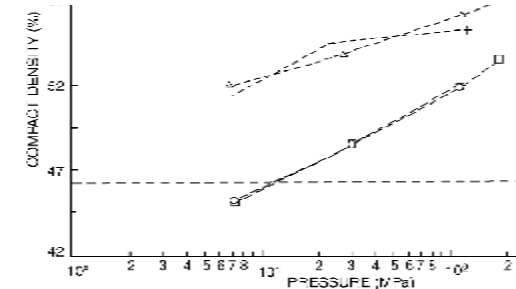
Compaction of powder is made by pushing down upper punch with a predetermined pressure. The pressure varies between 69 MPa - 830 MPa (10,000 psi - 120,000 psi).



Hydraulic and mechanical presses with load up to 750 tons are used for the powder die pressing.

# “Green” compact part ejection and removal (“green” compact–unsintered powder compact).

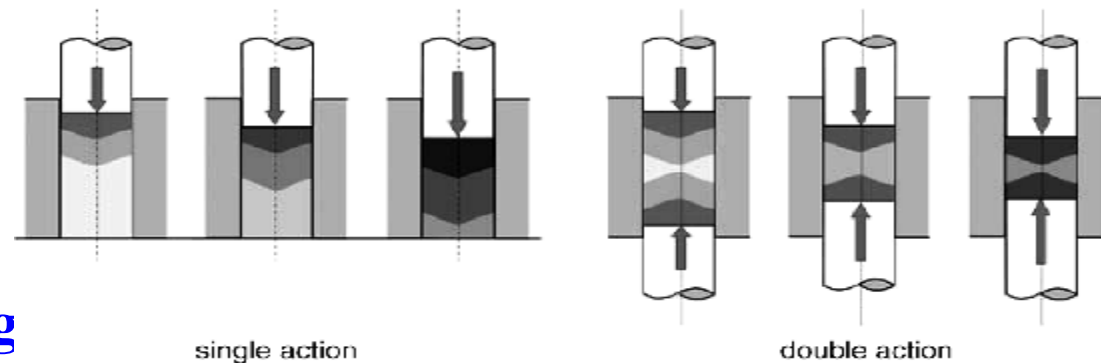
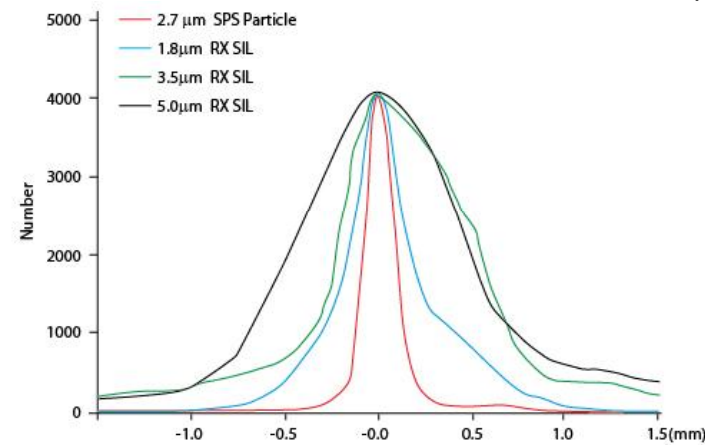
The degree of compaction (bulk density) is a linear function of log pressure. Typical pressed densities would be 45% to 65% of theoretical density.



A wide size distribution range powder tends to pack better than a narrow size range powder,

**Problems encountered with uniaxial pressing can be;**

**Density variation due to die-wall friction and particle-particle friction, improper size, die wear, lamination and cracking due to inadequate de-airing**



Die –wall friction lead to vertical decrease of compaction pressure.  
Too high an applied pressure tends to cause end-capping and lamination.  
Evacuation of the mould ahead of compaction prevent air compression in the pressed body and is effective in preventing lamination, while ensuring a homogenous distribution of density

dynamic (Vibro) impact pressing used for refractories does not require immensely strong mould construction and high capacity press and thus contribute to low cost production

