CANDLE Synchrotron Research Institute

(Center for the Advancement of Natural Discoveries using Light Emission)

Vacuum Systems and Metal-Ceramic Joints in Advanced Accelerators

A Thesis
Submitted for the degree of Doctor of Philosophy (PhD) of Technical Sciences in division of ''Charged Particle Beam Physics and Accelerator Technology'' 01.04.20

PhD Student – Vahagn Vardanyan

Scientific Supervisor – Prof. Vardan Sh. Avagyan

Yerevan 08.09.2017

The modernity and importance of the problem:

Vacuum-tight metal-ceramic joints are widely used in particle accelerators as important connections – especially for Ultra High Vacuum (UHV) systems, RF systems, electro-magnetic systems, beamlines as Insulators, feedthroughs, windows, vacuum chambers, etc.

There are many technologies for ceramic to metal vacuum tight connections (vacuum brazing, welding, soldering, etc.). Existing brazing and welding technologies for vacuum-tight ceramic-metal joints have many disadvantages and unsolved problems. Especially some laws and equations were received based on combination of experimental and theoretical calculations and experiments. Some fundamental (chemical, physical and mechanical) processes totally not described yet for ceramic to metals bonding. There are many non standard and new metal-ceramic joints in charged particle accelerators.

Design and fabrication of new reliable and effective vacuum-tight metal-ceramic joints and development and improvement of new and existing bonding technologies for vacuum systems are modern tasks-problems.

The goals of thesis:

- Design and investigation of vacuum-tight ceramic-metal joints for electromagnetic vacuum systems of accelerators – including thermo-mechanical design, diffusion brazing and welding technologies, experimental investigations, thermoregulation systems, UHV design, testing and evaluation methods, etc.

The main topics provided for thesis defense:

- UHV system of AREAL linear accelerator – main schematic view, Ti e-beam windows, achieved vacuum level, materials specifications, vacuum-tight ceramic-metal joints, etc.
- UHV test stand - main purposes, schematic view, etc.
- Thermoregulation systems of AREAL linear accelerator – thermoregulation system of RF gun, thermoregulation system of klystron and cooling system for solenoid magnet.
- Review of materials and brazing technologies for vacuum-tight ceramic-metal.
- Experimental results of ceramic to metal brazing based on different brazing technologies (moly-manganese, active brazing technologies).
- Thermo-mechanical simulations for ceramic-metal joints.
- New brazing method for dissimilar material brazing in different geometries was developed for UHV systems.
- New bonding technology for dissimilar cylindrical item bonding was developed.
- The vacuum RF window was mechanically developed and designed, including special ceramic/metal brazing technics and mechanical structure of RF window.
- Vacuum RF window test stand was developed and designed for testing of mechanical sealed and brazed ceramic/metal joints, including coated ceramic materials.
- Thermo-mechanical simulations of pillbox type RF window.

Scientific novelty :

- New brazing method for dissimilar material brazing with difficult geometries. This new brazing method was published as patent in Intellectual Property Agency of the Republic of Armenia – patent number AM201453.

- New bonding method for (diffusion welding or brazing) cylindrical materials item bonding, especially ceramic to metals by using locally heating and pressure receiving. This new method was registered as patent in Intellectual Property Agency of the Republic of Armenia– paten number AM20170070.

- Pillbox type vacuum RF window was developed and mechanically designed, including development of brazing technologies.

- RF window test stand was developed for testing brazed ceramic-metal joints and ceramic to metal sealing technologies in UHV, RF, thermal conditions.

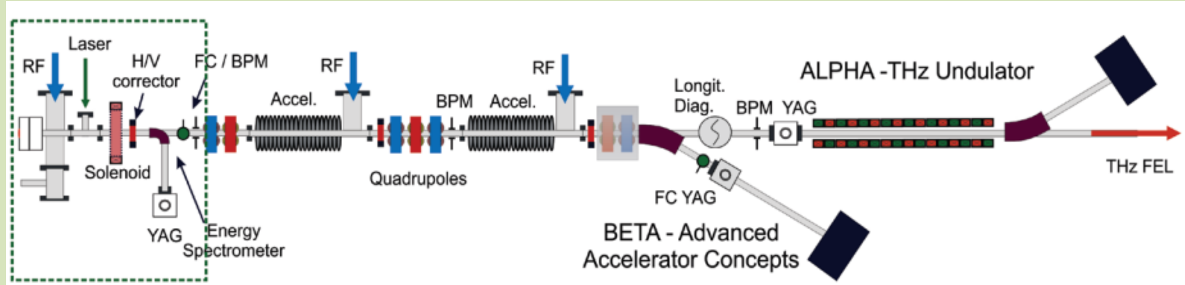
Chapter 1. AREAL Linear Accelerator – the main parameters, UHV and thermoregulation systems.

UHV and Thermoregulation systems of AREAL linear accelerator.

Electron Beam Energy

	Phase 1	Phase 2
Energy	5 MeV	50 MeV

Main scheme of AREAL Linear accelerator



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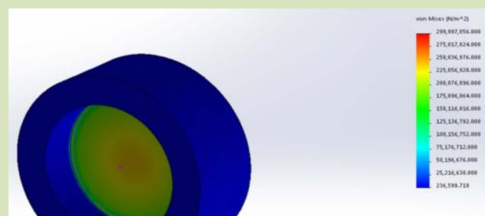
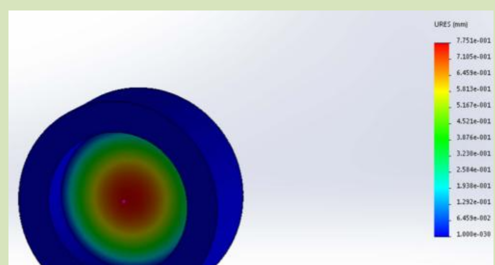
UHV System of AREAL

Achieved vacuum level – 2.3 10^{-9} Torr

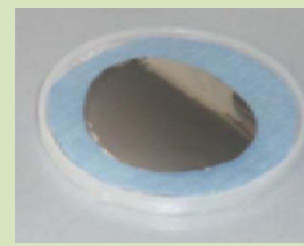
Ti E-beam windows

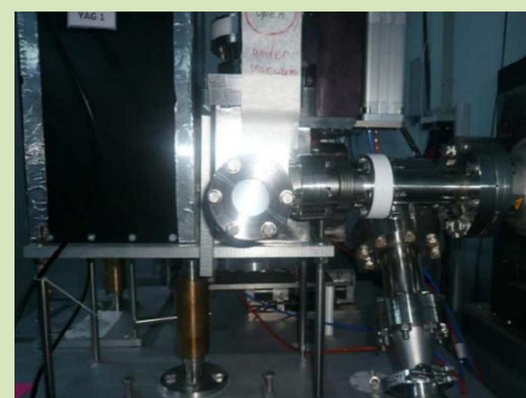


Stress

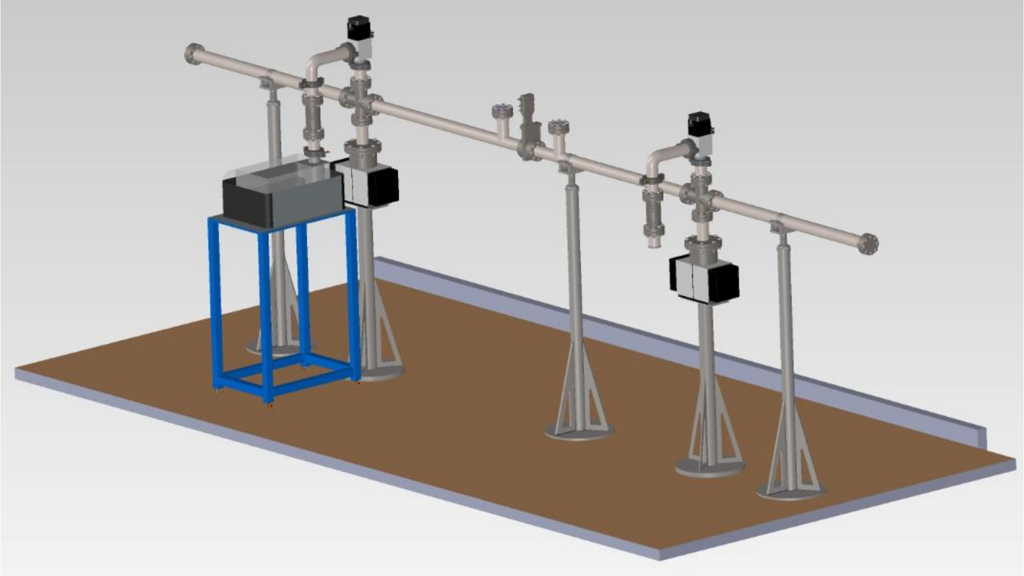


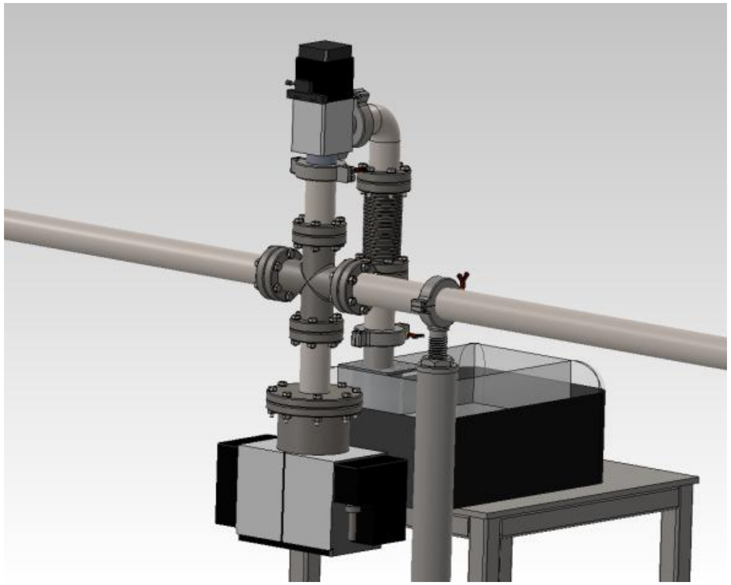
Displacement





UHV test stand



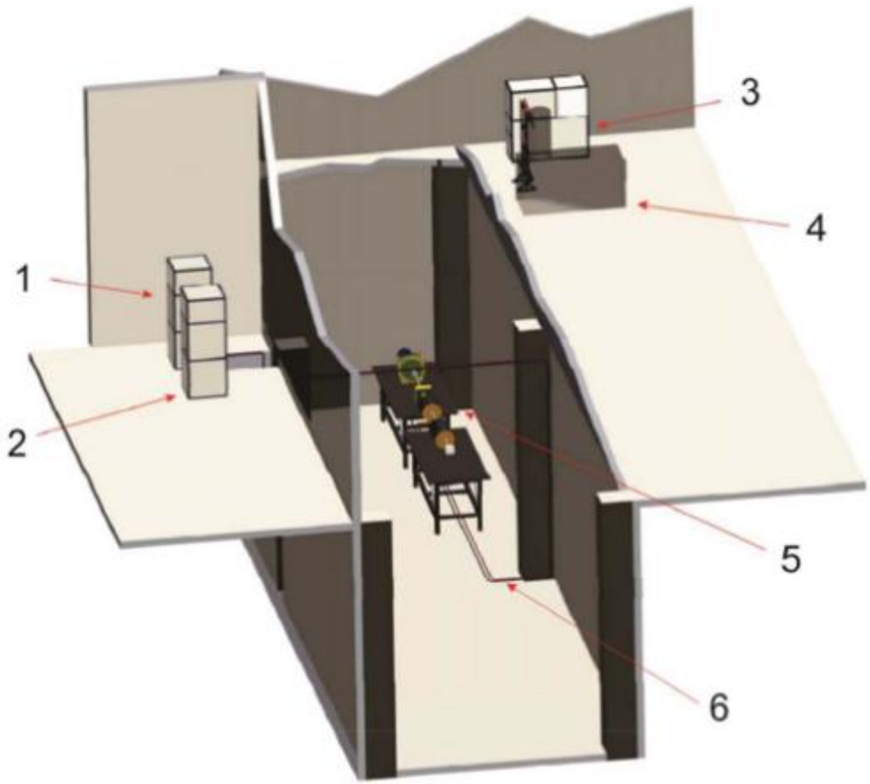


The main purposes of UHV test stand are the testing of all UHV components, control systems, devices, vacuum-tight joints (metal-metal, metal-ceramic) in vacuum movers, bake out processes of UHV components, etc., before installation in the main acceleration system.

Main parameters

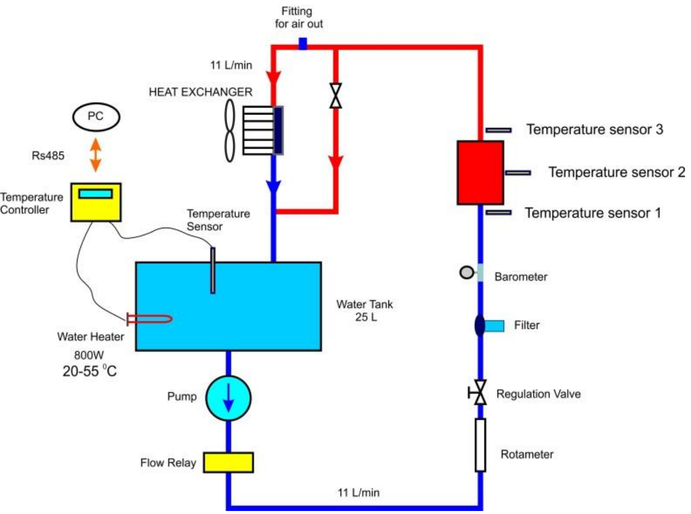
Vacuum level	Up to 10^{-10}Torr
Main construction material	304 stainless steel
Max. temperature	Up to 450 ^{0}C
Vacuum gauges	Inverted magnetron
	Penning
	Pirani
Vacuum pumps	Ion pumps
	TPS pump

Thermoregulation systems for AREAL linear accelerator.



1. Thermoregulation system of RF gun,
2. Cooling system of solenoid magnet ,
3. Thermoregulation system of Klystron ,
4. Klystron,
5. Linear accelerator ,
6. Feed water pipes for RF gun and solenoid magnet – water input and output pipes).

