

Ciao



# SINTERING PROCESS OF ADVANCED CERAMICS







# Different climate



13 AUG: Fariman 10 °C & Shoshtar 51 °C

Coldest place: Saghez -46 °C

Hottest place : Gandom beryan 71 °C













# Materials and Energy Research Center (MERC)

- 80 Faculty member
- 1971 Started
- first PhD program was established in 1991
- MERC Departments:

- Energy
- Ceramics
- Semiconductors
- Nano-Technology and Advanced Materials







# MATERIALS

## State of Materials



**Solid**

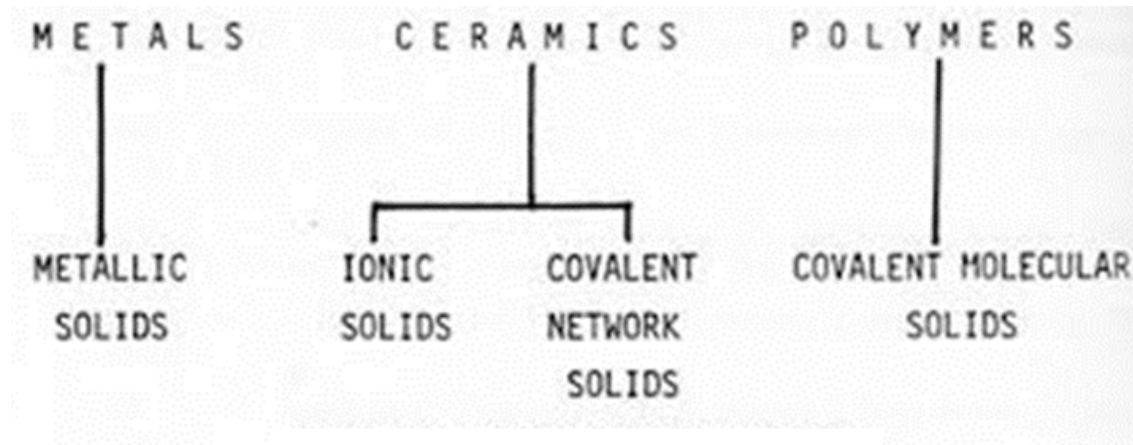


**Liquid**



**Gas**

# Solid Materials



**Density of Solid Materials**

Solid Material	Density (g/cm <sup>3</sup> )
copper	8.90
plastic	1.17
rubber	1.34
wood	0.71



