Seminar on Vacuum Technology and Processes for Metallurgical Applications

By

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A Short Term Course
On Vacuum Technology and Process Applications
on 11/11/11-21/11/11
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What is Vacuum ?

The atmospheric air around us is said to contain nearly 2.5×10^{19} molecules for every cubic centimeter space. Any given space having molecular density less than this is said to be under "**Vacuum" conditions.**

The technology dealing with the production of such reduced-pressure environments using different scientific concepts is known as "**Vacuum Technology".**

Vacuum technology is fundamental to a range of scientific explorations and technological processes, extending from analyzing atomically clean surfaces at extremely low pressures of the order of 10^{-11} Torr (**1 Torr = 1 mm Hg) to freeze drying** of foodstuffs at relatively high pressures in the range of 10^{-1} Torr. Vacuum conditions between these extremes are required for TV tube production, vacuum metallurgy, vacuum coating, semiconductor processing, particle accelerators, space simulation, etc.

Unit of Vacuum ?

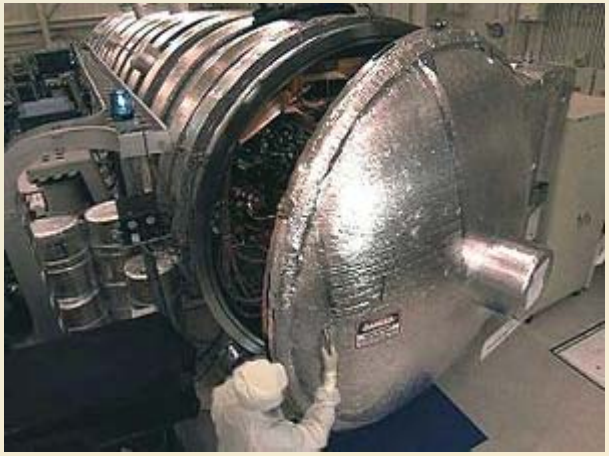
Vacuum is basically measured in pressure units. In a coherent unit system the pressure in a chamber is defined as the force acting on unit surface area and its dimensional formula is [L]-1 [M] [T]-2, where L, M, and T represent the base units of length, mass and time respectively. In SI units, the unit of pressure is Newton/m^2 or Pascal, and in the CGS system of units it is dyne/cm2. The standard atmosphere is defined as the pressure exerted by a column of mercury 760 mm high. In recent scientific literature, this standard is often expressed in Torr and mbar, which are non-coherent pressure units, but widely used.

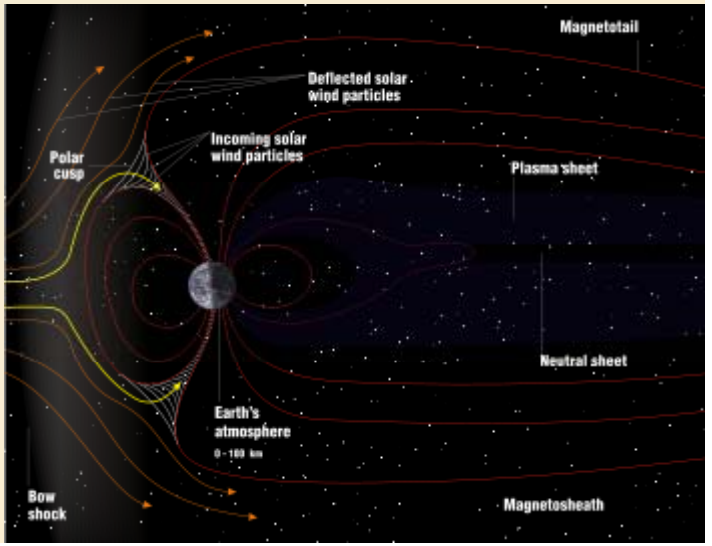
1 Torr = 1 mm Hg = 1/760 atm.

1 mbar = 100 Pascal =1/1013 atm.