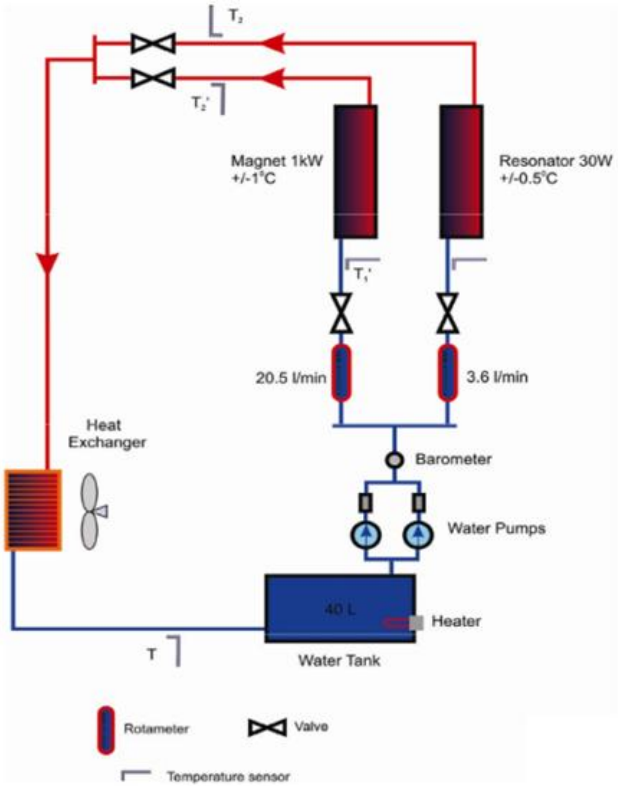
Thermoregulation System of RF Gun

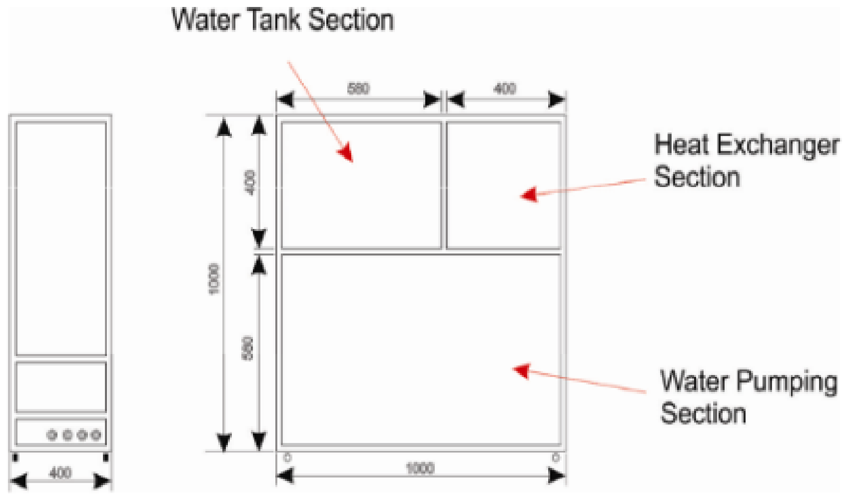


Characteristics	Value
Cooling capacity (W)	500
Temperature range (^{0}C)	30-55
Temperature stability (^{0}C)	+/-0.1
Water flow rate (l/min)	2-15
Pressure	Not exceed $4.2 kg/cm^2$
Coolant	De-ionized water
De-ionization level	5.6 MΩ·cm

Cooling system of Solenoid Magnet

Temperature range	20-40 ^{0}C
Temperature stability	+/-1 ^{0}C
Temperature sensor type	Pt100
Temperature regulation type	PID
Coolant	Demineralized water
Water deionization range Ω·cm	50 Ω·cm
Cooling capacity	2’000 W
Nominal pressure (bar)	3.3
Water flow rate	2-30 l/min





Characteristics	Value	
	Resonator	Magnet
Cooling capacity (W)	500-1500	
Temperature range	30-55	
Temperature stability °C	+/-0.5	+/-1
Water flow rate (l/min)	3.64	20.5
Pressure (kg/cm²)	<4.2	
Temperature sensor	Pt100	
Coolant	Distilled water	
Water deionization range	50M Ω·cm	
Nominal pressure (bar)	3.3	

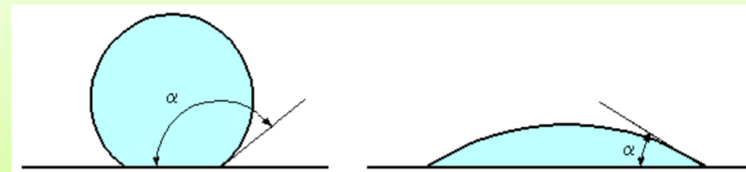
Chapter 2. Experimental investigations of ceramic-metal brazing technologies for accelerators UHV systems.

Materials for vacuum-tight ceramic-metal joints.

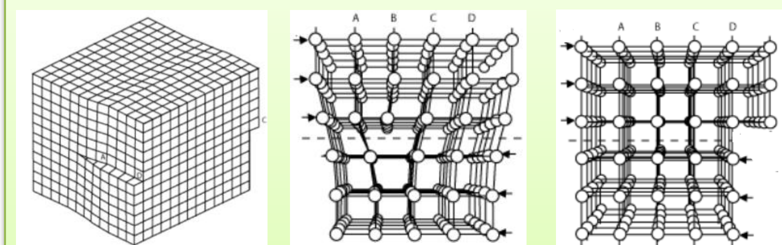
Main requirements

- Low outgassing rate,
- Thermal shock resistance,
- Low material penetration,
- High mechanical strength,
- High weldability and brazability,
- High machinability,
- Reliable during long time,
- Repeatability and Dimentional stability,
- Appropriate electro-mechanical characteristics,
- Absorbtion and desorbcion characteristics,
- Surface oxidation characteristics,
- Corrosion resistance,
- Metallization characteristics.

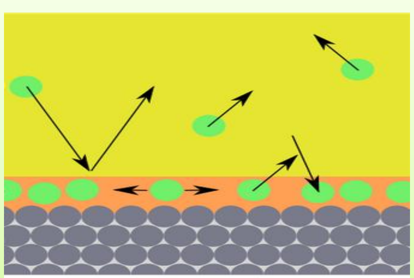
Solders and materials wettability



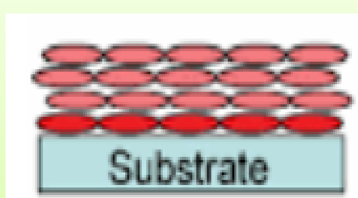
Materials structures - Homogeneity



Without dislocations, content inhomogeneities, cracks, inner impurities, etc.



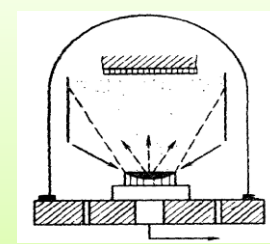
Adsorption and desorbtion



Chemisorption

Oxidation layers

Corrosion



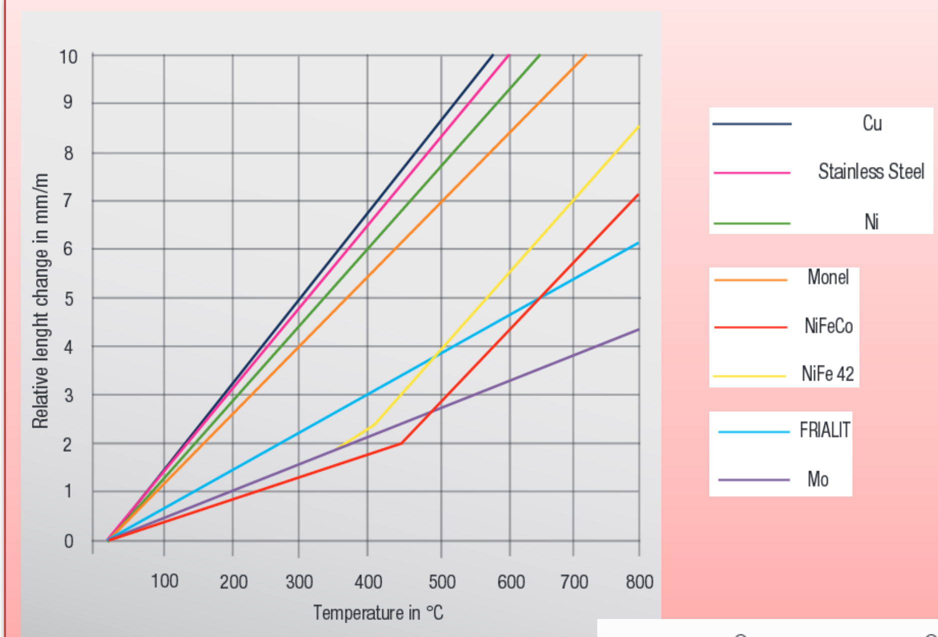
Metallization

Austenitic Stainless Steels

ANSI Grade	C max	Si max	Mn max	S max	P max	Ni	Cr	Mo max	N max
316	0.08	1.0	2.0	0.045	0.03	10.0-14.0	16.0-18.0	2.0-3.0	-
316L	0.03	1.0	2.0	0.045	0.03	10.0-14.0	16.0-18.0	1.2-2.75	-
316LN	0.03	1.0	2.0	0.045	0.03	10.5-14.5	16.5-18.5	2.0-3.0	0.12-0.22
310S	0.08	1.2	2.0	0.045	0.03	19.0-22.0	24.0-26.0	-	-
304	0.08	1.0	2.0	0.045	0.03	8.0-10.5	18.0	-	-
304N	0.08	1.0	2.0	0.045	0.03	8.0-10.5	18.0-20.0	-	0.1-0.16

Curie Temperature

Material	Temp. K
Iron (Fe)	1043
Cobalt (Co)	1400
Nickel (Ni)	627



Thermal expansion of metals compared with Al2O3 ceramic

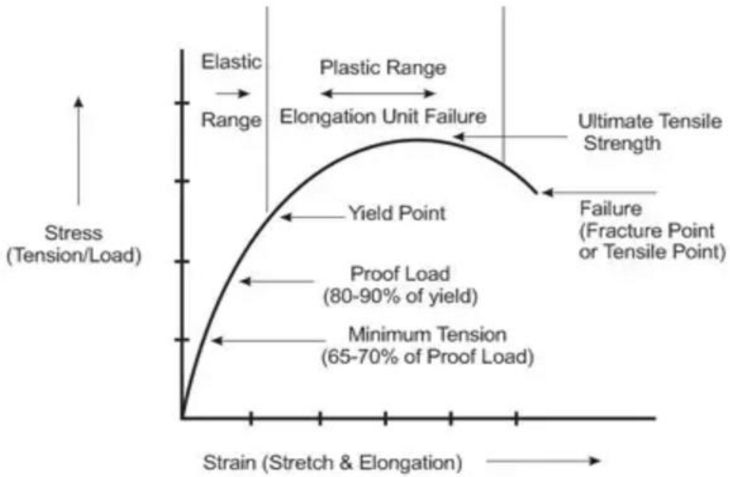
FRIALIT®-DEGUSSIT®
Oxide Ceramics

Kovar contant %

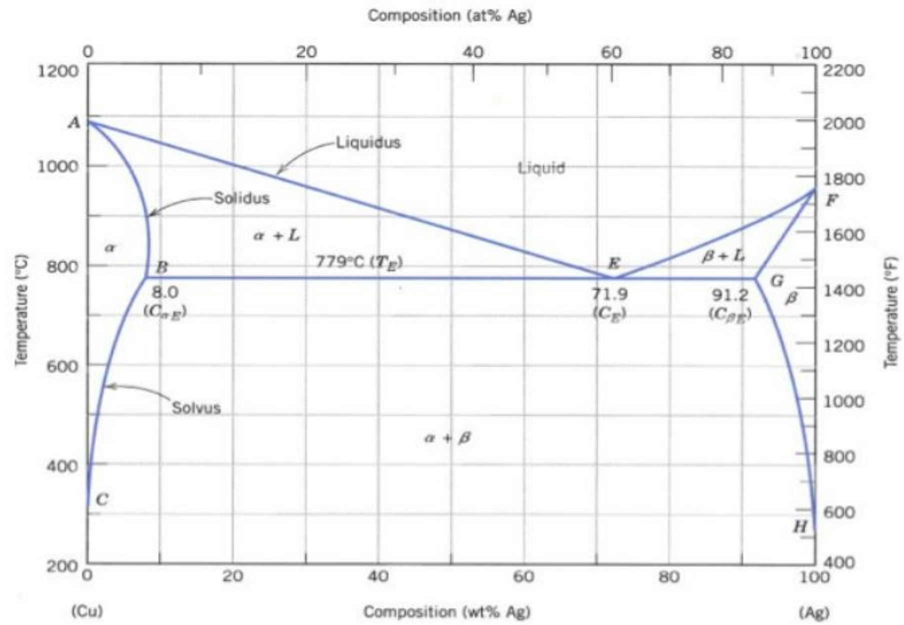
Fe	Ni	Co	C	Si	Mn
53.49	29	17	<0.01	0.2	0.3

Solders

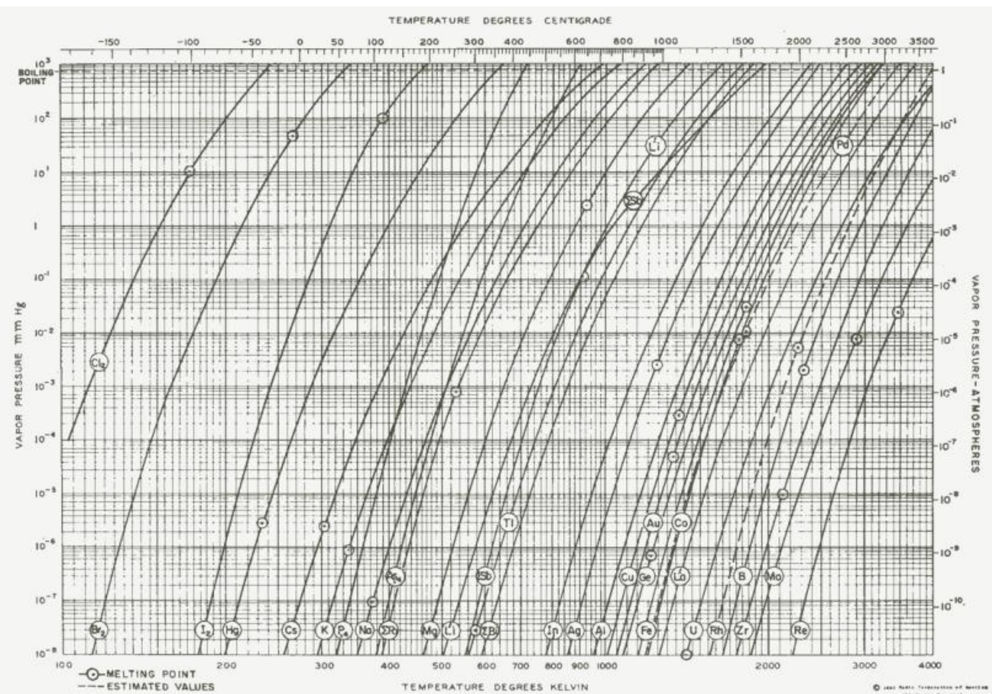
Solder	M. T. °C	Sn	Zn	In	Ag	Pd	Cu
Palcusil®10	850	-	-	-	58.5	10	31.5
Palcusil®5	814	-	-	-	58.5	5	26.5
Ag72 Cu28	780	-	-	-	72	-	28
Incusil 10	730	-	-	10	63	--	27
Cusiltin	718	10	-	-	60		30
ПСр-45	665—725	-	25.85	-	45	-	30.5
ПСр-65		-	14.1 - 15.85	-	64.5-65.5	-	19.5-20.5



Tensile Stress-Strain Diagram



Phase diagram CU-Ag



Vapour Pressure Curves for the Common Materials.