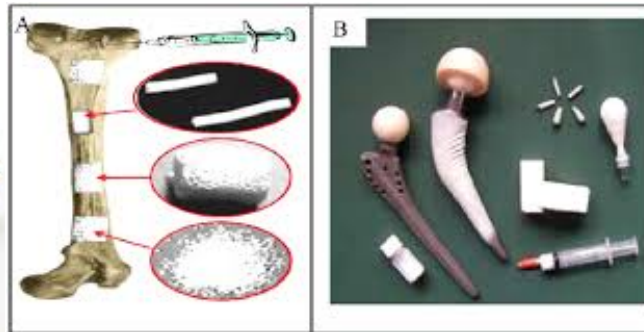
# CERAMICS

Art and science of making and using of inorganic nonmetallic materials

Clay products



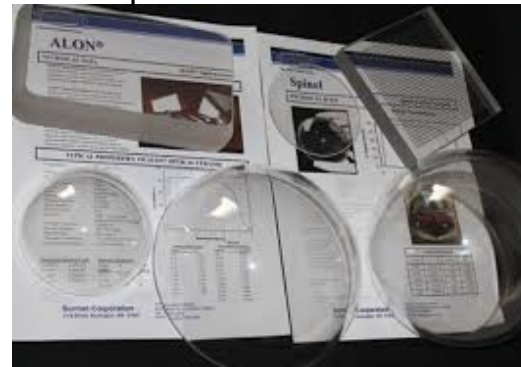
Bio ceramics



Refractories



Optical ceramics



Engineering ceramics

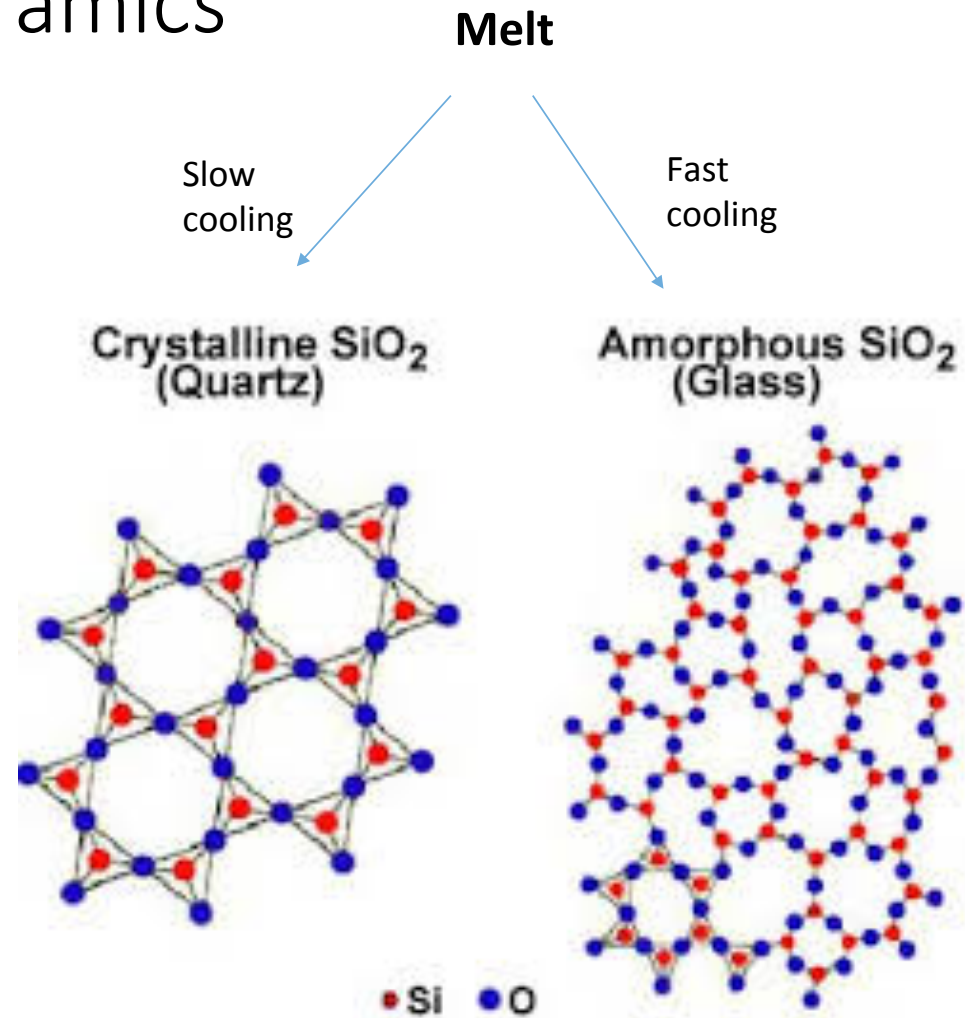
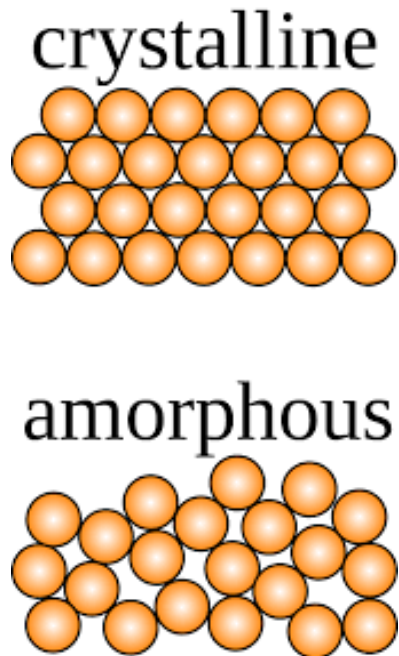


Electro ceramics



# ceramics

- Glass
- crystals





# Ceramics

- **Traditional Ceramics** (clay products, Refractories, Bricks and Tiles, White wares, Abrasive,... )
- **Modern Ceramics**, Advanced ceramics, Functional Ceramics:  
(Optical ceramics, Magnetic ceramics, Bio ceramics, Non oxide ceramics, Engineering ceramics,

# Advanced ceramics

- Mechanical properties
- Electrical properties
- Magnetic properties
- Biological properties
- Thermal properties

# CERAMIC PROCESS

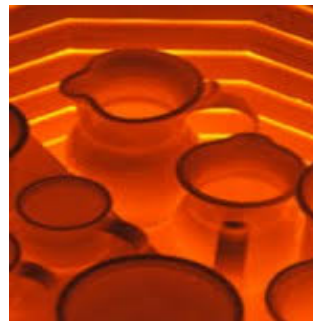
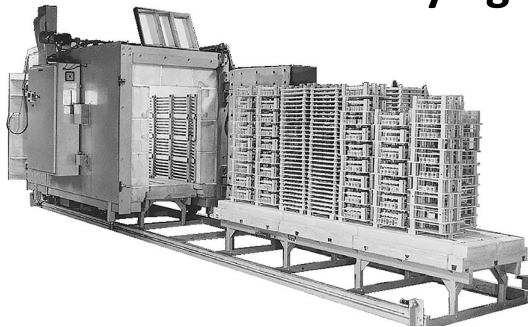
## 1- Raw materials preparation