Classification of Vacuum:

	Pressure (Torr)	Pressure (Pa)	Pressure (mbar)
Atmospheric pressure	760	101.3 kPa	1013 mbar
Low vacuum	760 to 25	100 kPa to 3 kPa	1000 – 30 mbar
Medium vacuum	25 to 1×10^{-3}	3 kPa to 100 mPa	30- 1×10^{-3} mbar
High vacuum	1×10^{-3} to 1×10^{-9}	100 mPa to 100 nPa	1×10^{-3} to 1×10^{-9} mbar
Ultra high vacuum	1×10^{-9} to 1×10^{-12}	100 nPa to 100 pPa	1×10^{-9} to 1×10^{-12} mbar
Extremely high vacuum	$<1\times10^{-12}$	<100 pPa	$<1\times10^{-12}$ mbar
Outer Space	1×10^{-6} to $<3\times10^{-17}$	100 µPa to <3fPa	





Based on different physical characteristics of vacuum, we can achieve different industrial/scientific applications. For example, vacuum in a chamber allows us to have controlled sub atmospheric pressures, useful for several mechanical operations and controlled flow of gases in specified direction.

Industry Product of scope

1. **Electrical/Electronics:**
   Gas-filled tubes, electron tubes, TV picture tubes, X-ray tubes, capacitors and transistors, rectifier tubes, cathode ray tubes, fluorescent tubes, switching tubes, interrupters, photocells, gas discharge lamps, incandescent lamps.
2. **Scientific instruments:**
   Maintaining the vacuum in electron microscopes **FESEM,SEM, TEM, HRTEM**, mass spectrometers, surface analysis systems, oscilloscopes, thermoflasks, and thermometers.
3. **Mechanical operations**:
   Railway braking, industrial filtering, vacuum snifters, vacuum cleaning ,holding /lifting /transporting solids and liquids.
4. Refrigeration, cryogenic engineering Insulation of vessels and tanks for liquid petroleum gases, cryogenic liquids.
5. Automobile Filling of air-conditioning, cooling and servo systems.
6. Research and development **Space simulation chambers**, bubble chambers, fusion experiments, fusion reactors, particle accelerators, ion implantation systems,thermal insulation, cryogenic experimentation

Applications in Vacuum Technology in Industry

Sl. No	Industry	Product of Scope
1	Mechanical operations	Railway braking, industrial filtering, vacuum snifters, vacuum cleaning, holding/lifting/transporting solids and liquids.
2	Refrigeration, cryogenic engineering	Insulation of vessels and tanks for liquid petroleum gases, cryogenic liquids.
3	Electrical/Electronics	Gas-filled tubes, electron tubes, TV picture tubes, X-ray tubes, capacitors and transistors, rectifier tubes, cathode ray tubes, fluorescent tubes, switching tubes, interrupters, photocells, gas discharge lamps, incandescent lamps.
4	Scientific instruments	Maintaining the vacuum in electron microscopes, mass spectrometers, surface analysis systems, oscilloscopes, thermoflasks, and thermometers.
5	Automobile	Filling of air-conditioning, cooling and servo systems.
26	Research and development	Space simulation chambers, bubble chambers, fusion experiments, fusion reactors, particle accelerators, ion implantation systems, thermal insulation, cryogenic experimentation.

Applications in Metallurgy

•High vacuum treatment of metals and their alloys susceptible to oxidation and/or gas.
•Vacuum cast forging ingots. Vacuum degassed alloyed steels and vacuum degassed cast steel

Production of Pure Metal and alloys

Production of pure metals such as bismuth, selenium, zinc, antimony, magnesium, zirconium and titanium

Equipment s or Furnace Requirement

Vacuum Induction Melting and casting **(VIM/VID/VIDP)**

Remelting or Secondary Processes:
Electro Slag Remelting (ESR)
Vacuum Arc Remelting (VAR)
Electron Beam melting (EB)

Casting and Coating:
Vacuum Induction Melting – Investment Casting (VIM-IC)
Vacuum turbine blade coating (EB/PVD)

Special Furnaces:
Hot Isothermal Forging (HIF)
Vacuum Induction melting Gas Atomizer (VIGA)
Electrode Induction melting Gas Atomizer (EIGA)
Induction heated Quartz tube furnace (IWQ)
High vacuum resistance furnace (WI)

Requirement of Vacuum Technology in Powder Metallurgy

Powder Metallurgy (PM) is the innovative and environmentally friendly process of producing component parts using metal powder.