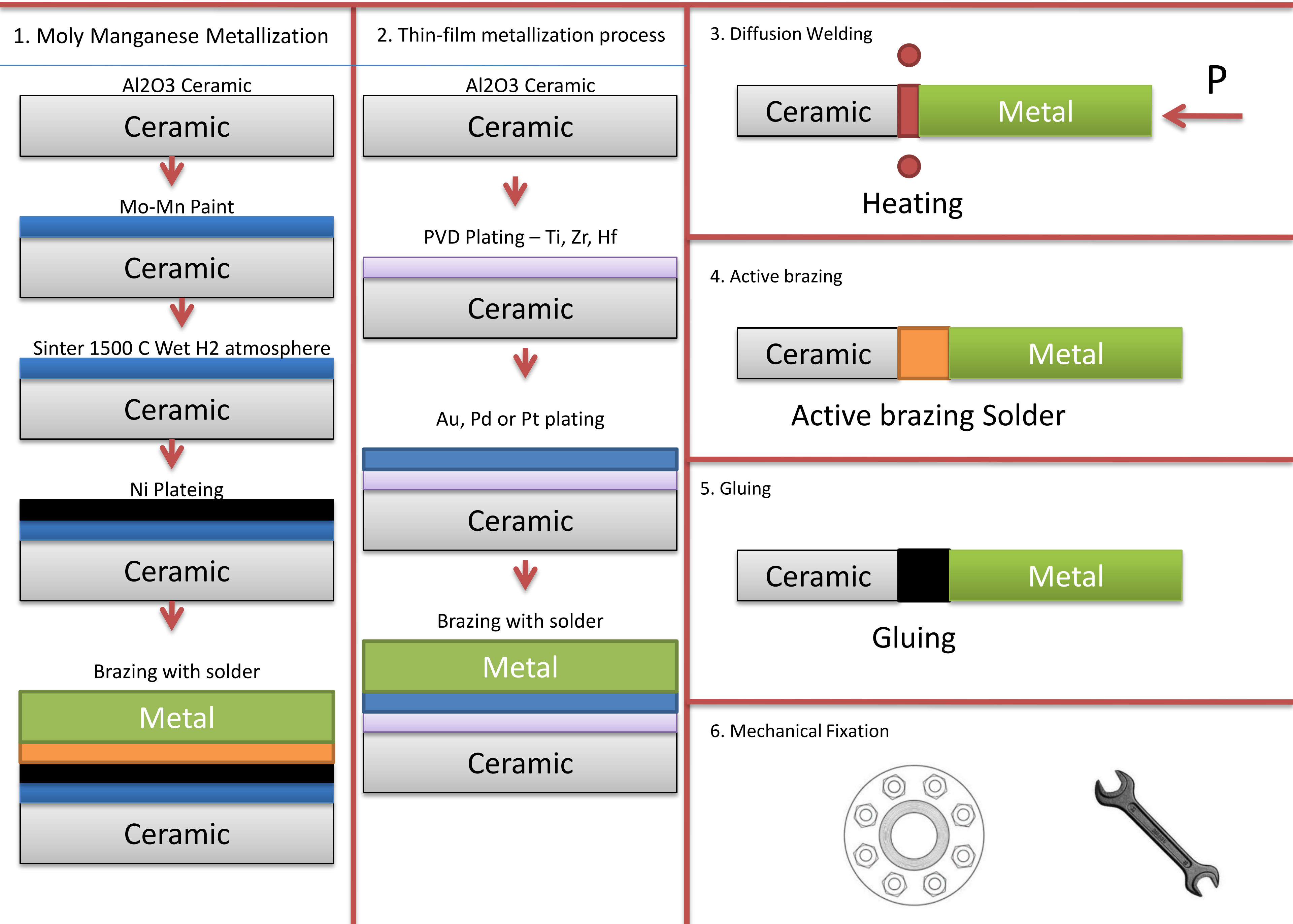
Main requirements for vacuum-tight ceramic-metal joints.

- High mechanical strength (wide range of temperature);
- Thermal shock resistance (numerous thermal cycles);
- Low outgassing level (corresponding bake-out, adsorption, desorption level);
- Low material penetration for gasses (H_2, Ar, N_2, H_2O, etc.);
- Corresponding electromagnetic features;
- High reliability and durability (geometry and structure stability during operation);
- Reproducibility – geometry, structure;
- Non-magnetic properties of brazed materials (depends on operational environment);

Bonding Technologies for Vacuum-tight Ceramic-metal joints.

- Active brazing technology;
- Brazing based on ceramic metallization technology;
- Thermo-compression bonding technology (diffusion welding);
- Gluing technics;
- Mechanical sealing technics.

Technologies for ceramic to metal bonding.



Moly-Manganese Metallization

Ceramic - Type		Metallization Past	Concentration %
Cearmaic Steatit, K-1		Mo : Fe	98 : 2
Ceramic Forsterit, ФС-5Л, АФ-555		Mo : Mn Mo : TiH_2 : Al_2O_3	96 : 4 63.8-74,0.8-6.1
Alumina silicate ceramic		WC : TiC : Fe	60 : 10 : 30
Alumina	22X, 22XC	Mo Mo : Mn Mo : Mn : Si Mo : Mn : TiH_2 Mn : Mo_2B_5 , Mo	100 80 : 20 80:20 (+5) 80 :20 : 10 20 : 10-15 : 70-65
	M7	Mo ; Mn : MoB Mo : Mn : $MoSi_2$ Mo ; Mn : C-48	62.5 : 20 : 17.5 77 : 20 : 3 75 : 20 :5
	ВГ - 4	Mo : Mn : Si	75-78 : 20 : 5-3
	A-995	Mo : Mn : Mo_2B_5 : БД-22	74 : 15 : 5 : 6
	Sapphirite	Mo : Mn : V_2O_5	75 : 20 : 5
	Policore	Mo : Mn : Si	80 : 20 : (+5)
Monocrystal	sapphire	Mo : Mn : Mo_2B_5 : БВ22	74 : 15 : 5 : 6
	Rubine	Mo : glass CT-1	70 : 30
Beryllium ceramic		Mo : Mn : Si	80 : 20 : (+5%)

Metallization process

Coating type	Temperature ^0C	duration	Cooling speed ^0C/min	Environment
Mn, Mo (22X, 22XC, A-995, M-7)	1 270 – 1 400	20 - 40	5 - 10	N_2 : H_2 = 2 : 1 N_2 : H_2 = 3 : 1 dew point +15 - +25^{0}C
Mo, Mn, Si	1 280 – 1 320	40	Cooling - 4.2	N_2 : H_2 = 3 : 1 dew point +15 - +25^{0}C

Chemical Nickel Plating

1. Nickel chloride – 45g/l
2. Ammonium chloride – 50 g/l
3. Sodium citrate – 45g/l
4. Sodium hypophosphite – 20g/l
5. Ammonia water 25% – 50g/l

pH level – 8.0-8.5

Galvanic Nickel Plating
Electrochemical Ni plating

Composition - g/l
- Sulfuric acid nickel 200-250
- Magnesium sulphate 17-25
- boric acid 10-20
- lemon acid -2
- Sodium chloride 0.5 -1
- Sodium citrate 45

Electrolit pH - 5.2-5.8

Laboratory equipment

Vacuum Furnace

Max. temperature	$2000\ ^{0}C$
Vacuum level	10^{-6}Torr
Heater	Tungsten
Power	35KW
Working chamber size	150/150/460mm
Chamber cooling	Water
Chamber shielding	Molybdenum
Heater voltage increasing and decreasing	By hand

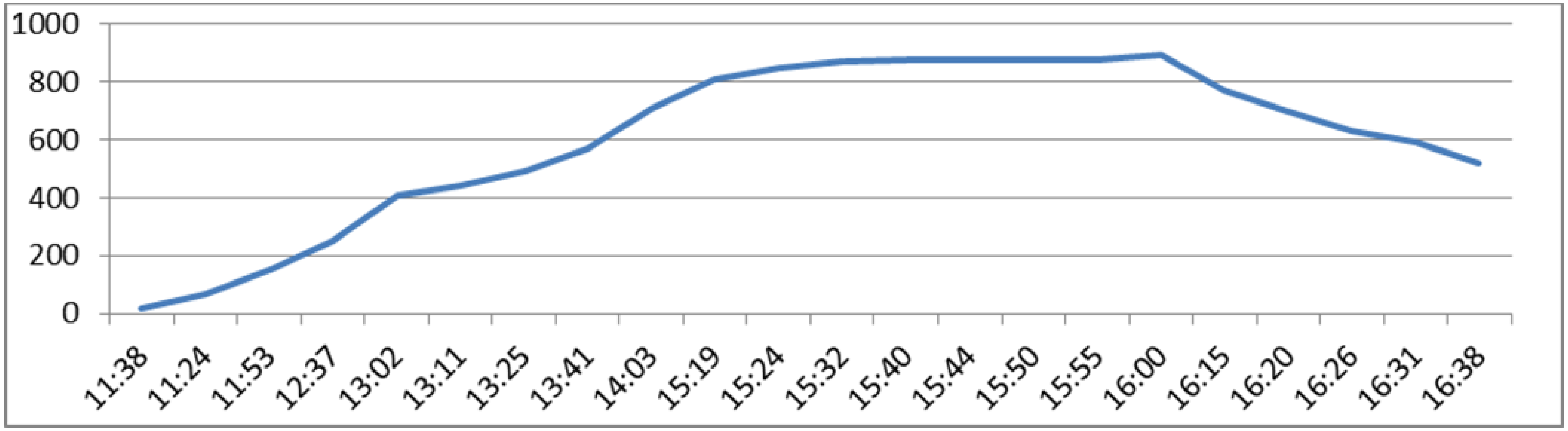
Ceramic machining system

Mixing machine (metal powders)

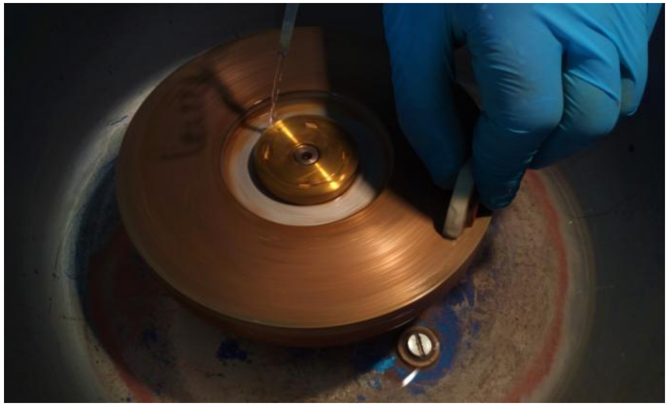
Metallurgical microscope

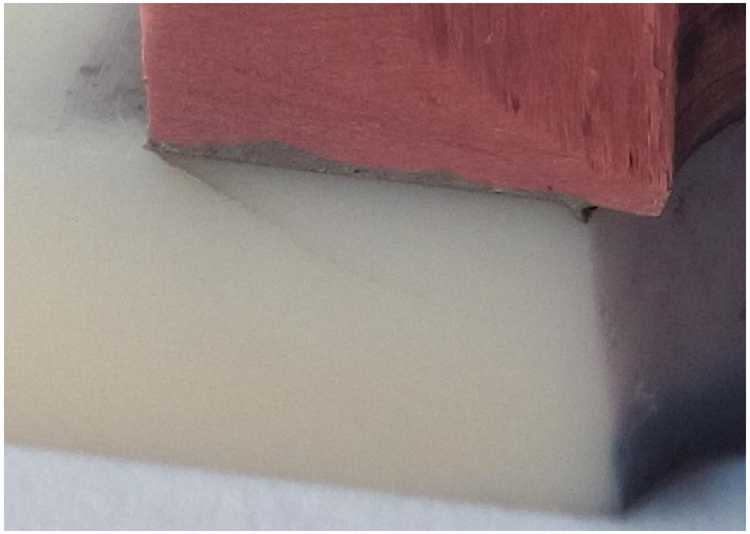
Increasing level - times	50x - 1600x
Eyepiece	WF 10x/20mm, WF 10x/20mm (With a scale), WF 16x/13mm
Planochromatic Objective lenses	5x/0,12 20x/0,35 40x/0,65 100x/1,25
Table size	180x165
Range of movement	50x40mm
Light filter	Blue, green, red, white
Digital camera	CMOS 9Mn
Transmitted permission	4096x3288
Software	Micam (Netherlands)

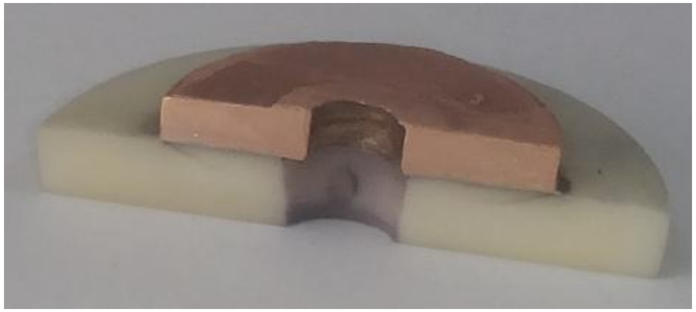
Experimentation: Active Brazing Technology