## 2- Forming



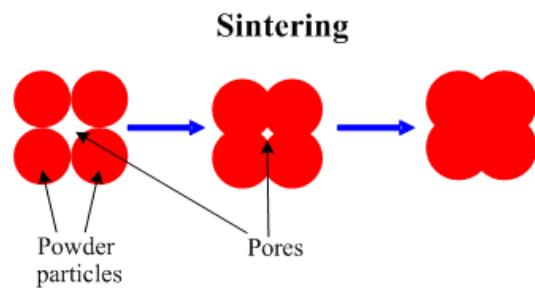
## 3- Drying and firing



# Ceramics firing

- Dehydration
- Burn-Off
- Decomposition
- Phase transformation
- Sintering

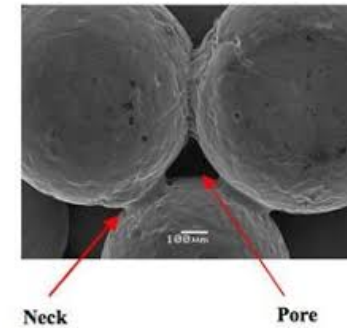
# sintering





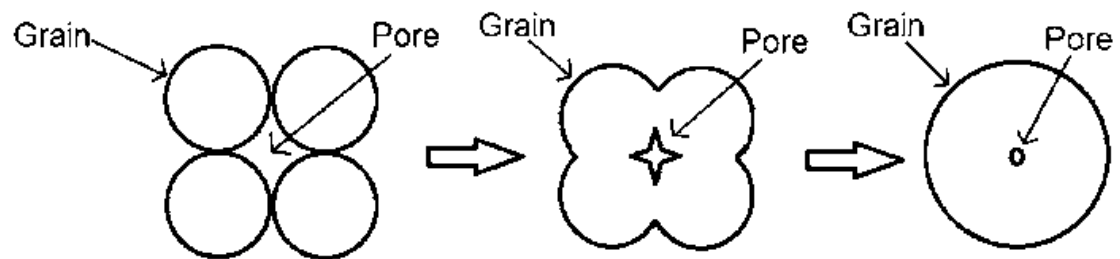
# Sintering stage

- **First stage:** neck formation

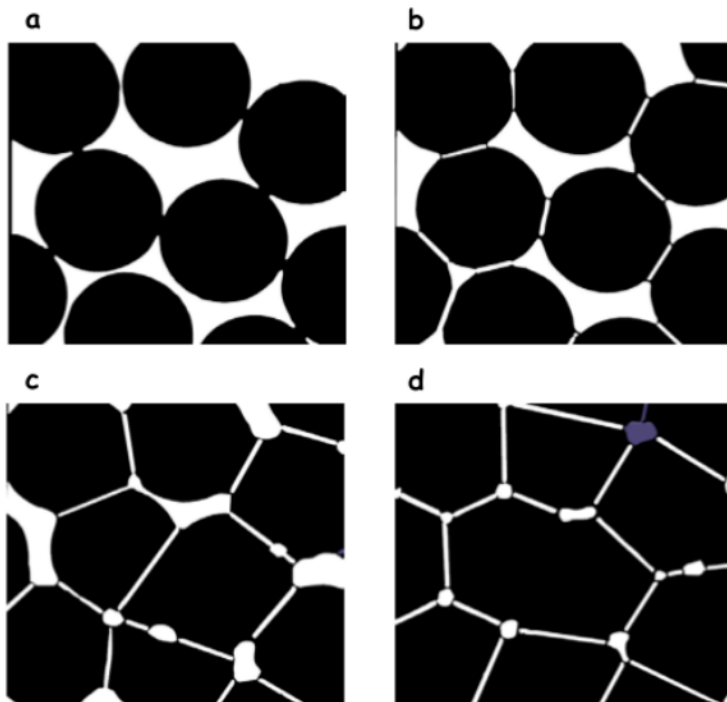


- **Second stage:** pore shrinks,

- **Third stage**



# Sintering stages



a) Green body, loose powder

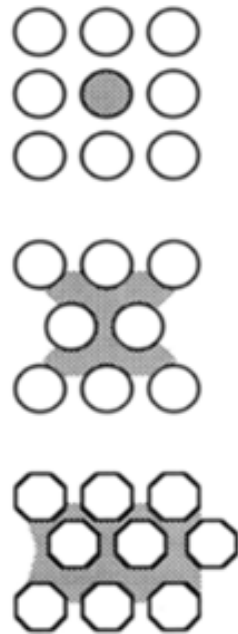
b) Initial stage: increase of the interparticle contact area from 0 to 0.2 grain diameter, increase of the density from 60 to 65%

c) Intermediate stage: further increase of the contact area, stage characterized by continuous pore channels along three grain edges, increase of the density from 65 to 90%.

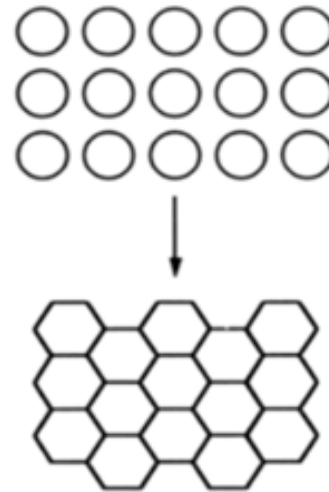
d) Elimination of the pore channel along three grain edges, increase of the density to 95 - 99%