Production of Pure Metal and alloys

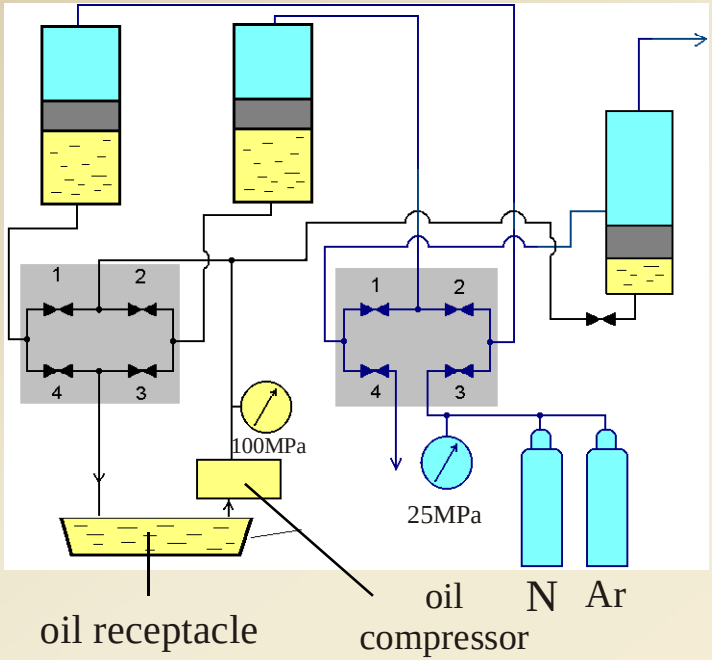
Manufacture of metal powders, such as **Ferrous, Bronze, Brass, Copper, Tungsten and Hard metal powders.**

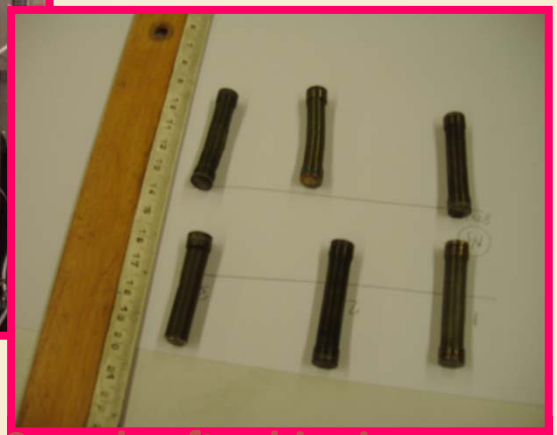
Equipments , Pressing units or Furnace Requirement

Furnaces/sintering kilns, vacuum or atmospheres, **Hot Pressing, Hot Isostatic Pressing (HIP), Spark Plasma Sintering (SPS), Pulse Plasma Sintering(PPS),** equipment and optional manufacturing steps, sizing, repressing, metal infiltration and optional finishing steps, heat treatment and plating.