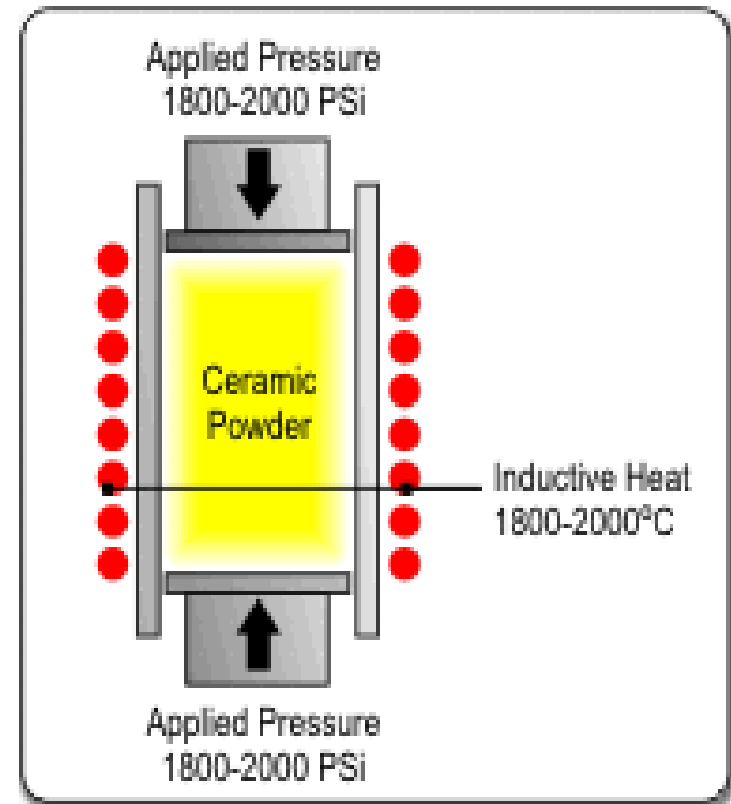
Die pressing, which is conducted at the room temperature is called **cold pressing**.

If the pressing process is conducted at increased temperature it is called **hot pressing**.

## Hot Pressing

In this process heat is produced within the mould when it is subjected to a high frequency electromagnetic field, generated by using an induction coil coupled to an electronic generator. The mold or die is made out of graphite, and pressure is applied onto punches. The graphite die is filled with ceramic powder and positioned within the induction coil. The high temperature provided by the induction coil and external pressure applied can lead to near theoretical density.

For example hot pressing of SiC is carried out at temperature about 2000°C.



## Isostatic Pressing

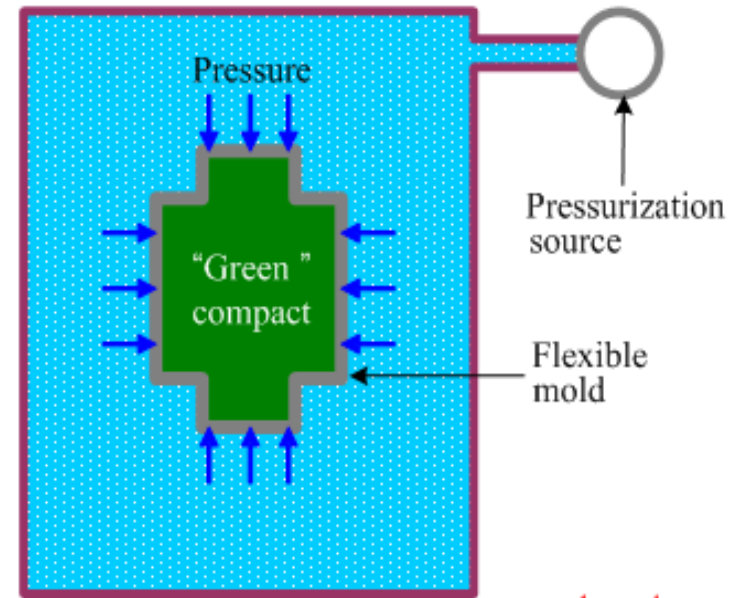
*Isostatic pressing* is the powder compaction method involving applying pressure from all directions through a liquid or gaseous medium surrounding the powder which is loaded into air-tight mould.

### Cold isostatic pressing (CIP)

is conducted at room temperature. Typical applied pressure is 7.0 MPa-137 MPa. The powder is loaded in a flexible (commonly Polyurethane) mould surrounded with perforated metal canister and immersed in a pressurized liquid medium (commonly water)

There are two types of cold isostatic pressing: **wet bag** and **dry bag**.

Cold isostatic pressing



In the **wet bag** method the mould is removed and refilled after each pressure cycle. This method is suitable for compaction of large and complicated parts.

In the **dry bag** method the mould is an integral part of the vessel. The dry bag method is used for compaction of simpler and smaller parts like spark plugs.