# Sintering type

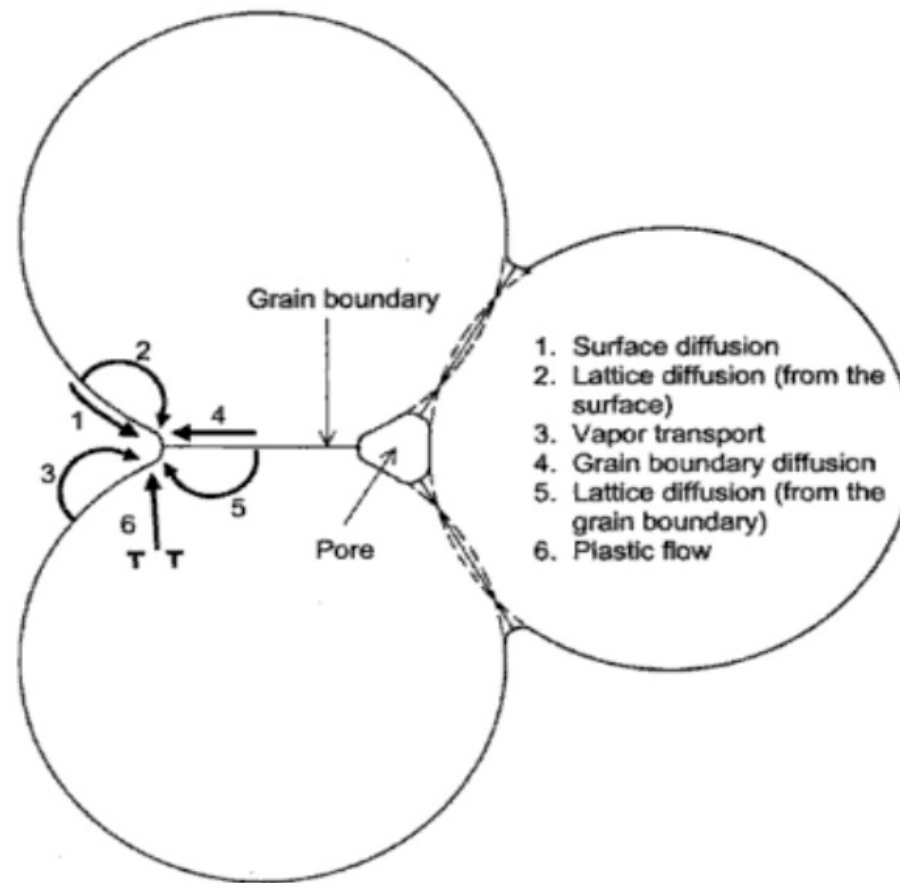
**Liquid phase sintering**



**Solid phase sintering**



# Mechanisms of sintering



# Sintering

- Sintering of traditional ceramics (Conventional Sintering)
- Sintering of Advanced ceramics (Advanced Sintering)



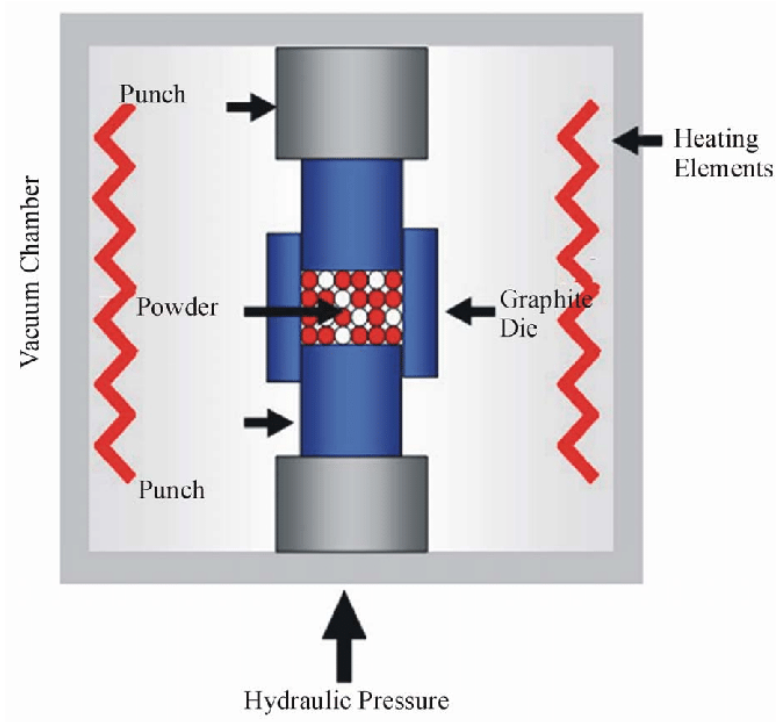
# Why Advanced Sintering

- Sintering time dependency
- Long conventional sintering time
- High sintering temperature
- Grain growth