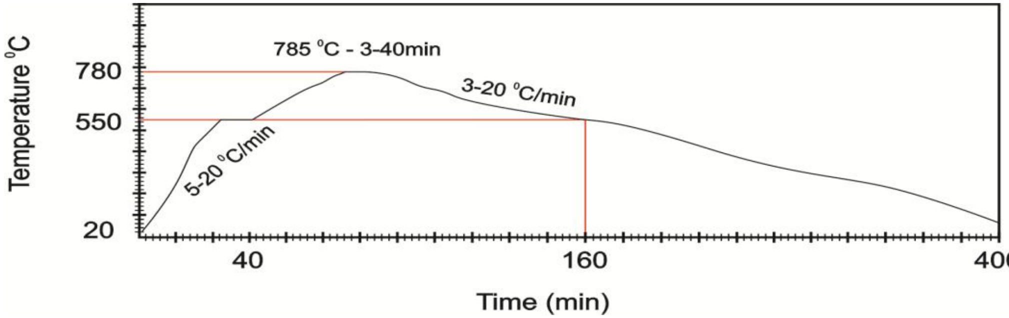


Temperature dependence on time for brazing process

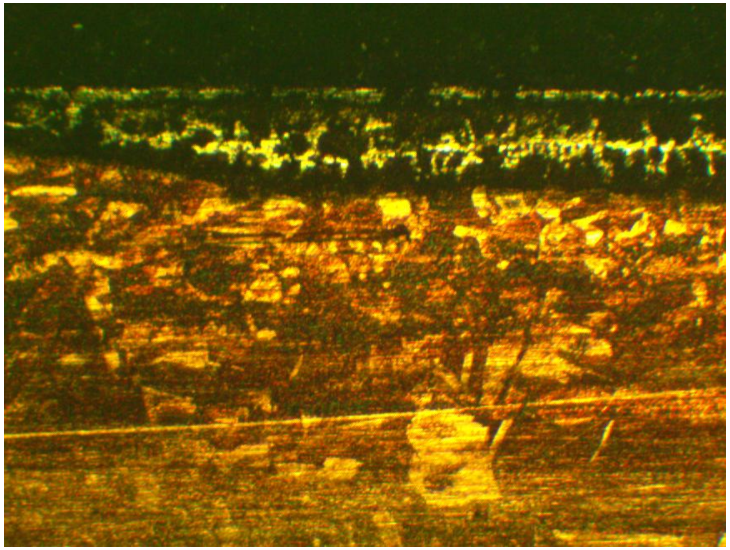


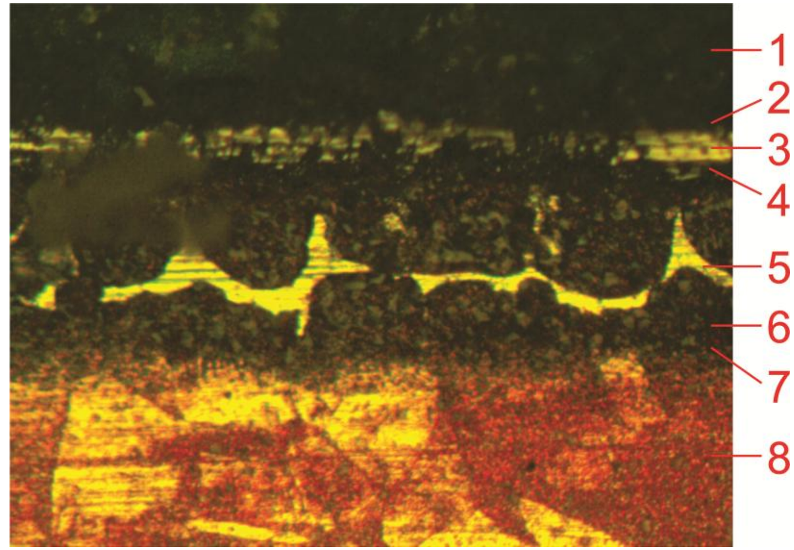


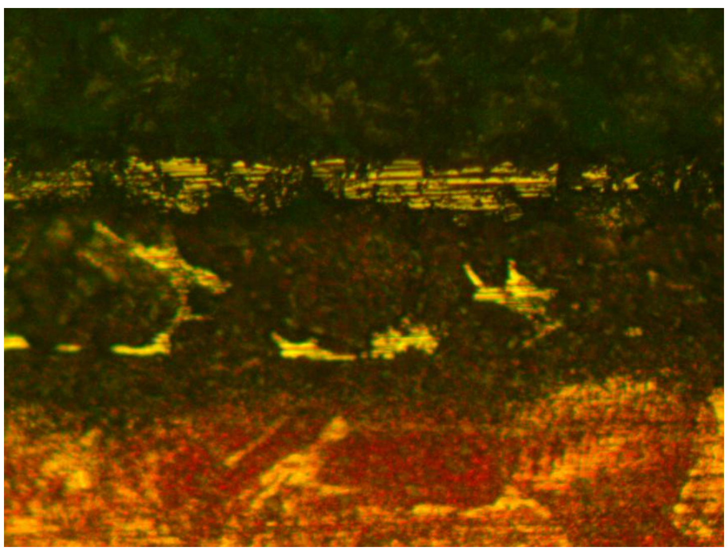


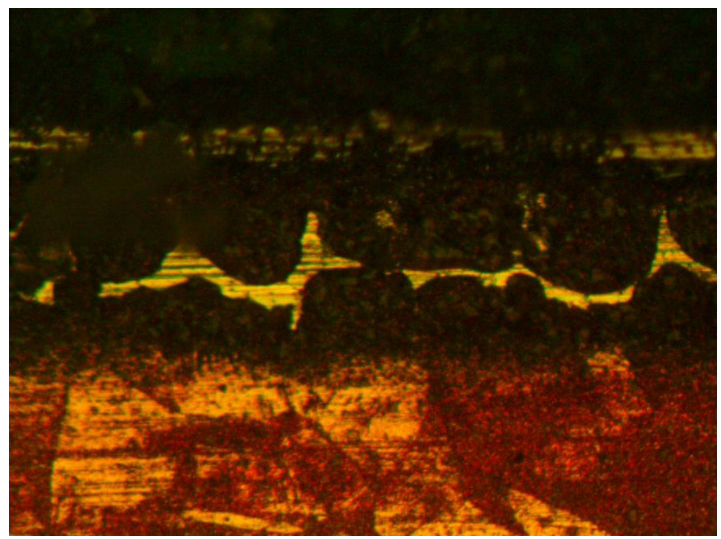


Metallurgical Microscopy



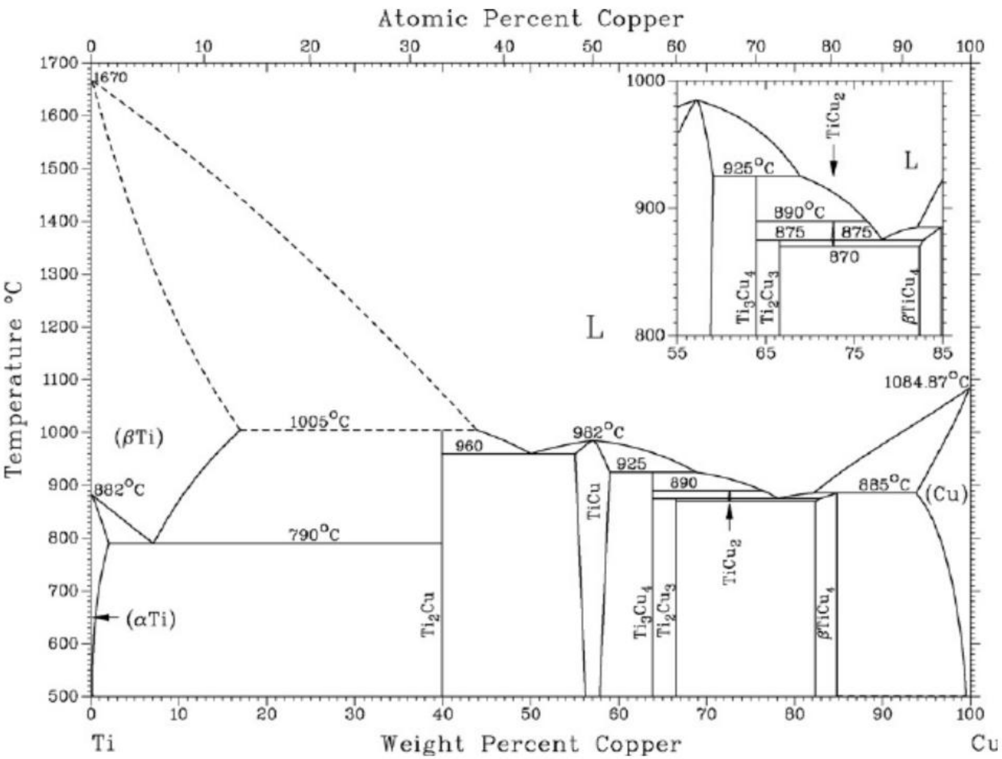




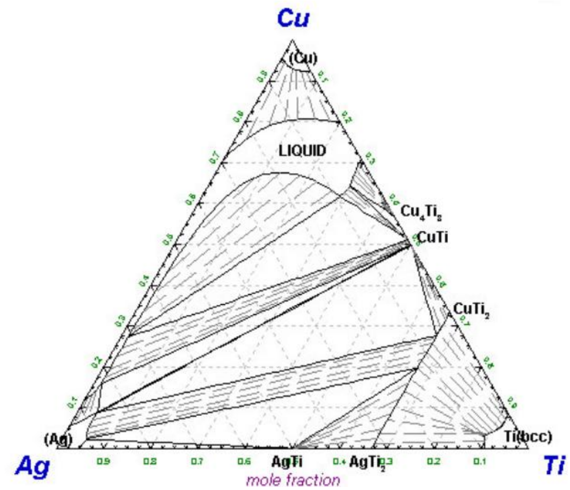


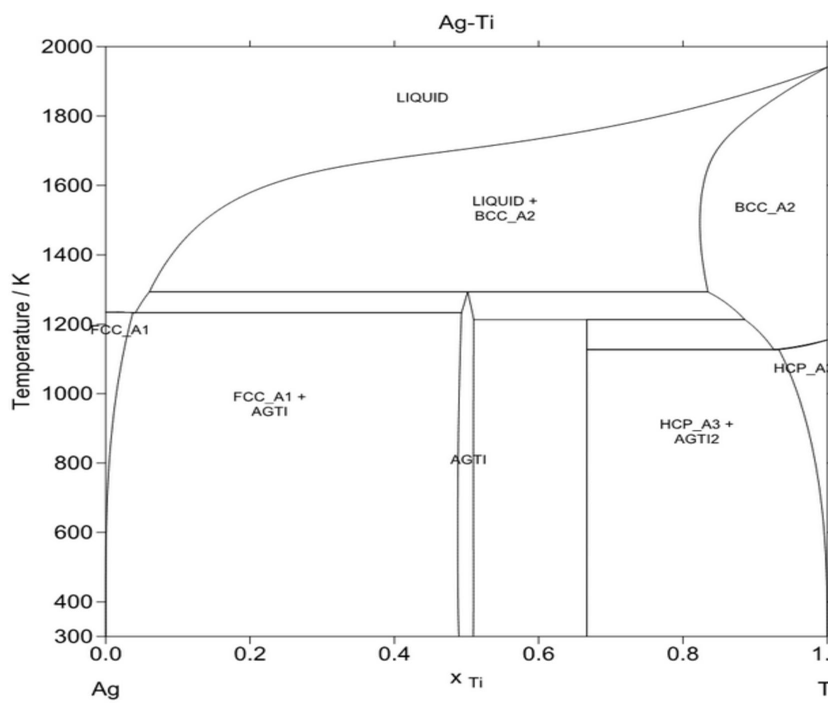
1 – Alumina
8- Cu

Alumina (99.5%)-copper structure zone - x200

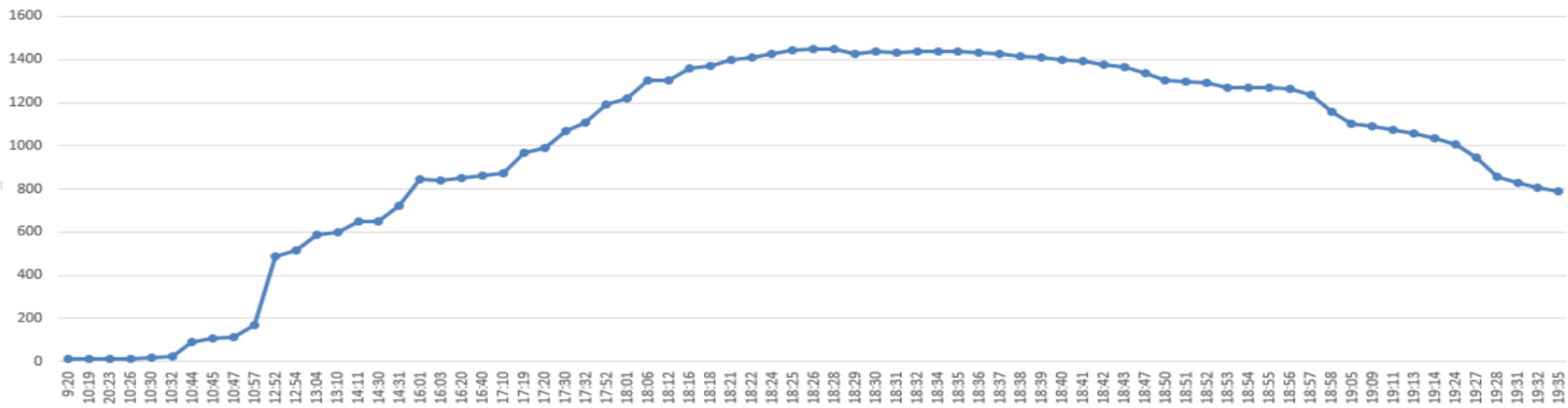


Ti-Cu binary phase diagram

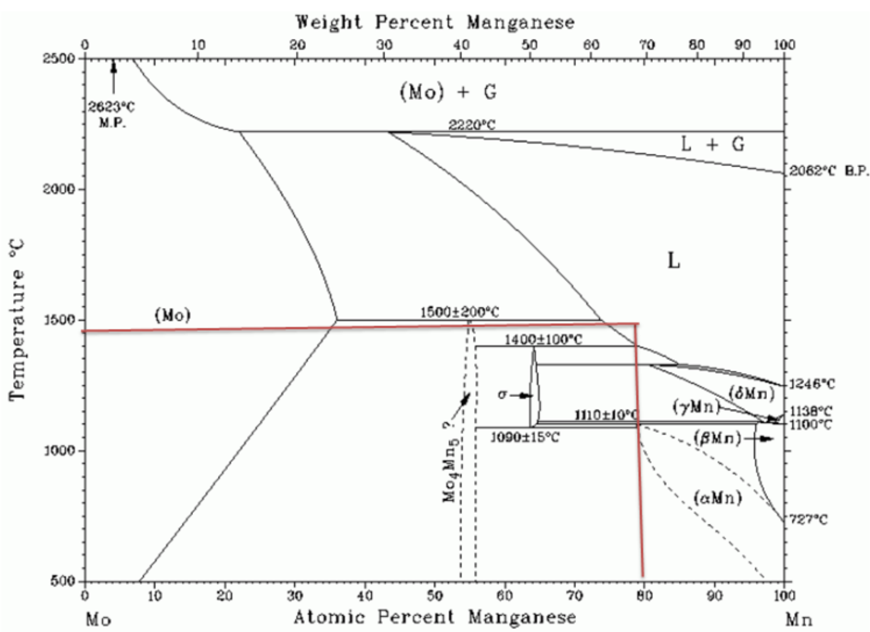




Experimentation: Molybdenum-Manganese Technology

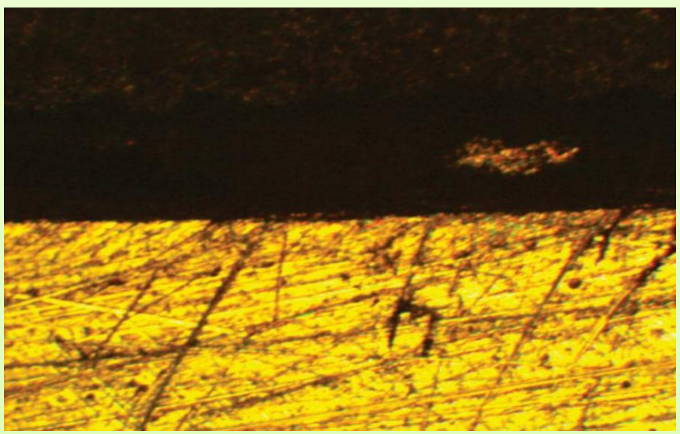


Metallization regime



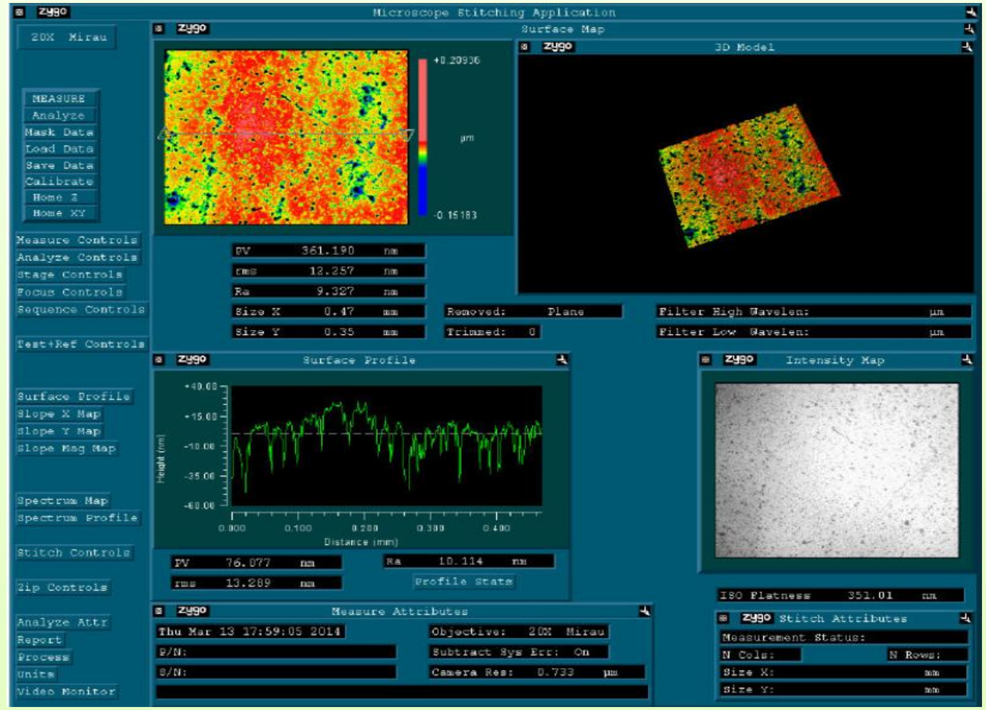
Phase diagram of Mo-Mn

95 % Alumina to SS (Stainless Steel) brazing

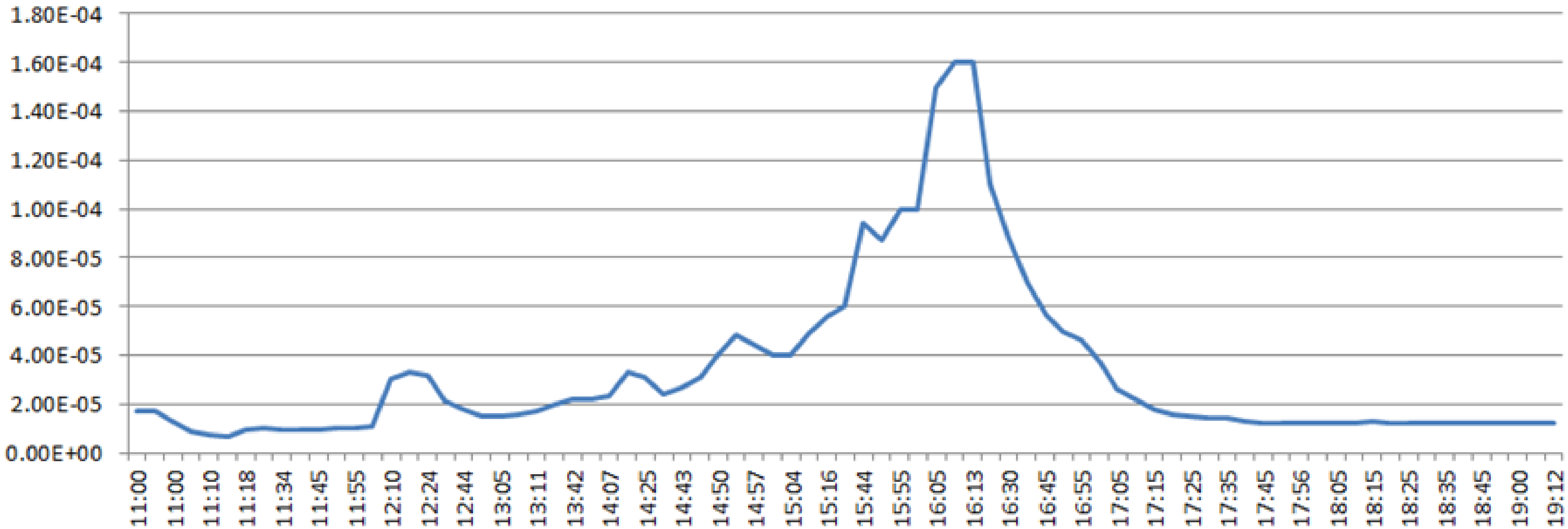


95 % Alumina to SS brazing

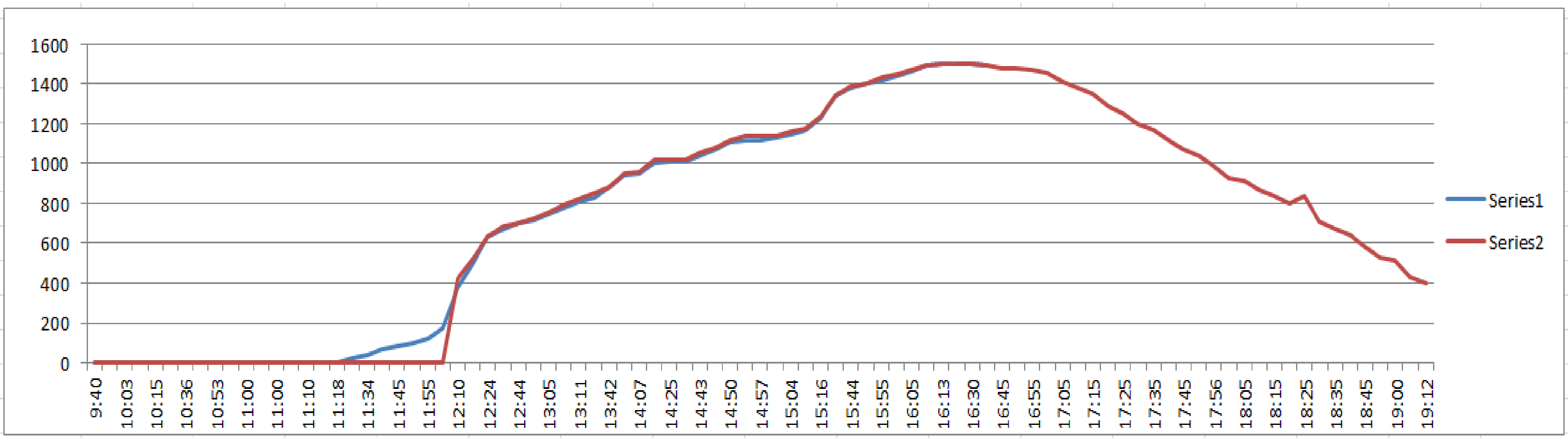
98 % alumina



Mn-Mo metallization process



Time dependence on vacuum.



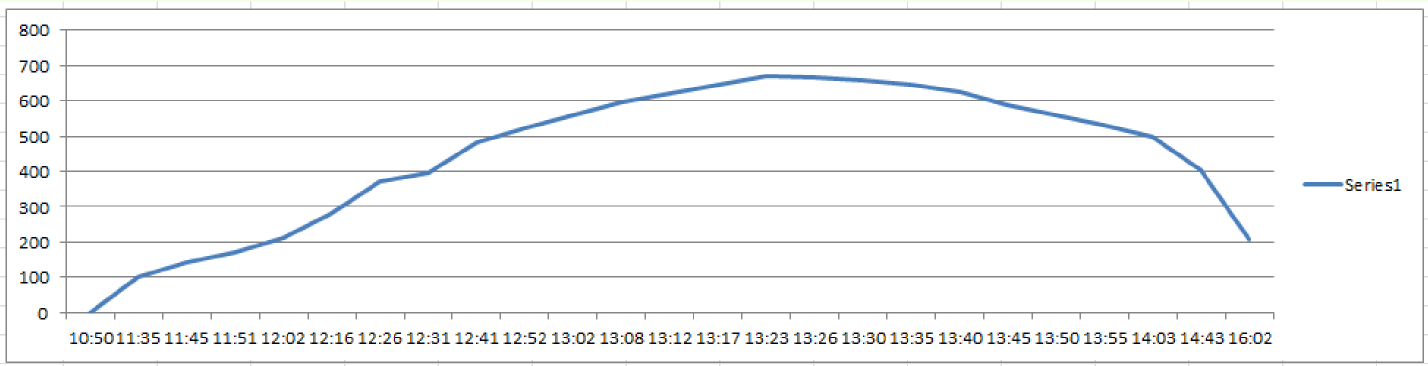
Time dependence on temperature

Metallization (Mn-Mo) and Ni plating