*The cold isostatic pressing (CIP) method has the following advantages as compared to the die cold pressing method:*

- Product uniformity
- More complex forms (for example long thin-walled tubes) may be compacted;
- High green strength permits possible machining

Consideration:

- Compaction ratio CR (volume change) =  $\frac{\text{unpressed compact } V_1}{\text{pressed compact } V_2}$
- Vibration of the mould prior to pressing
- Preferred evacuation of mould prior to pressing
- Mould size calculation: mould volume = volume of fired piece + firing shrinkage volume + shrinkage volume due to compaction:  $L_2 = \sqrt[3]{CR} L_1$  and  $D_2 = \sqrt[3]{CR} D_1$





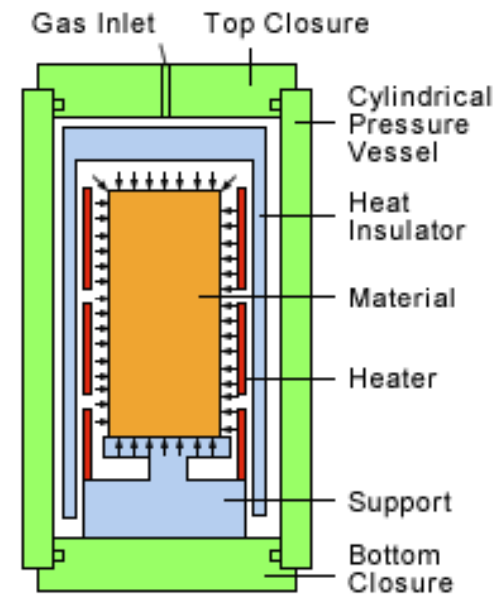
## Hot Isostatic Pressing: (HIP)

involves isostatic pressing conducted at increased temperature.

As a pressure medium a gas (Nitrogen or Argon) is used.

The work pressures, which are applied in the hot isostatic pressing method, are commonly between 100 MPa to 300 MPa.

Hot isostatic method (HIP) combines pressing and sintering, causing consolidation of powder particles, healing voids and pores. The part shrinks and densifies, forming high strength structure with density near theoretical density. Cans made of stainless steel or mild steel are used in the method.



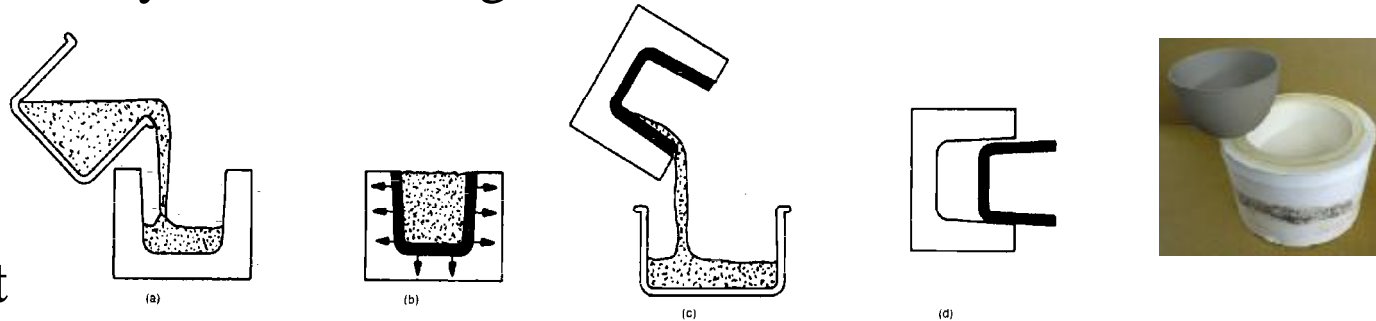
The method may be used without a mould. In this case the part is first compacted by cold isostatic pressing method, and then it is sintered in order to close the interconnecting porosity. The sintered (but still porous) part is then pressed isostatically at high temperature without any can (mould).

## Slurry Infiltration (Slip Casting)

Refers to the filling of a plaster of Paris mould, a negative of the desired shape with slurry. The slurry consist of a carrier liquid (water or solvent), ceramic powder (micrometer size) an organic binder and dispersing agent.