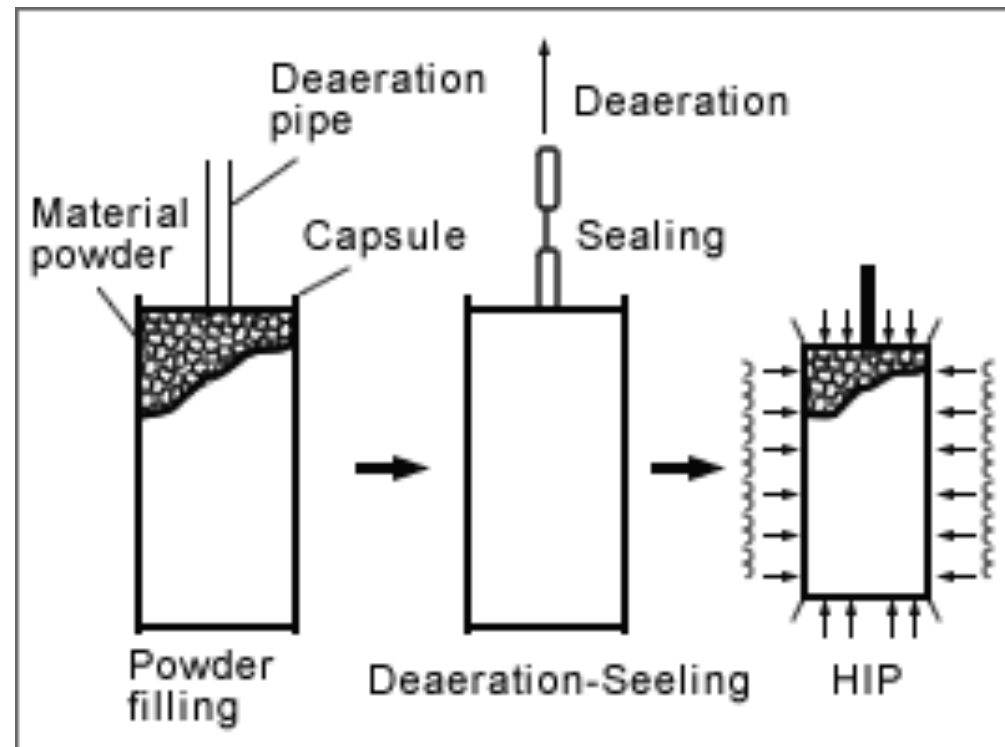
# Advanced Sintering Processes

- Hot Pressing (HP)
- Hot Isotactic Pressing (HIP)
- Spark Plasma Sintering (SPS)
- Selective Laser Sintering (SLS)
- Flash Sintering (FS)
- Microwave Sintering

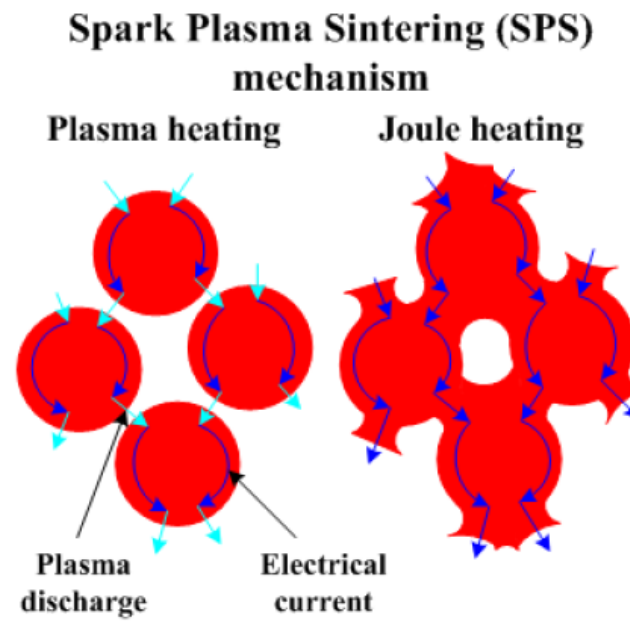
# Hot Pressing (HP)



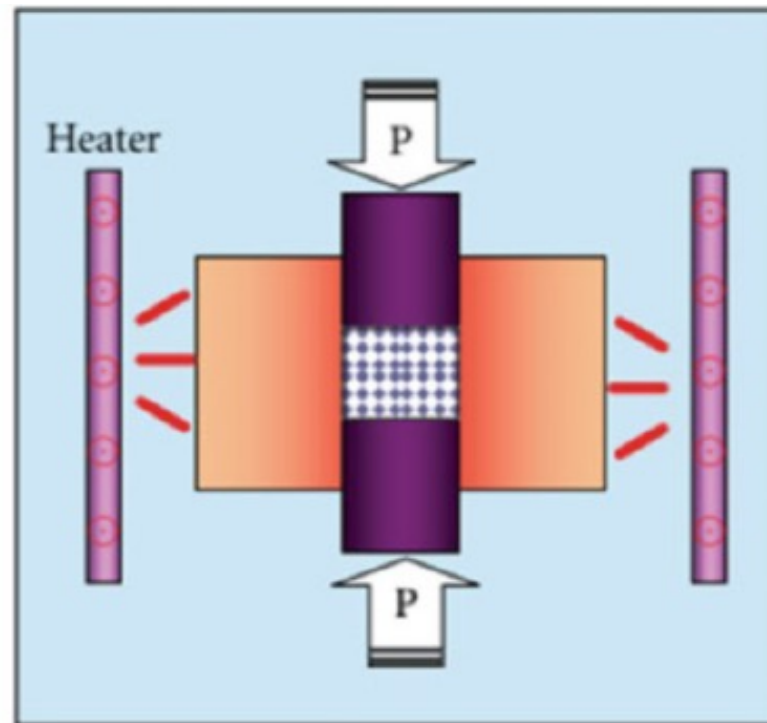
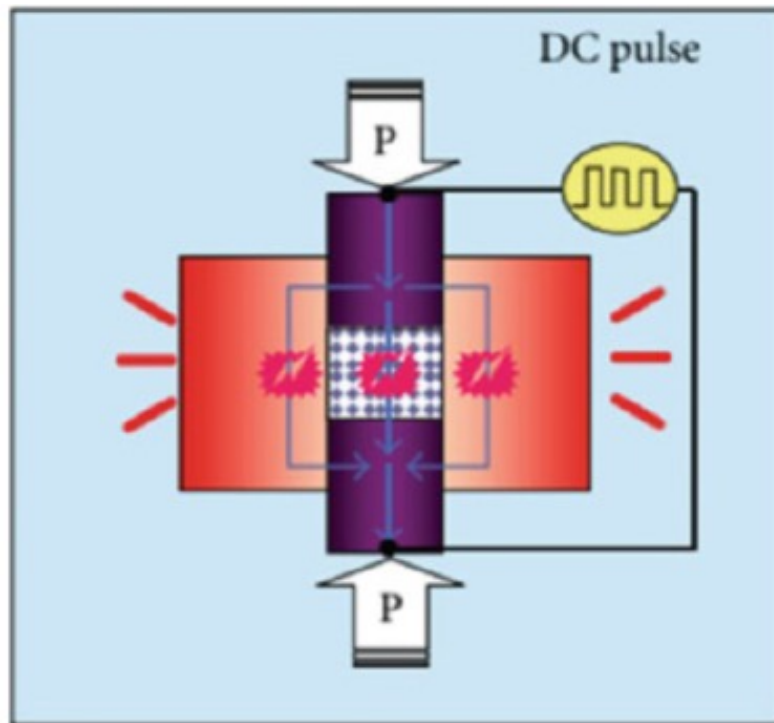
# Hot Isostatic Pressing (HIP)