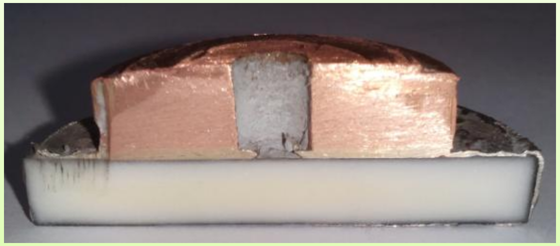
Metallization samples

Ni Plated Samples

Silver Soldering.



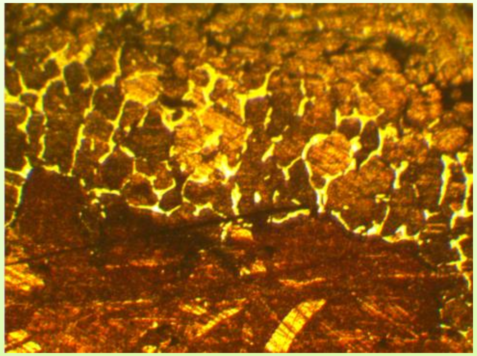
Temperature dependence on time.

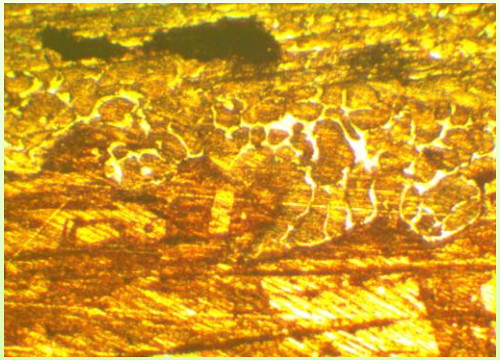


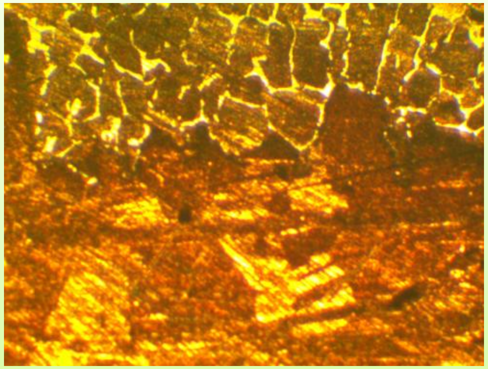
Alumina – Cu joints

x200

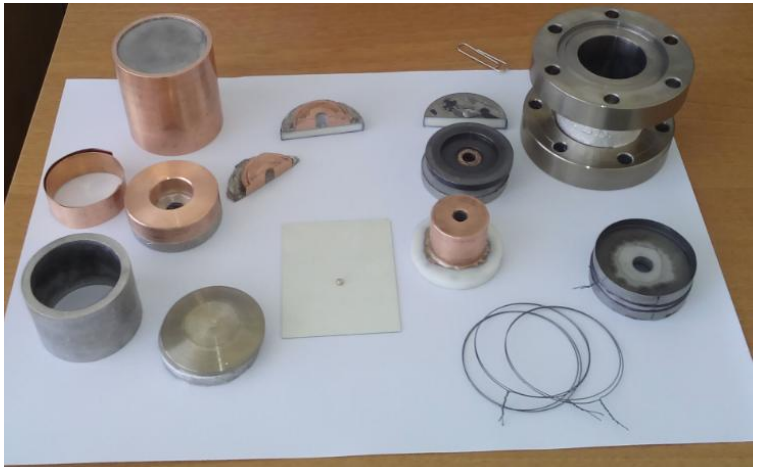
Alumina – Cu Brazed joint

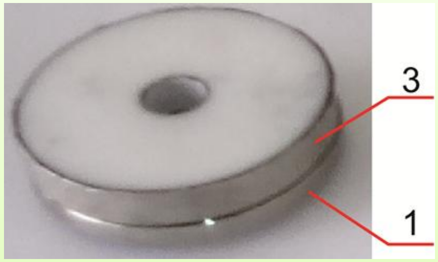






Brazing of Alumina to Metals – Fixation Technologies





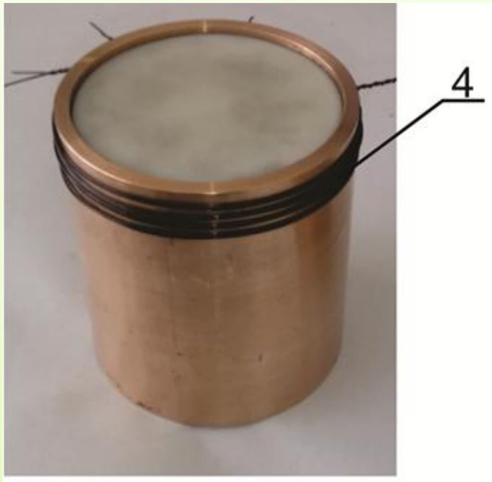
Alumina to SS brazing

1.-stainless steel
2.-alumina

Alumina to Cu brazing

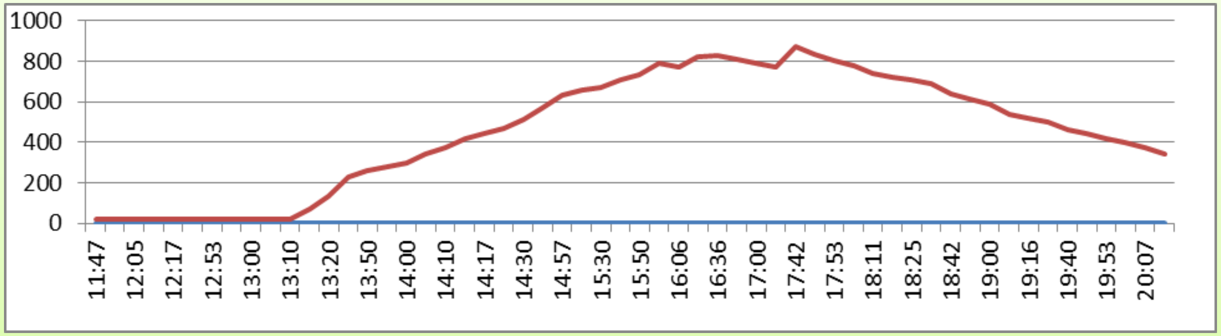
1.-Cu
2.-alumina

Brazing Alumina to Kovar



Alumina to Cu brazing

Mo wire fixation (4)

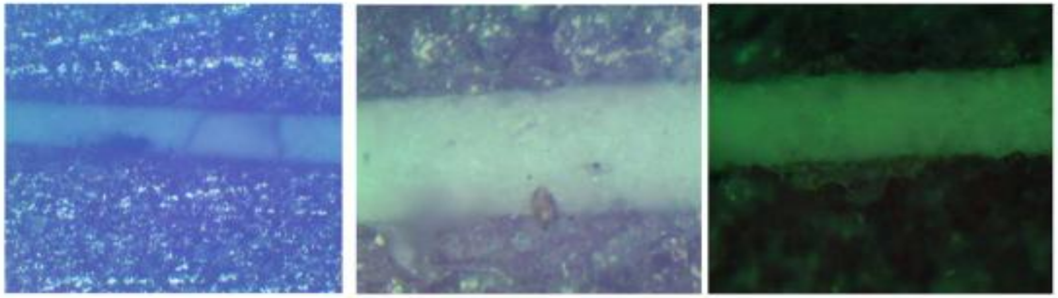


Temperature dependence on time of brazing process.

Thermo-compression Bonding Technology

Diffusion Welding Machine

Gluing technics



Alumina to Cu

Disadvantages
-Low mechanical strength,
-Low working temperature,
-Short lifetime,

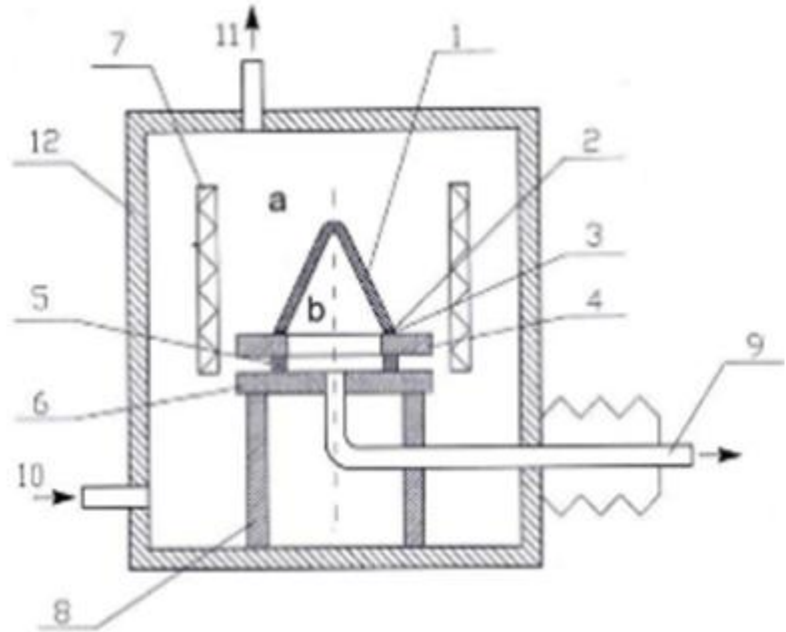
95% Alumina to Alumina Joint

Chapter 3. Brazing technologies for ceramic-metal joints and thermo-mechanical simulations.