### **Gravitational (Drain Cast)**

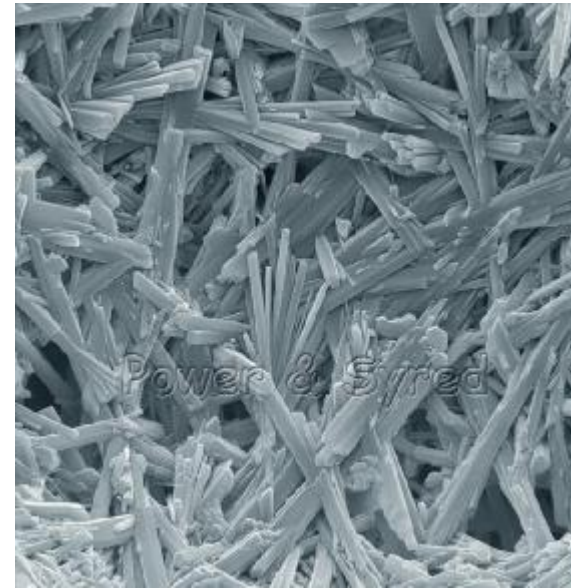
The slurry is poured into a mould made which is capable to soak the liquid from the slurry, consolidating the ceramic part.



### **Pressure Cast**

Multi pieces plaster of Paris mould or porous resin mould is filled with pressurised slurry under pneumatic or hydraulic action to consolidate large block of porous refractories, sanitary ware, fibre composites and solid articles.

This process results in high densification, faster casting cycle and drying times and large production rate.



Plaster of Paris needles crystal structure



## Dispersion of ceramic Powder

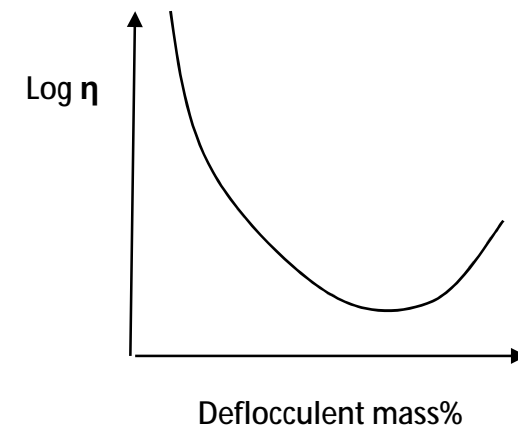
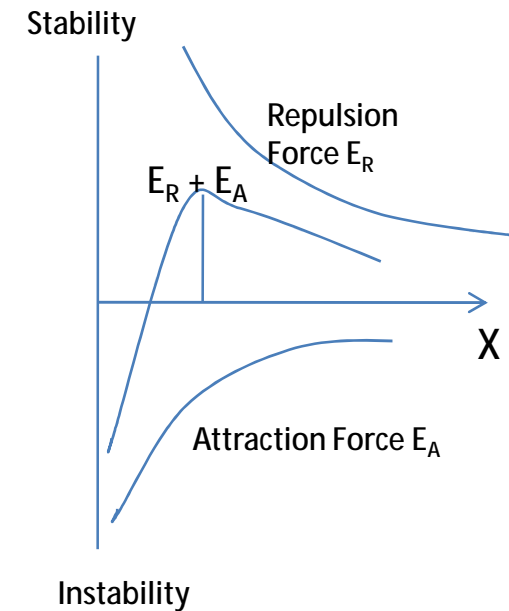
Solid particles suspended in a liquid medium become electrically charged (like sign)

If the repulsion force is greater than Vander Waals force the system deflocculate.

The charge at the surface of particles is controlled by pH of the liquid and by addition of chemicals (Acids, Alkalise) that supply monovalent cations ( $\text{Na}^+$ ,  $\text{NH}_4^+$ ) for absorption at the surface of particles. Controlling the charge zone around the particles achieve good repulsion.

Addition of 0.05% - 0.5% of surfactants such as Polysilicates, Polyacrylates (Dispex A40), Polyphosphates (Calgon) and provides uniform steric charges around the particles and thus provides good suspension and reduced viscosity.