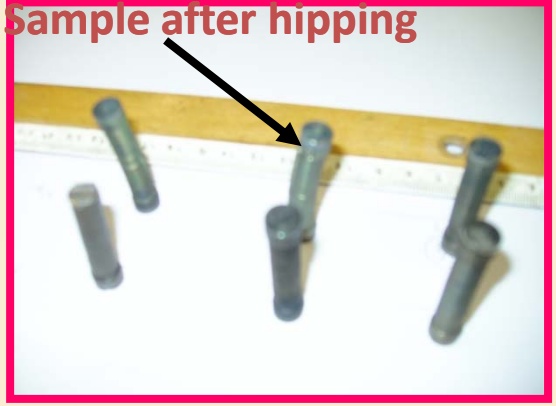
Hot Isostatic Pressure (HIP)

Working Chamber





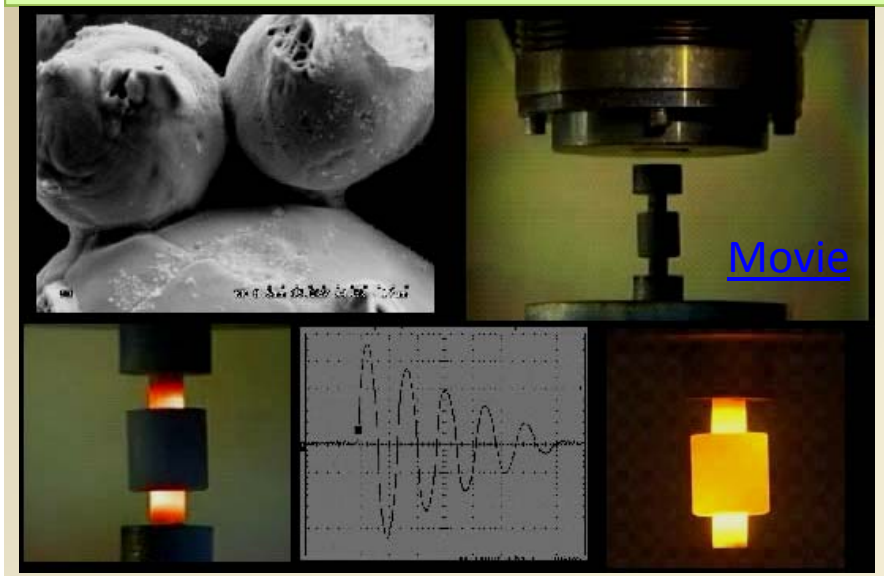
Sample after hipping

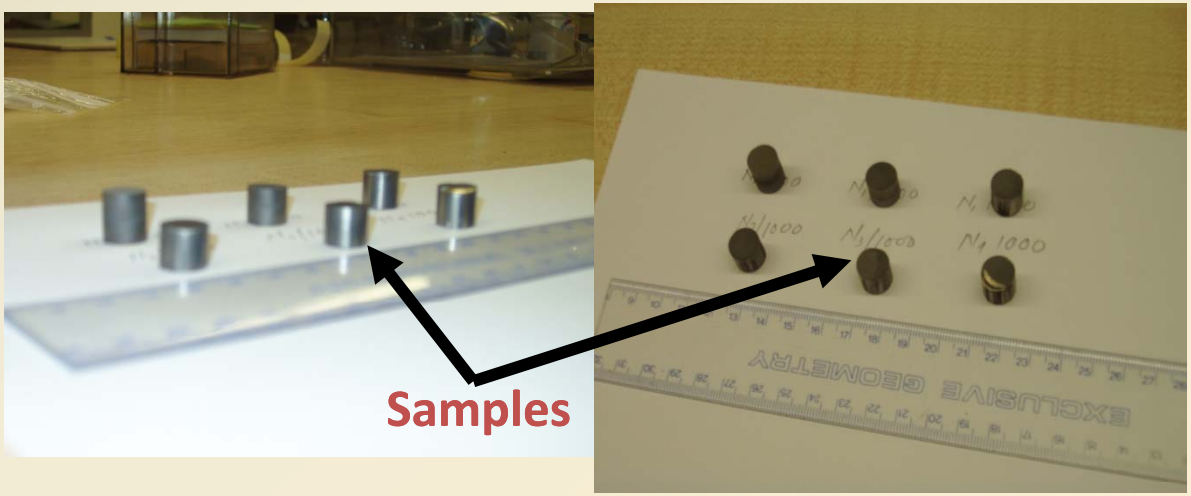


HIP Parameters:

- Diameter, d = 10 mm, Length l = 30mm
- Pressure, P = 1.5 GPa
- Temperature, T = 600°C,800°C,1000°C
- Time, t = 30 min
- Atmospheres argon gas

Pulse Plasma Sintering (PPS)





- Chamber 600x600x600 mm
- Vacuum 10^{-6} mbar

Hydraulic press :

- Pressure 50 kN
- Stroke of press 200 mm

HIP Parameters:

- Diameter, d = 15 mm, Height, h = 12mm
- Pressure, P = 50 kN
- Temperature, T = 600°C,800°C,1000°C
- Time, t = 5 min

Requirement of Vacuum Technology for Brazing , Diffusion Bonding and Brazing Alloy Development

Professional Experience

In NFTDC,Hyderbad

ADVANCED JOINING TECHNOLOGY APPLICATION LABORATORY

AJTAL

OUR GROUP MEMBERS

Swapan Kumar Karak

M. Govindaraju

Non-Ferrous Materials Technology Development Centre
Hyderabad, INDIA

FACILITIES

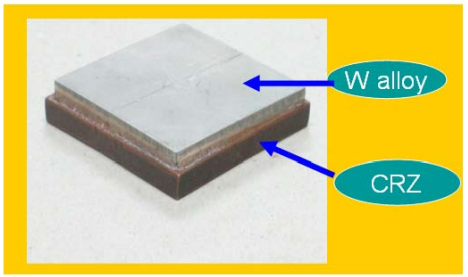
	Max. Temp (°C)	*Hot Zone dimension*	*Vac. Level (mbar)*
High Vacuum High Temperature Furnace	1600 ± 0.3	300mm×300m m×300mm	10^{-5} 10^{-6}
High Vacuum Annealing Furnace	800 ± 5	Φ 300mm ×800mm length	10^{-5}
High Vacuum Rapid Experimentation Furnace	1100 ± 2	Φ 100mm ×150mm length	10^{-5}

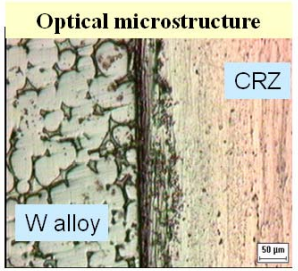
Vacuum Brazing

Metal to Metal Brazing

- Similar metal Brazing
- Dissimilar metal Brazing

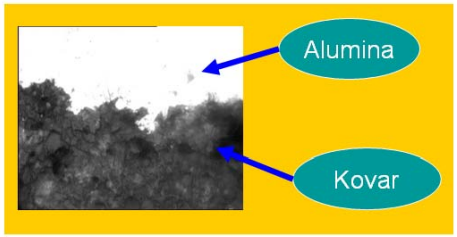
Brazed Materials: SS, CuCrZr, W alloy, Super alloy, PHSS etc.





Active Brazing

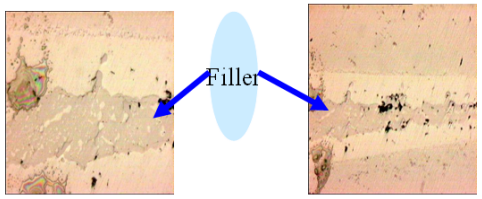
Ceramic to Ceramic	**Alumina-Alumina**
Ceramic to Metal	**Alumina-SS, Alumina-Kovar, Alumina-Cu, Alumina-Ti**
Refractory metal to non-metal	**Mo-Graphite**
Non-metal to non-metal	**Graphite-Graphite**