3.1. New diffusion brazing method for dissimilar items with difficult geometries.
3.2. Experimentation of new diffusion brazing method for dissimilar items with difficult geometries.
3.3. New diffusion bonding method for cylindrical materials .
3.4. Diffusion bonding process based on molybdenum foil.
3.5. Thermo-mechanical simulation of ceramic-metal joints for vacuum systems.
   3.5.1. Thermo-mechanical simulations of ceramic disc – Cu ring system.
   3.5.2. Thermo-mechanical simulations of vacuum break.
   3.5.3. Thermo-mechanical simulations of vacuum break with conical joint zone.
3.6. Summary.

New Diffusion Brazing Method.

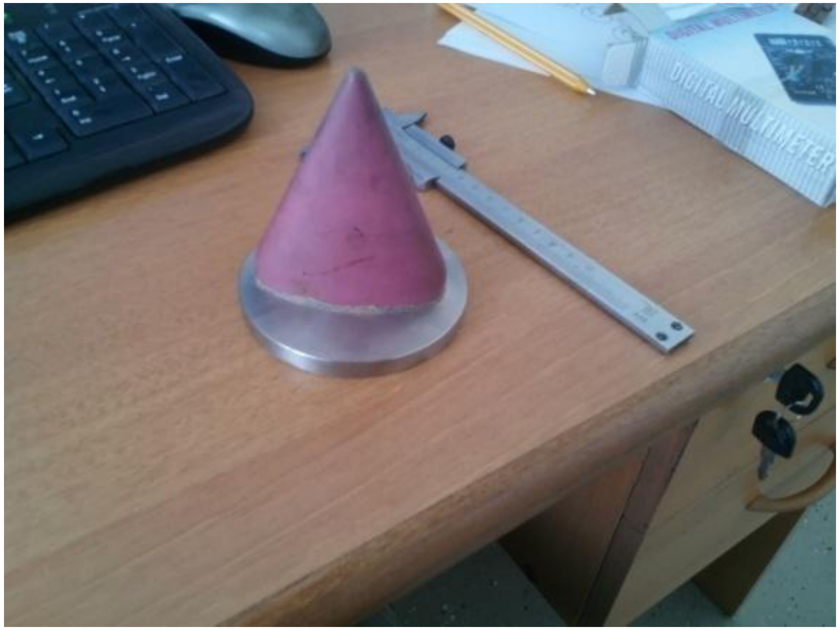
New Diffusion Brazing Method for Dissimilar Items and Difficult Geometry.



Diffusion brazing method for dissimilar and difficult geometry items.

2883 A, 2014, Yerevan
Vardan Shavarsh Avagyan, Vahagn Vanik Vardanyan
Intellectual Property Agency of the Republic of Armenia

Experimental results

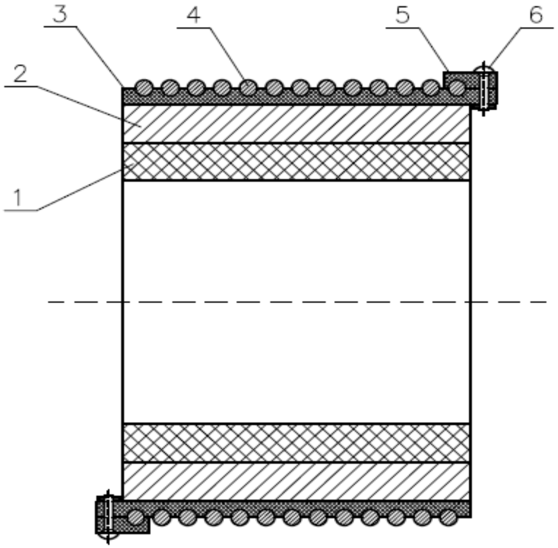


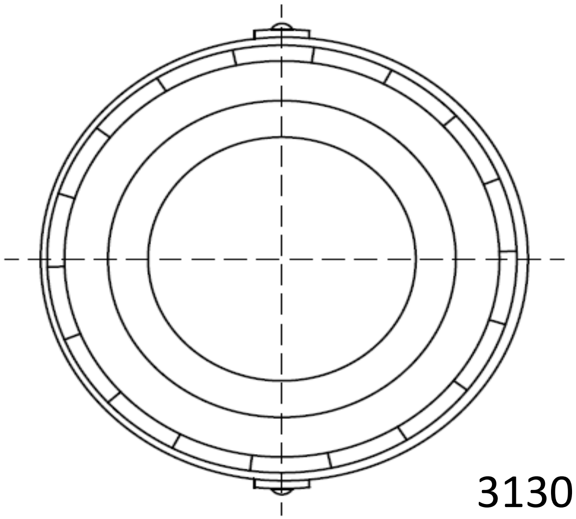
Experimental machine

Pressure difference 10^{-3} Torr and atmospheric or 0.5 Atm

New Bonding Method for Materials – Patent Number - AM 20170070

New bonding method (diffusion brazing or welding) for cylindrical materials.



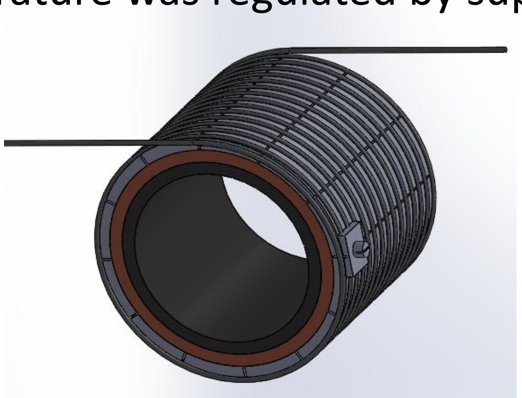


1. Ceramic,
2. Metal,
3. Ceramic (BeO),
4. Molybdenum wire,
5., 6. Wire fixators.

3130 A, Yerevan, 2017

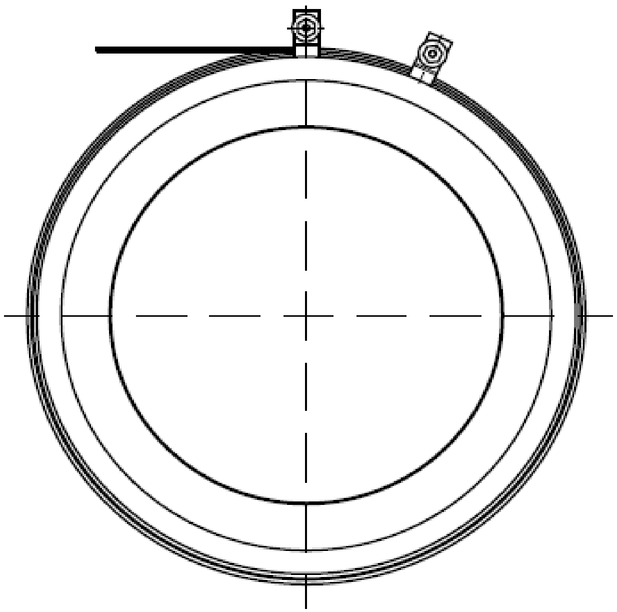
Vardan Shavarsh Avagyan, Vahagn Vanik Vardanyan
Intellectual Property Agency of the Republic of Armenia

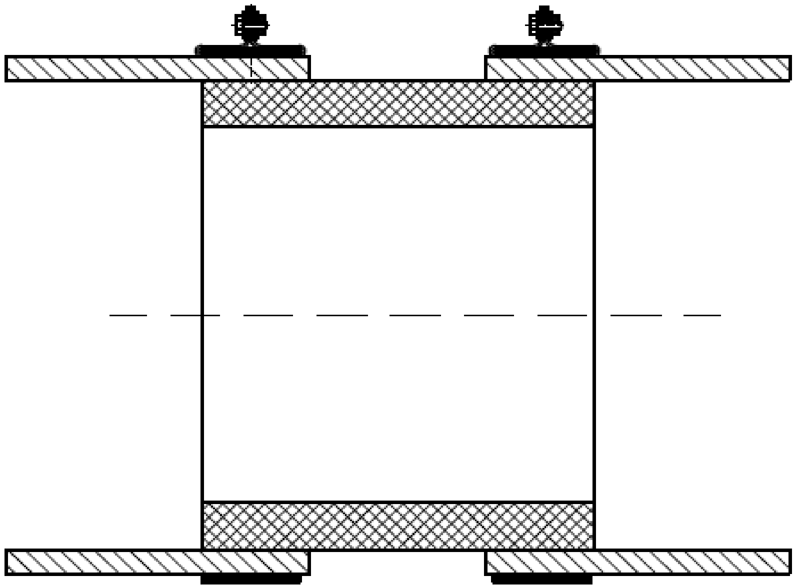
The temperature was regulated by supplied electrical current.

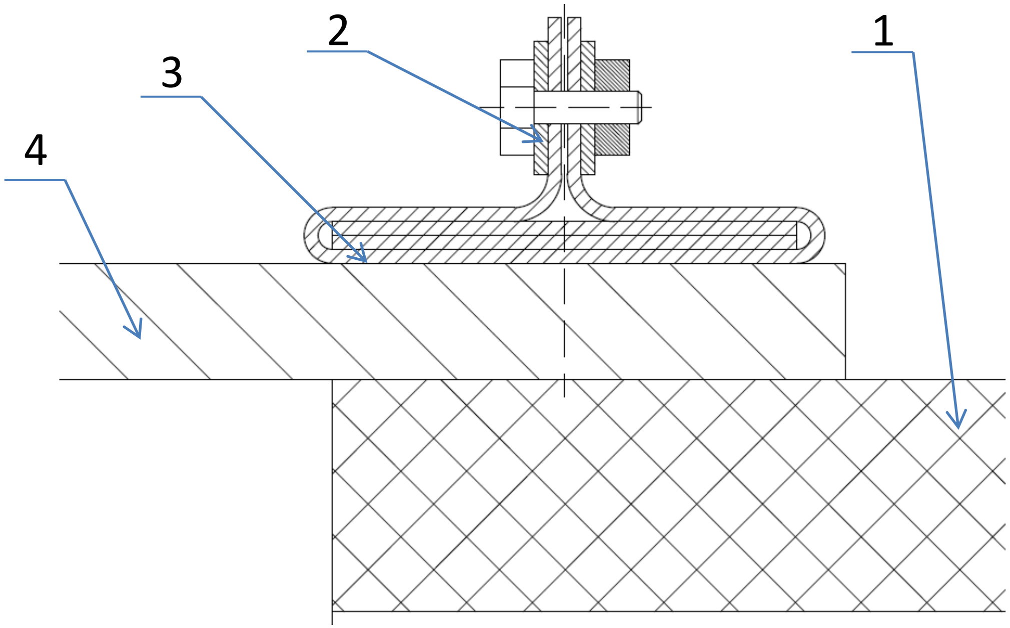


Advantages
- local heating;
- local pressure;
- Fluent regulation of temperature and pressure;
- Equal Pressure exert

Fixation Method by Metal Foil Usage – (Molybdenum foil).

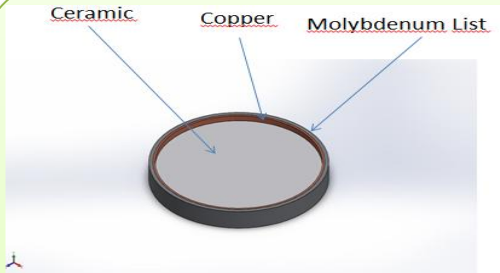


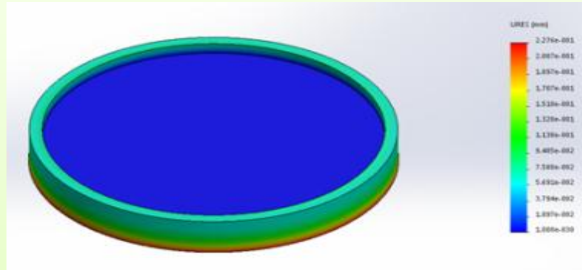


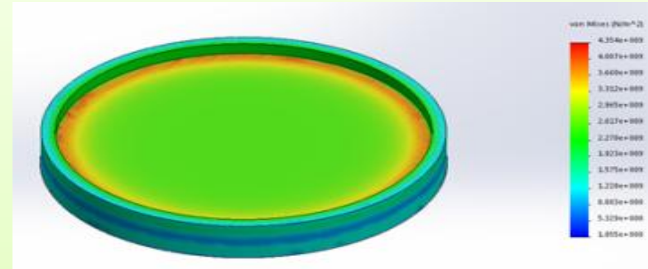


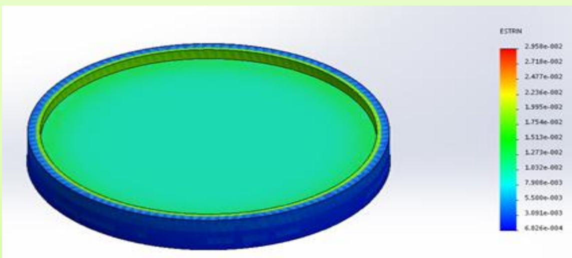
1. Ceramic,
2. Foil Fixing Parts,
3. Molybdenum Foil,
4. Metal

Thermo-Mechanical Simulations – (Preliminary)