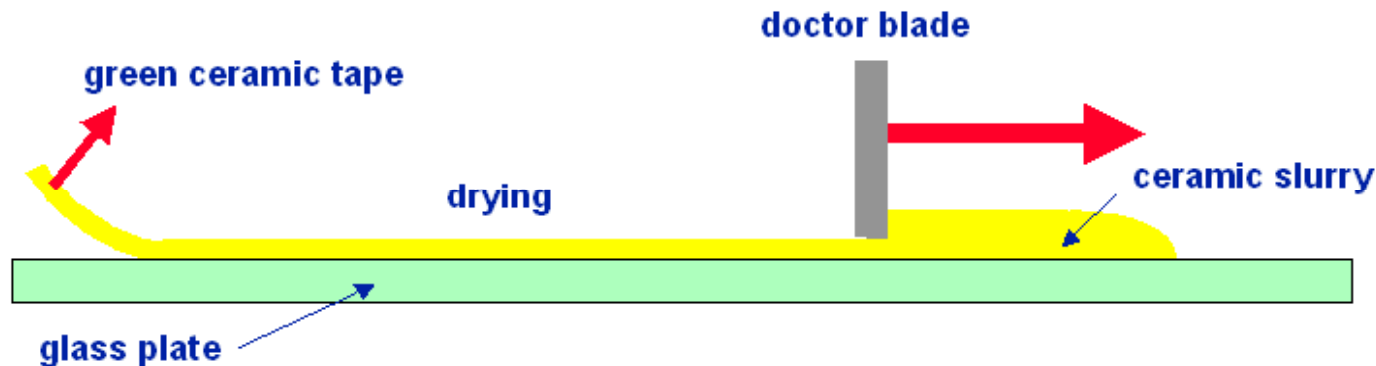
Most common binders are poly(vinyl alcohol) (PVA) or poly(vinyl butyral) (PVB)



## Tape Casting

*Tape Casting* is a forming method of flat, thin tapes with surface area up to  $1\text{m}^2$  and thickness of a layer between 0,1-2,0 mm. This process involves the casting of a slurry onto flat moving carrier surface..

The slurry film thickness is controlled by a knife edge located above the moving carrier surface.



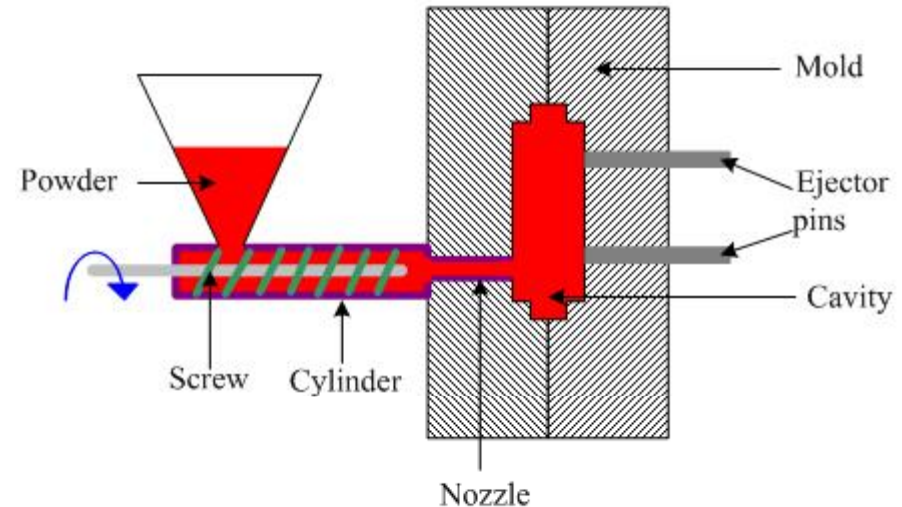
The solvent, containing in the slurry, evaporate to leave a relatively dense flexible ceramic sheet, which may be stripped from the carrier in a continuous process.

Tape Casting is used for manufacturing multilayer inductors, varistors, piezoelectrics, ceramic fuel cells and lithium ion battery components.

## Injection Moulding

**Injection moulding** is the method of compaction of a mixture of ceramic powder and binder fed and injected into a mould cavity by means of a screw rotating in cylinder.

- **Mixing** the ceramic powder with 30% - 40% of a binder – low melt polymer.
- **Injection** of the warm powder with molten binder into the mould by means of the screw.
- **Removal of the part** from the mould after cooling down of the mixture.



- **Debinding** – removal of the binder. There are two debinding methods:
  - Solvent debinding – the binder is dissolved by a solvent or by water;
  - Thermal debinding – the binder is heated above the volatilization temperature.
- **Sintering** the “green” compact.

Injection moulding method is widely used for manufacturing small parts having complex shapes with close tolerance, due to the consistent shrinkage. This shrinkage is taken into account in the mould design.