Challenging Work

Super alloy Brazing

Filler Material: Nicrobraze alloy



Microstructure of the brazed joint

High Temperature Tensile Testing Results

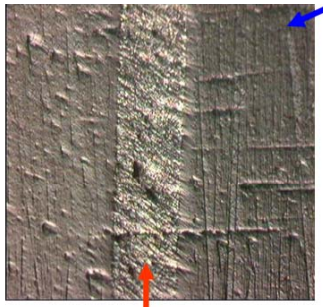
Testing Temperature: 870° C

In Argon Atmosphere

UTS Value at brazed joint: 513MPa

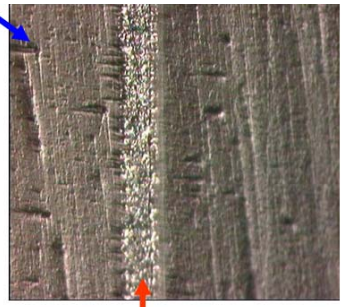
Ti alloy Brazing for Cryogenic Application

Material: **Ti-5Al-2.5Sn**



Filler Material:

Silver based



Joint with 100 µm thick Filler Material

Joint with 50 µm thick Filler Material

Microstructures of brazed Ti alloy joint

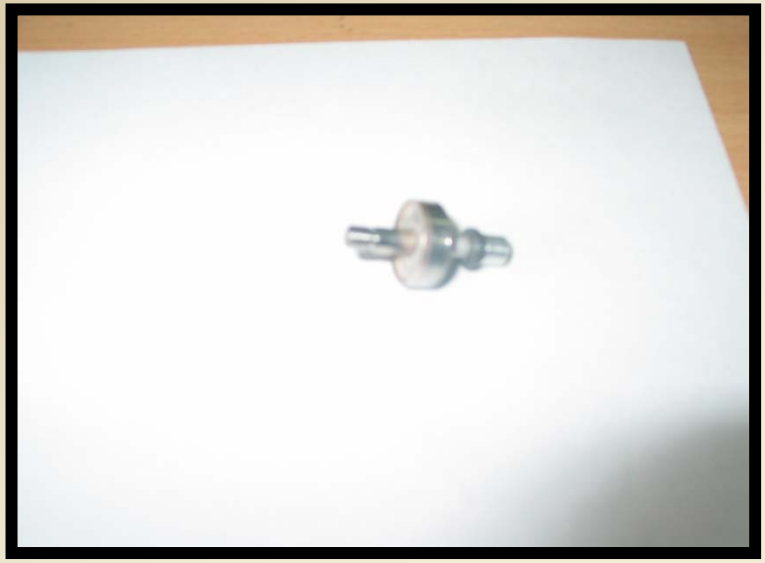
Diffusion Bonding → Cu-SS and Supper alloy

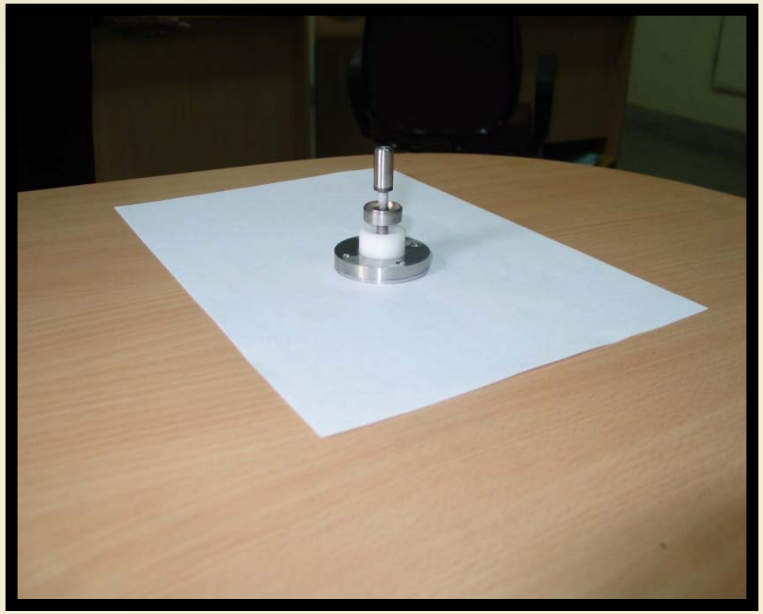
Development of Materials →
- ✓Active Brazing Alloys (Ag-Cu-Ti and Cu-Al-Si-Ti)
- ✓Vacuum Brazing Alloys
- ✓UHV Components and Brazing Alloys