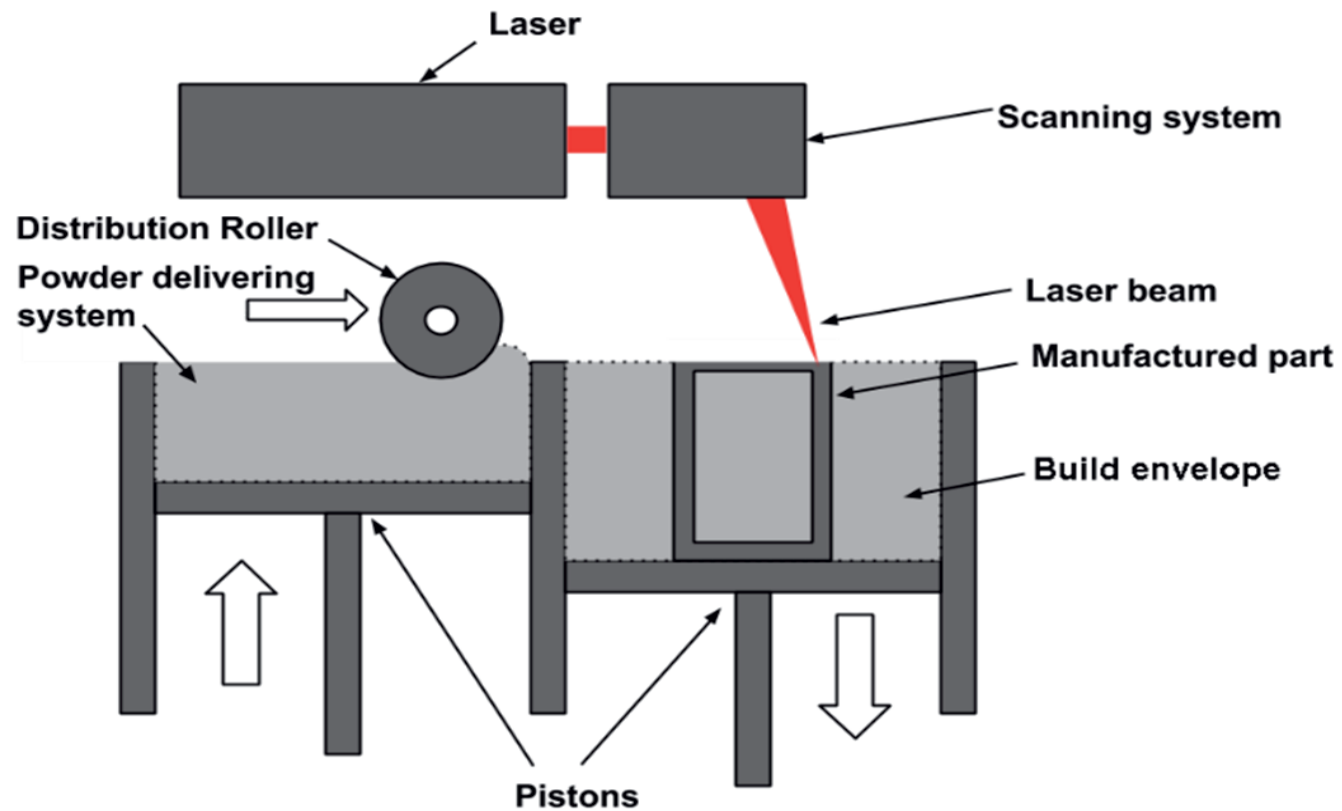
# Spark Plasma Sintering (SPS)