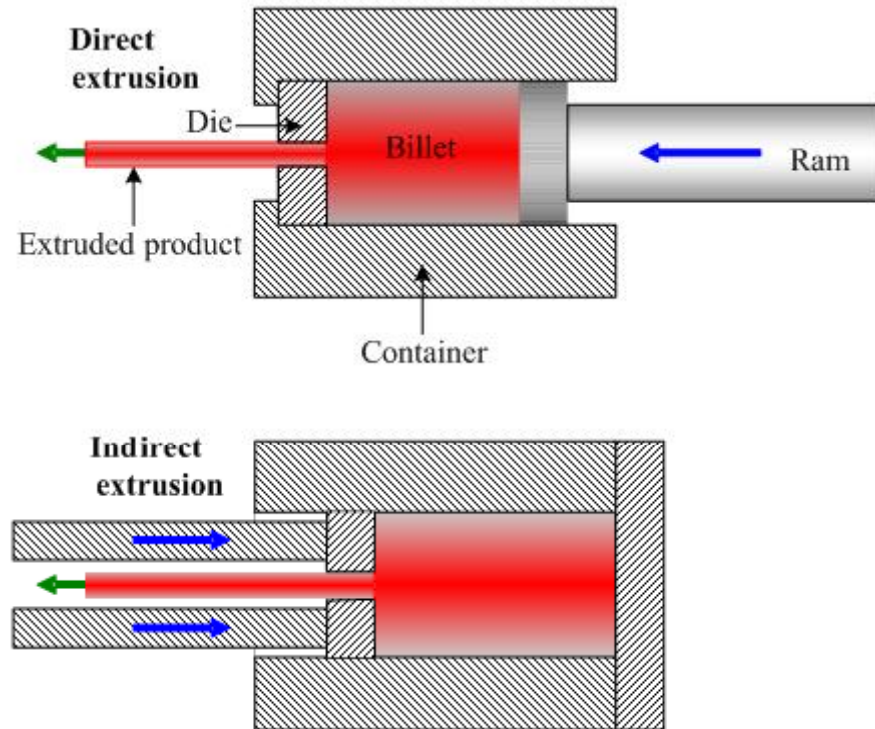
## Extrusion:

In this method a stiff-plastic mix is forced through a die orifice to produce a column cross section.

The two possible schemes of extrusion are presented in the picture:

Extrusion ram forces the ceramic paste through a die, resulting in a long product (rods, bars, long plates, pipes) of regular cross-section, which may be cut into pieces of required length.

Extrusion is used for manufacturing furnace tubes, thermocouple components, heat exchanger tubes.

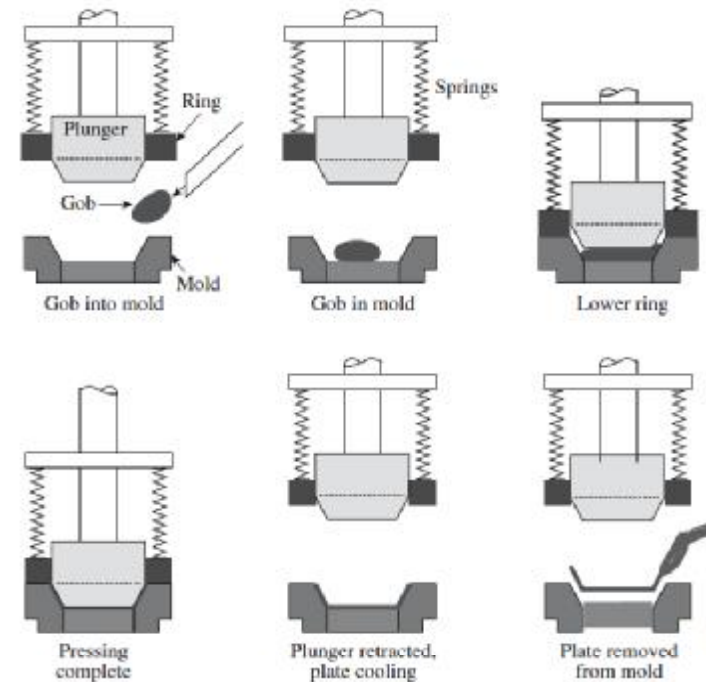




# SHAPING GLASS

Glass can be shaped by many different processes.

Casting or molding: is accomplished by dropping a hot gob of glass into a mold, then pressing it with a plunger until it spreads and fills the inside of the mold. Cast of less than 1mm up to 500 mm thick such as telescope mirror. Pressing mould used are cast iron, st, st. and bronz



Glass blowing: Temperature is critical since it determines the working range, other factors such as air pressure and gravitational and centrifugal forces produced by the blower.

Drawing: is used for glass tubes and sheets. Sheets are drawn using a slot orifice, with an overflow pipe, using updraw or floating. is shaped by drawing a wide sheet of molten glass into a furnace containing a bath of molten tin. This furnace is called a *float bath* because the glass "floats" in an even layer on the perfectly smooth surface of the molten tin.

Spinning: is used for fibers formation