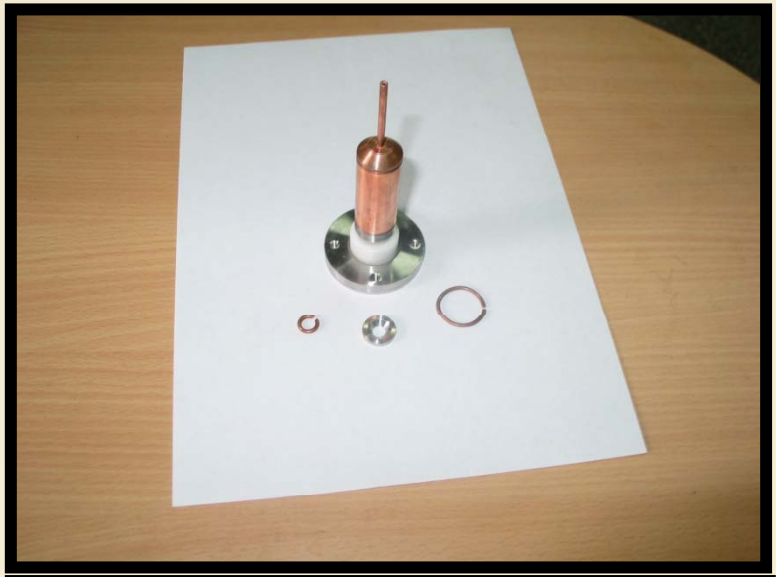
Development of Processes → Heat Treatment, Thermal Treatment, Melting and Sintering

Design Consultancy →
- ✓High Vacuum Quenching Blower Motors
- ✓Materials for UHV Systems
- ✓High Vacuum Furnaces
- ✓Diffusion Bonding SET-UP