# SPS & HP

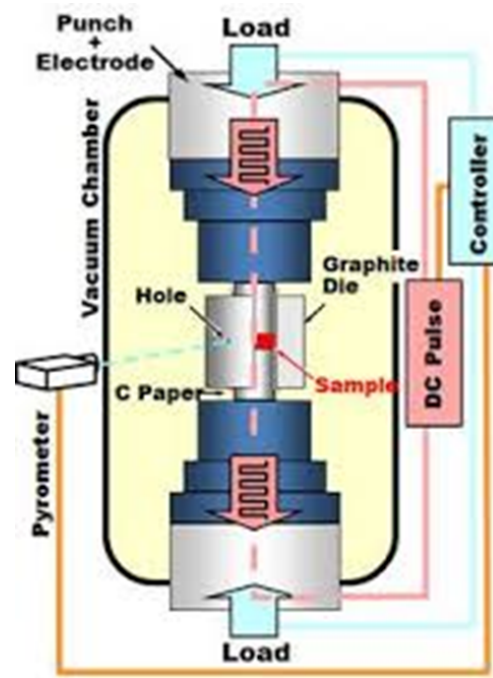


# Selective Laser Sintering (SLS)



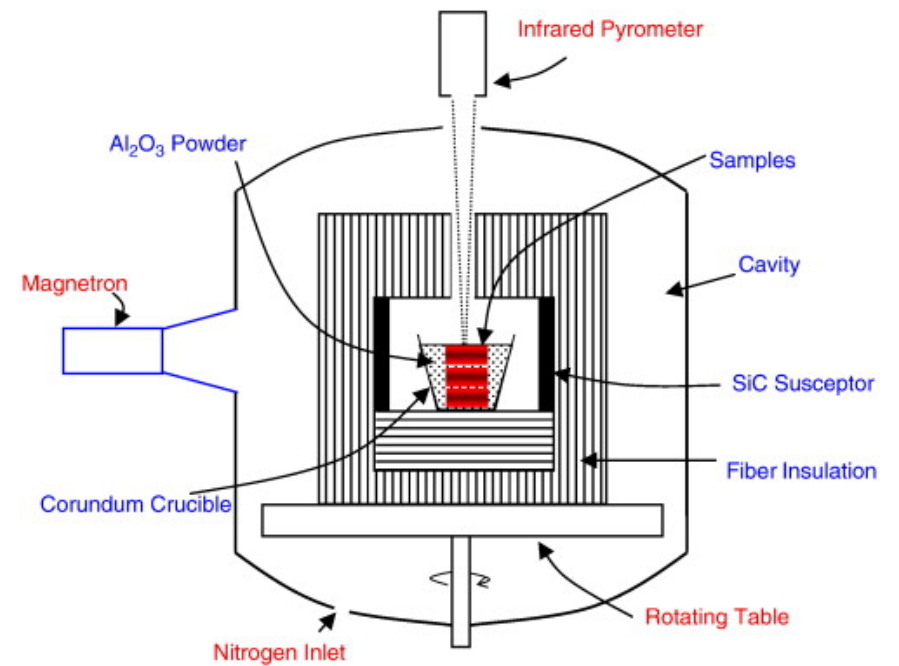
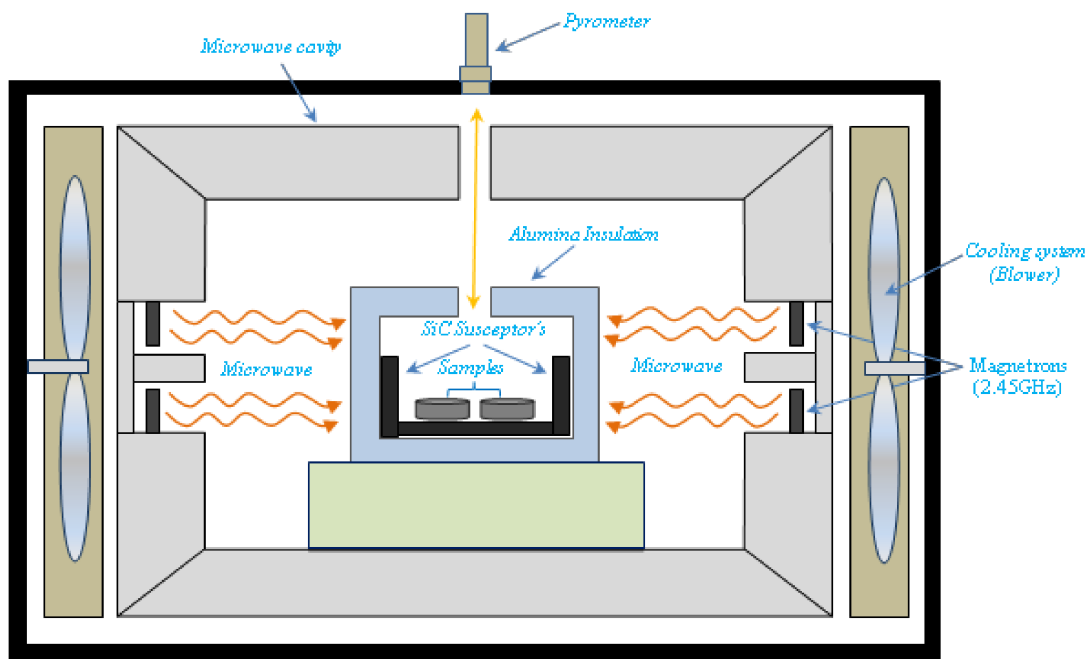