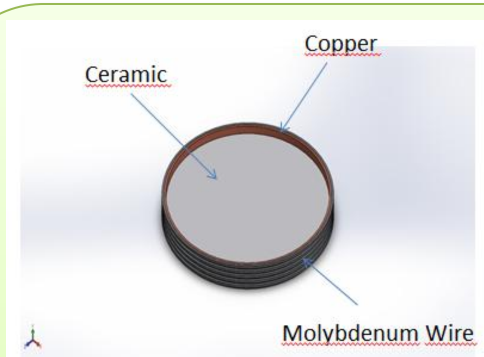


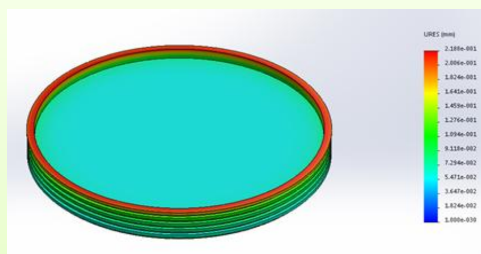


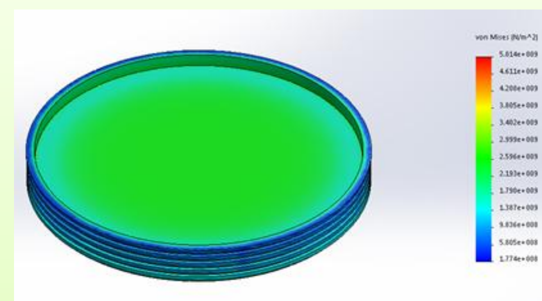


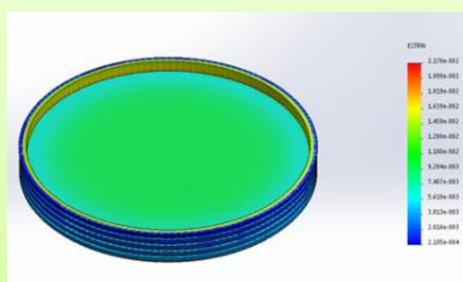
Temperature - 850 ^{0}C

Fixation - Mo Foil





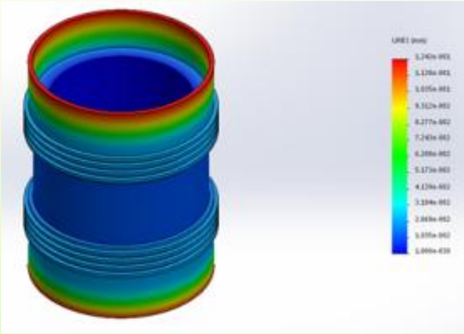


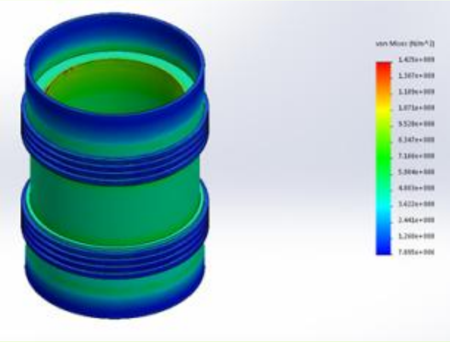


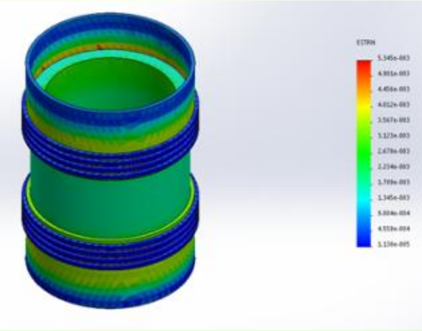
Temperature - 850 ^{0}C

Fixation - Mo Wire

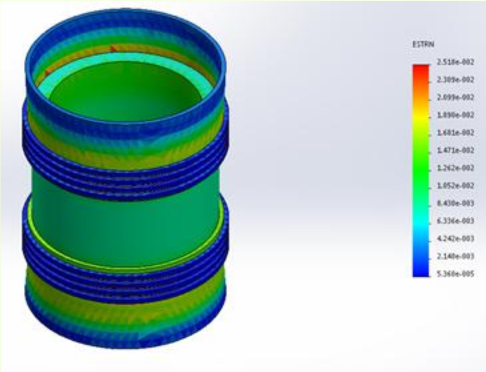
Thermo-Mechanical Simulations (Preliminary)

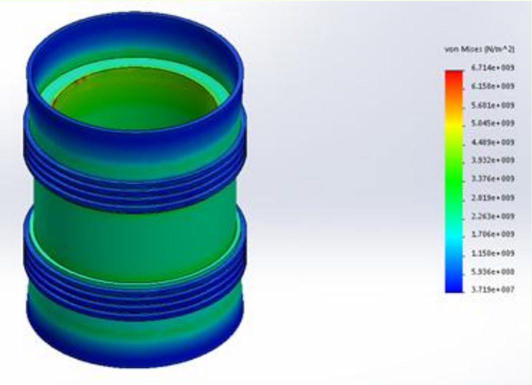


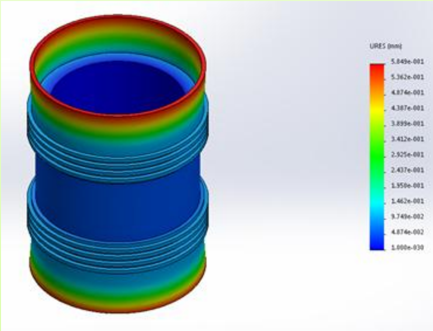


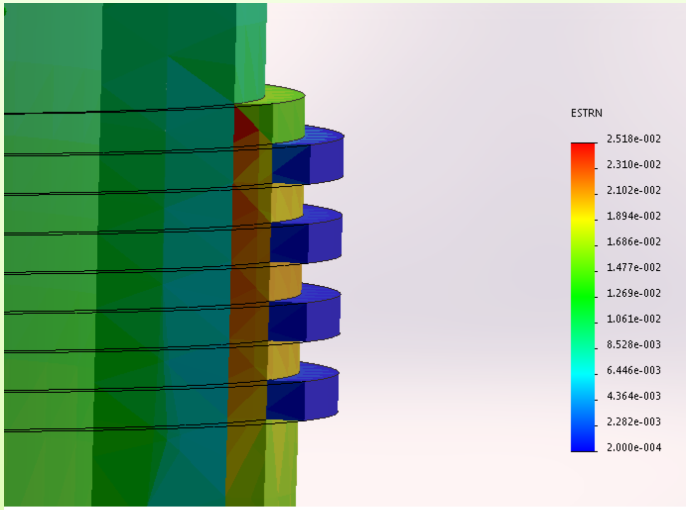


Temperature - 200 ^{0}C Fixation - Mo Foil



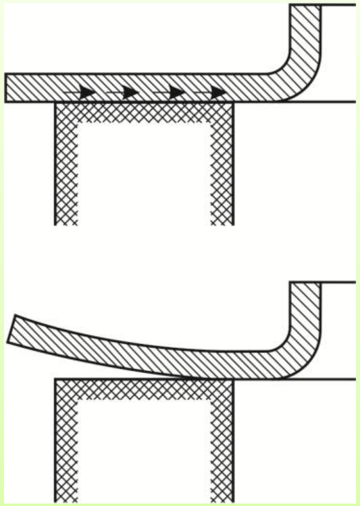


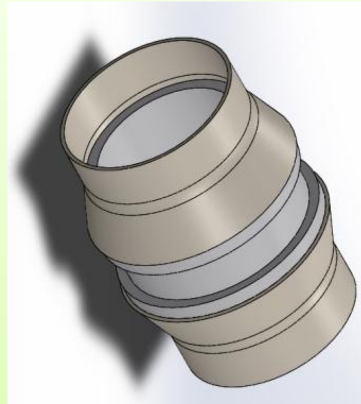


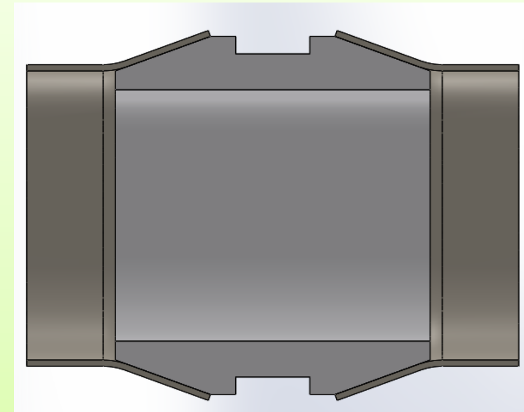


Temperature - 850 ^{0}C
Fixation - Mo Wire

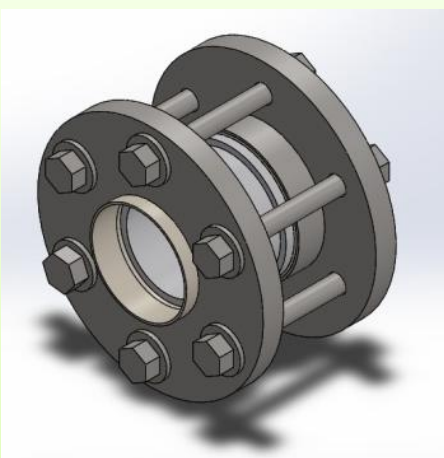
Thermo-Mechanical Simulations

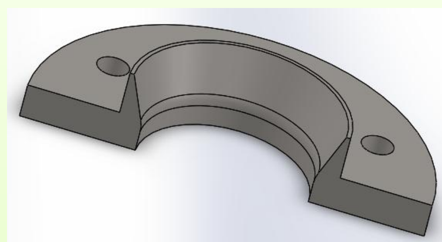


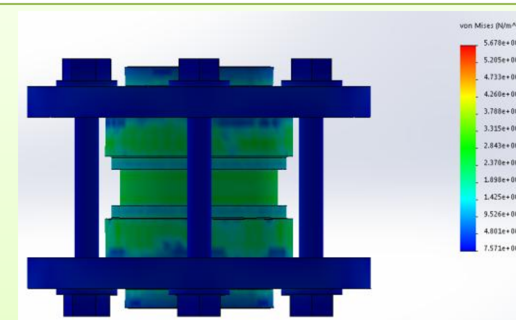


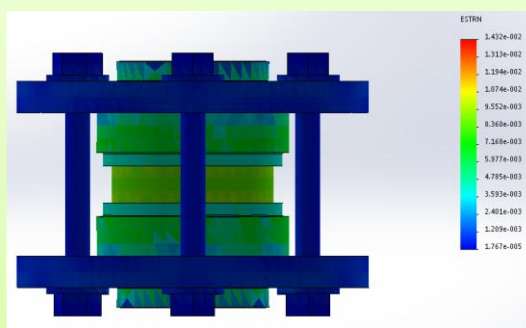


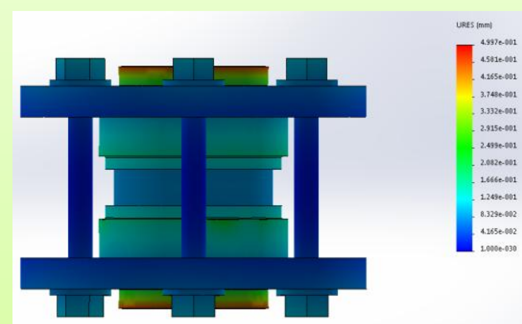
Temperature - 200 ^{0}C









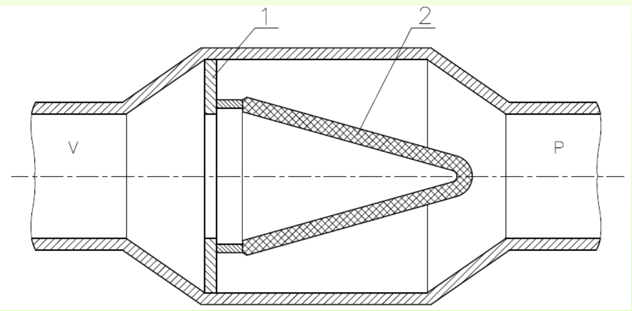


Temperature - 850 ^{0}C

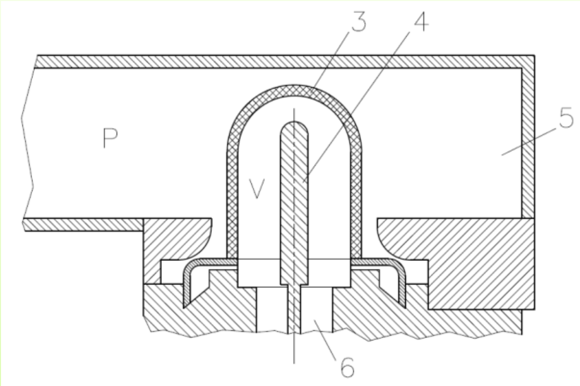
Chapter 4. Vacuum-tight ceramic-metal joints in particle accelerators – RF window.

Variety of vacuum RF windows

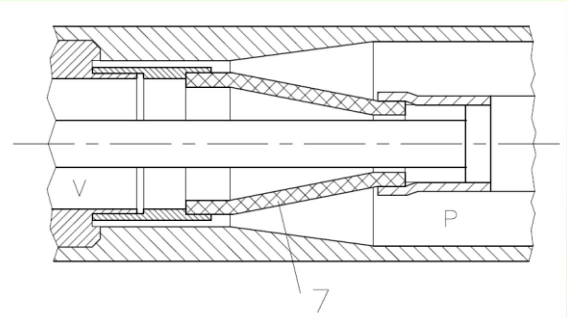
Frequency band name	Frequency (GHz)	Size (mm)	Waveguide name
L-Band	1.15 — 1.72	165.1 × 62.55	WR650
S-Band	2.60 — 3.95	72.14 × 34,94	WR284
C-Band	3.95 — 5.85	47.55 × 22.2	WR187