Brazing of Plasma Discharge Tube







Vacuum annealing of Columbium

Temp-1225^{o}C

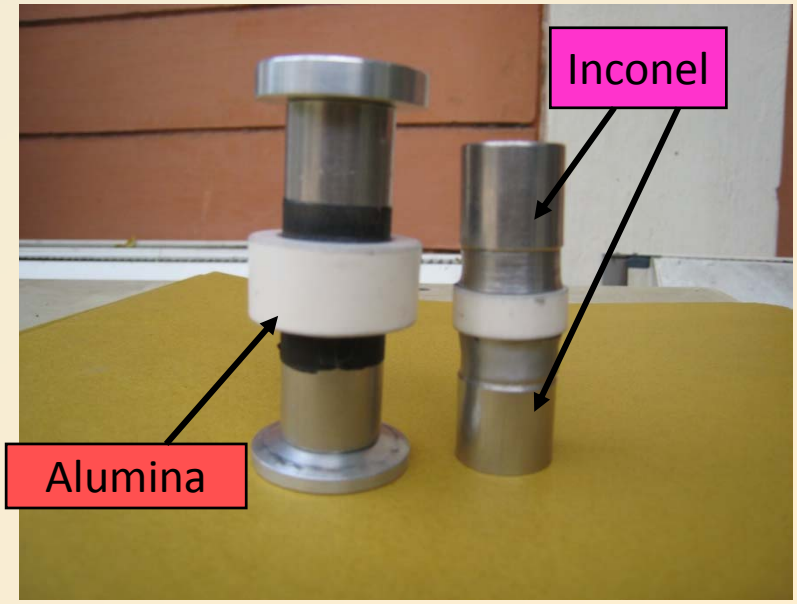
Holding Time-2hrs

Brazing of Inconel with Alumina

Temp-1050 ^{o} C

Time-25min

Filler Material-CuABA

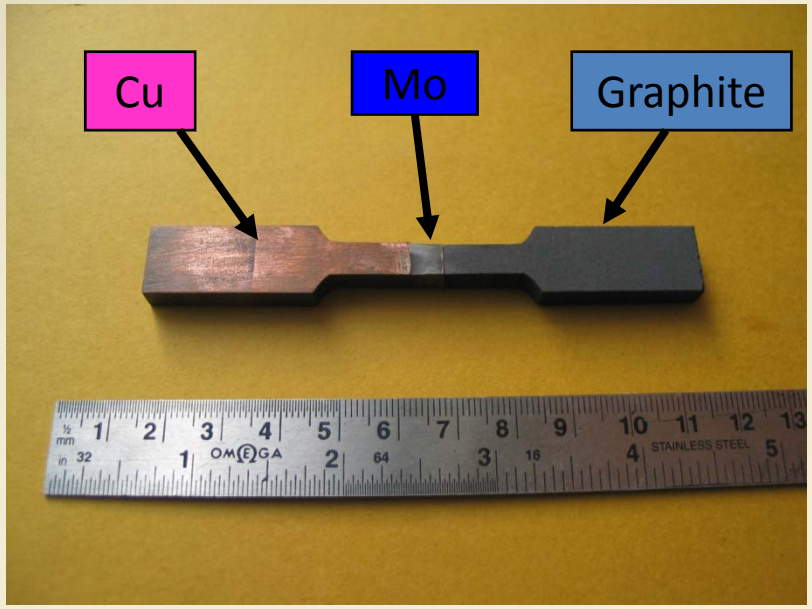


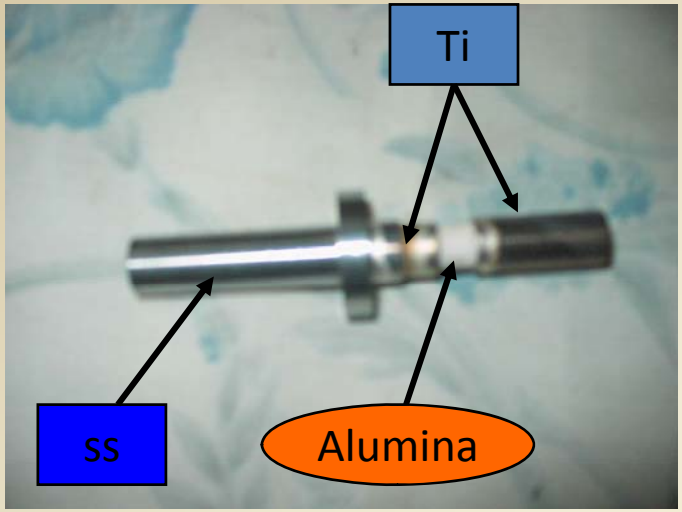
Inter-Layer Brazing

Temp-975

Time-25min

Filler Materials-Cu-Mn-Ni





Brazing of Alumina with Ti +SS

Temp-843.5

Time-2 min

Filler Material-Ag-Cu-Ti

Major Developments:

- *Inter layer brazing of CRZ, Mo and Graphite.*
- *Brazing of Ti-Al_2O_3-SS component in Lab scale.*
- *Brazing of Ni based super alloy and high temperature Tensile at brazed joint.*
- *Brazing of CRZ with W alloy.*
- *Brazing of Kovar with Alumina.*
- *Brazing of Graphite with Mo.*
- *Brazing of Inconel with Alumina*
- *Development of filler materials-Ag-Cu eutectic, Ag-Cu-Ti alloy, Ag-Cu-Zn alloy, Pd-Ni alloy, Cu-Mn-Ni alloy*

Thank you