# Flash Sintering (FS)

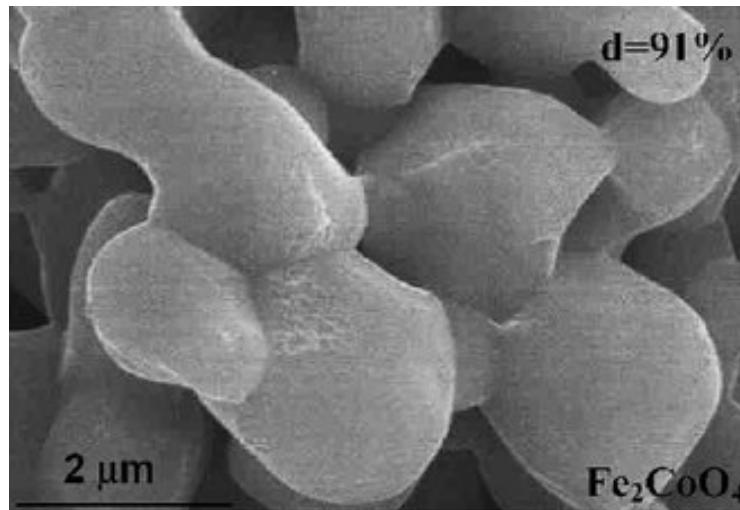


- Very rapid densification <60 S

# Microwave Sintering

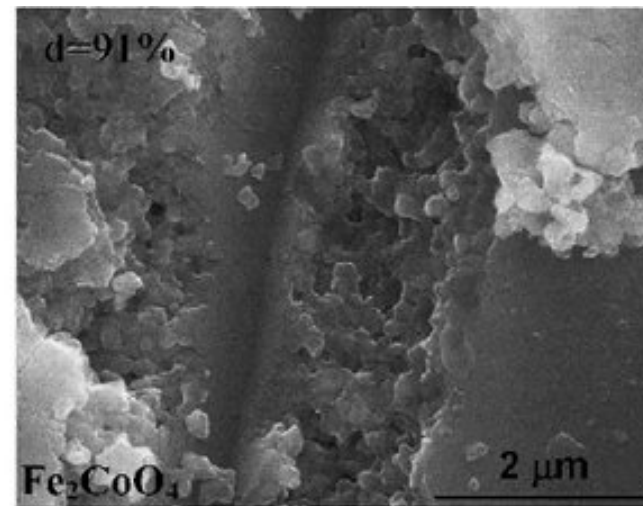


# Microstructure Comparison



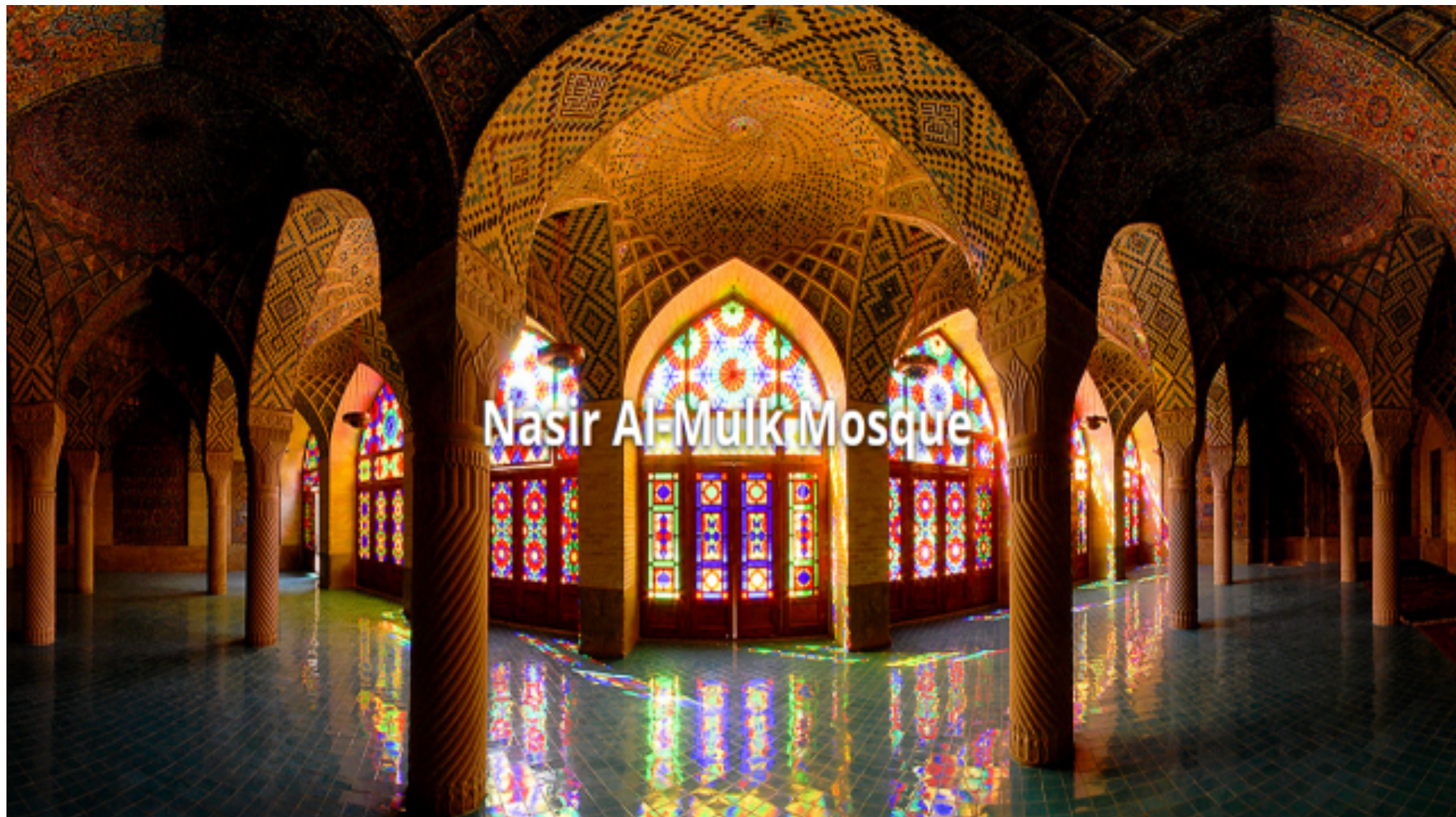
(a)

Conventional sintering



(b)

SPS



Nasir Al-Mulk Mosque