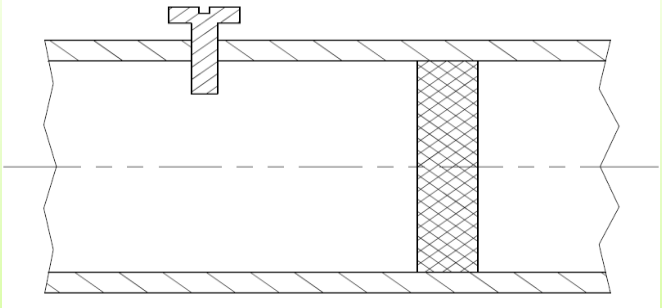
Waveguide type

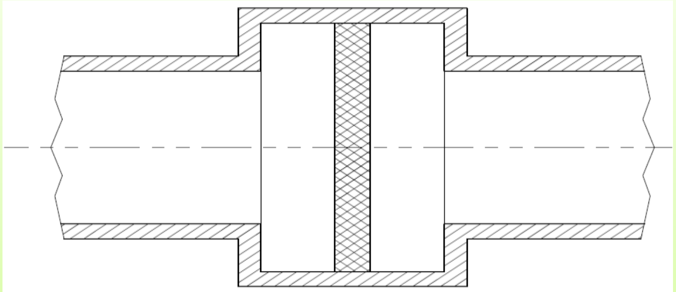


Coaxial type



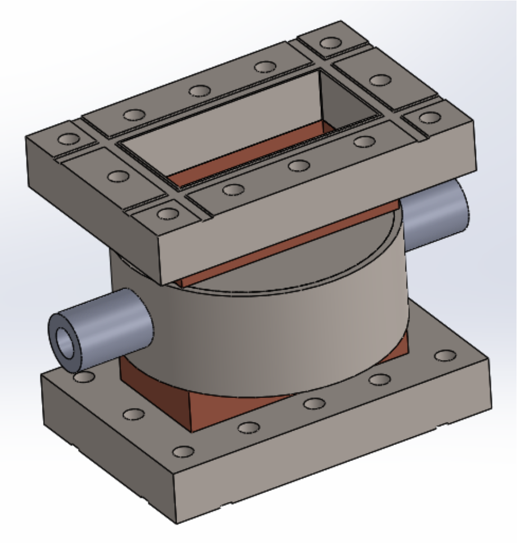
Waveguide-coaxial type

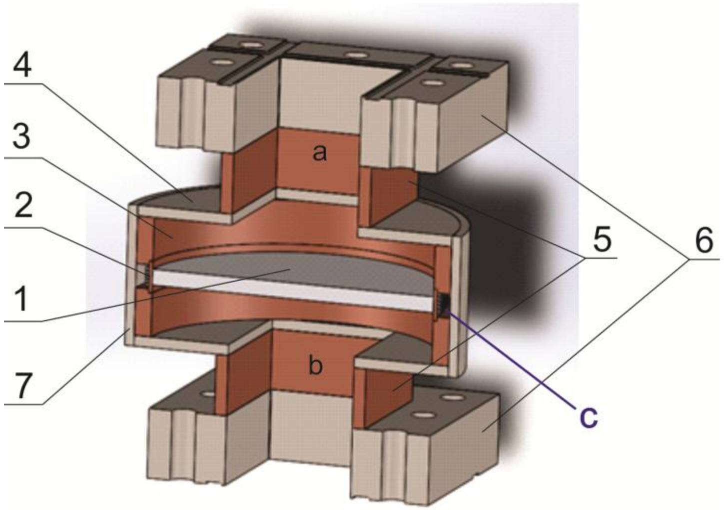




Effective transition

Pill box type RF window





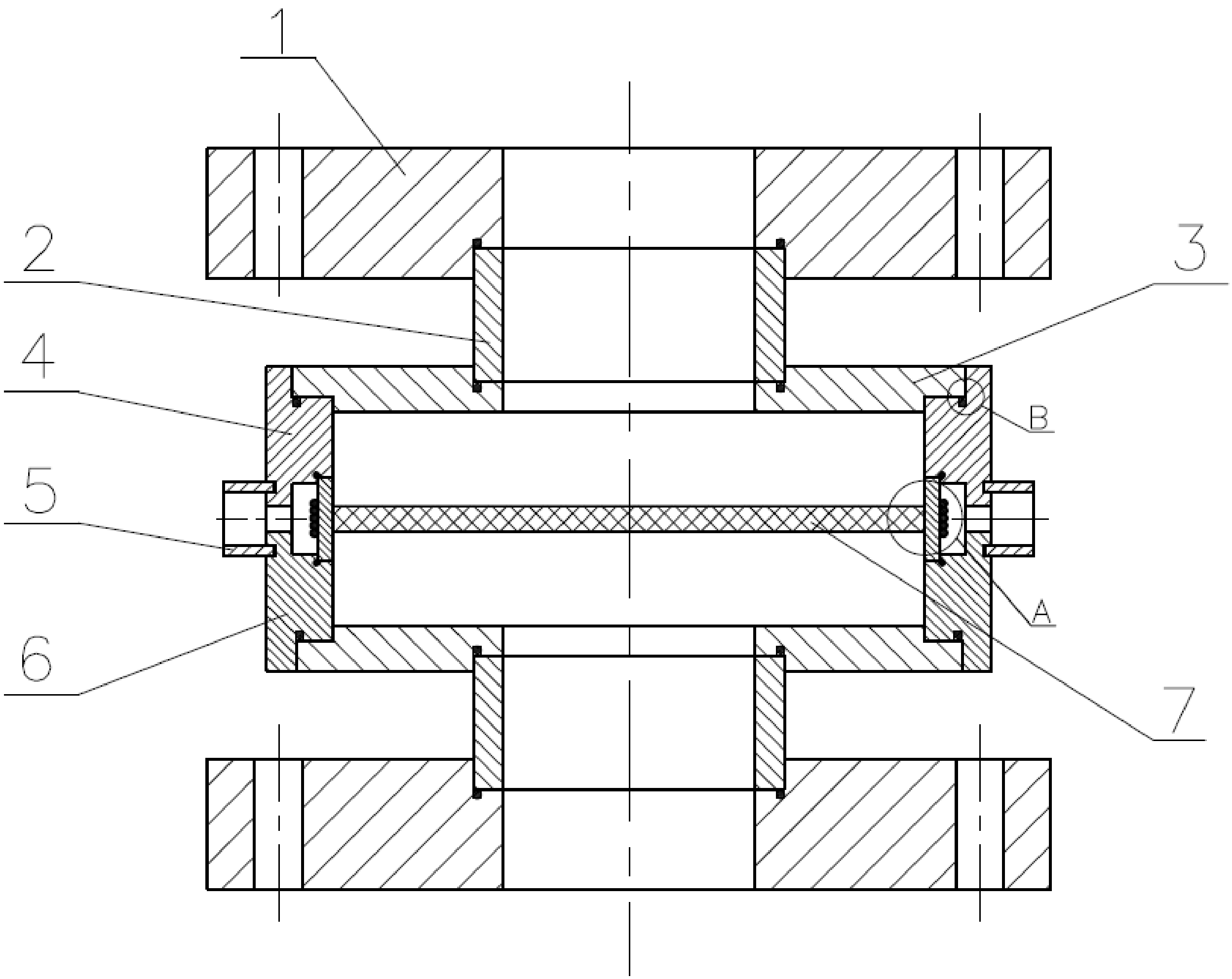
Requirements

- High mechanical strength;
- High transparent level for electro-magnetic waves;
- Lower secondary electron emission;
- High conductivity of walls (metal);
- Reliability and durability;
- Outgassing low level;
- Higher reproducibility;
- High level of homogeneity of materials structures;

Design Process

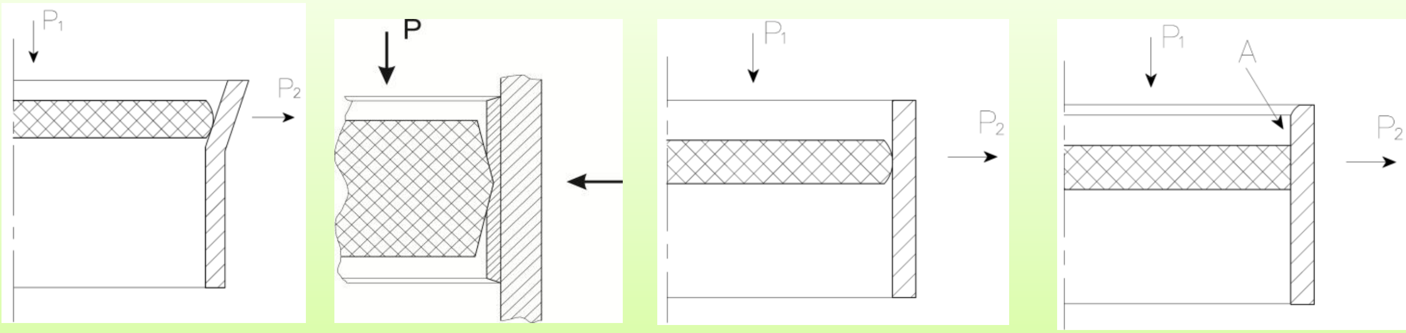
- Desired required characteristics – required documentation (RF parameters, vacuum and pressure levels, etc.);
- Electro-magnetic design (calculation, simulations for inner geometry and corresponding effective materials);
- Mechanical and thermal design (developing of effective mechanical structure and drafting – including development of materials brazing and welding technologies, items machining specifications, heat removal cycle design – thermoregulation unites, etc.);
- Selection of corresponding materials;
- Machining (rough & fine) of unit parts based on developed and designed technologies and drawings;
- Surface preparation – treatment (cleaning, polishing, etc.);
- Precise assembly;
- Brazing and welding in corresponding accuracies (diffusion brazing and welding, thermocompression welding in vacuum or inert gas environments);
- UHV test – residual gas analyzing, leak detection under high temperature conditions;
- Tuning;
- Pre-processing;
- High power conditioning;
- Conditioning with RF;
- Operation in real working environments – In high RF power, UHV, pressured gas and cooling conditions;

Pillbox type Vacuum RF window – Mechanical design

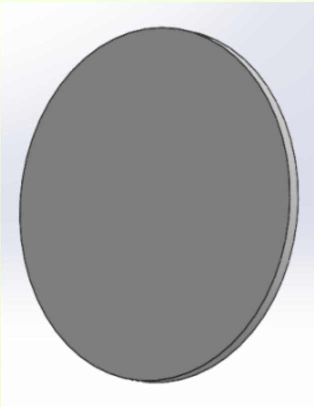


1. Flange
2. Waveguide
3. Pill box cover
4. Cylinder 1.
5. Water input and output pipes
6. Cylinder 2.
7. Ceramic disc

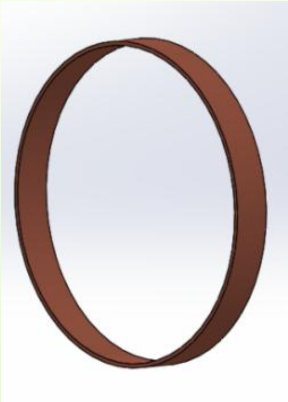
Ceramic to Metal Fixation



Difficulties of assembling



Ceramic disc



Cu cylinder

Assembling

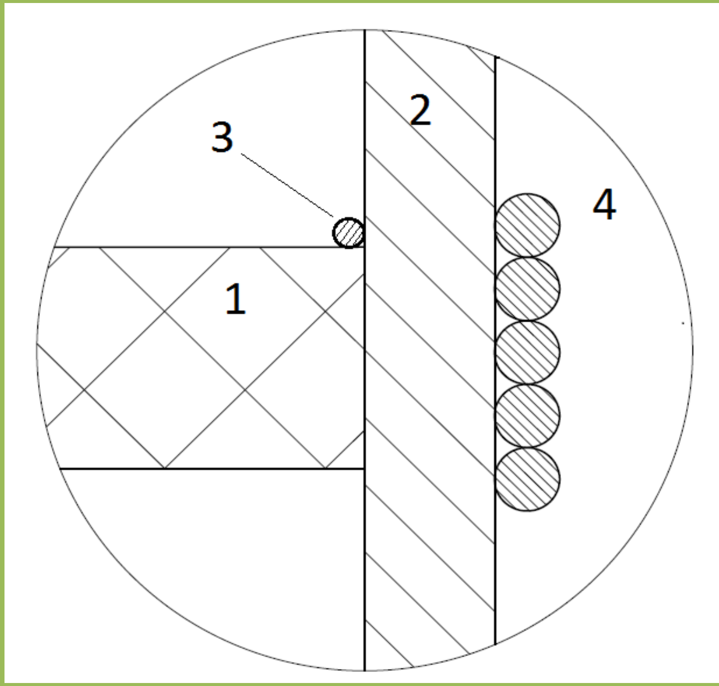
Fixation

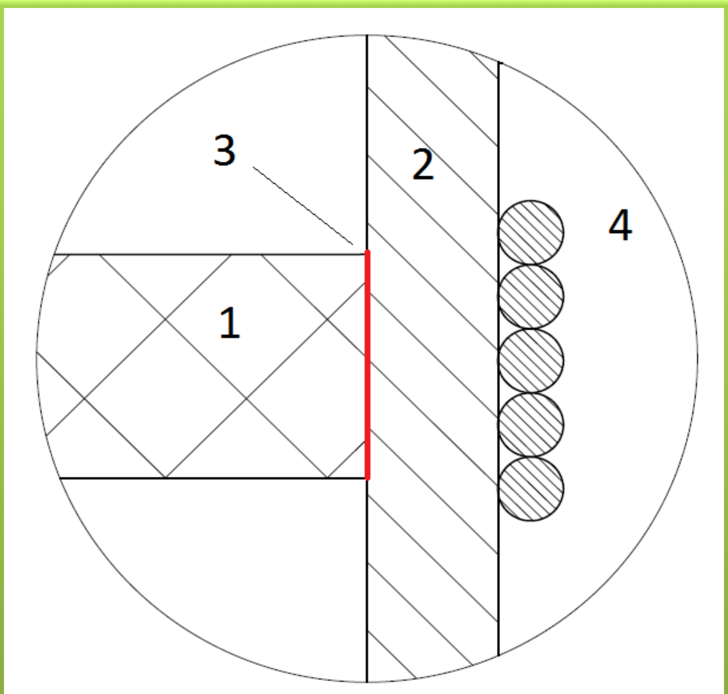
Ceramic disc to Cu Cylinder assembling

Fixation - Mo wire

Solder fixation

Ceramic Disc to metal (Cu) Cylinder Brazing – Solder Fixation

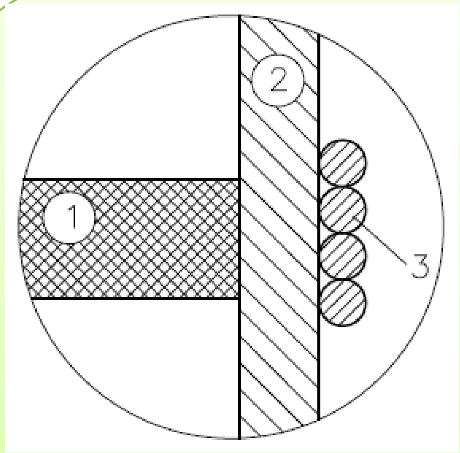


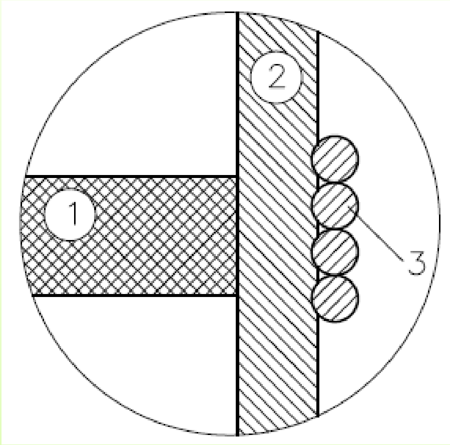


a – Solder Foil
b – Coated Solder Layer

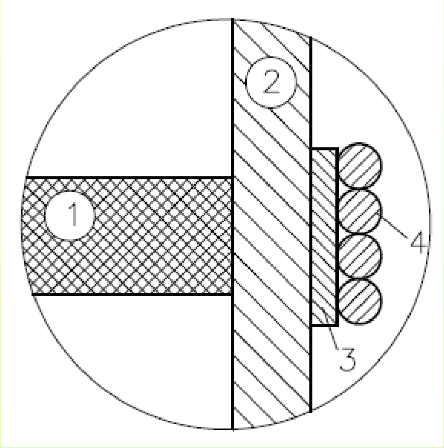
1 – ceramic disc, 2- metal cylinder (Cu), 3- solder, 4- Mo wire

Mo Wire Fixation Methods



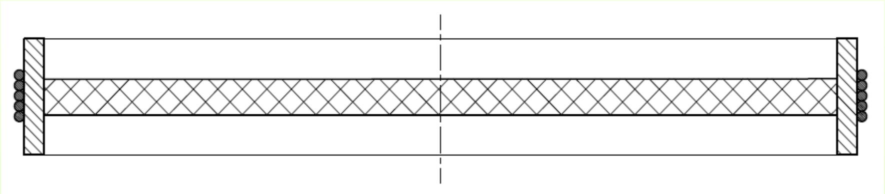


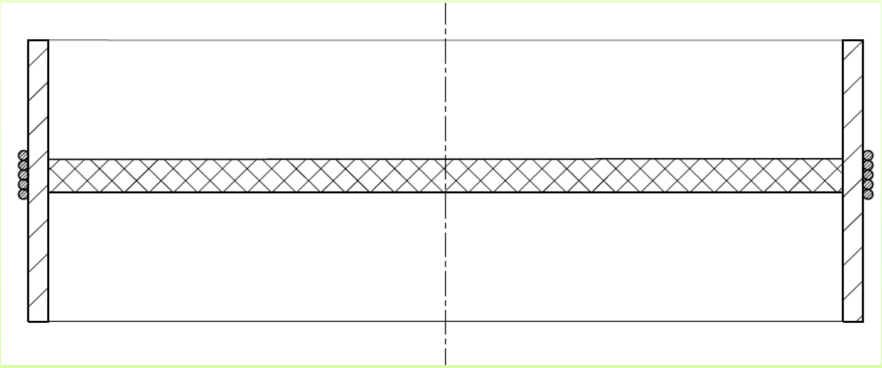
Mo wire immersion (high deformation)

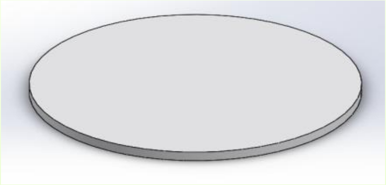


Mo Wire to Mo foil combination

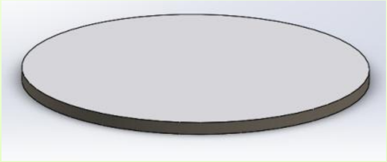
1 – ceramic disc, 2- Cu cylinder



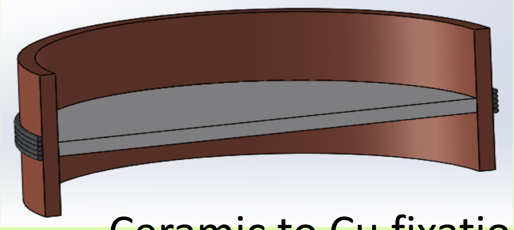




Ceramic

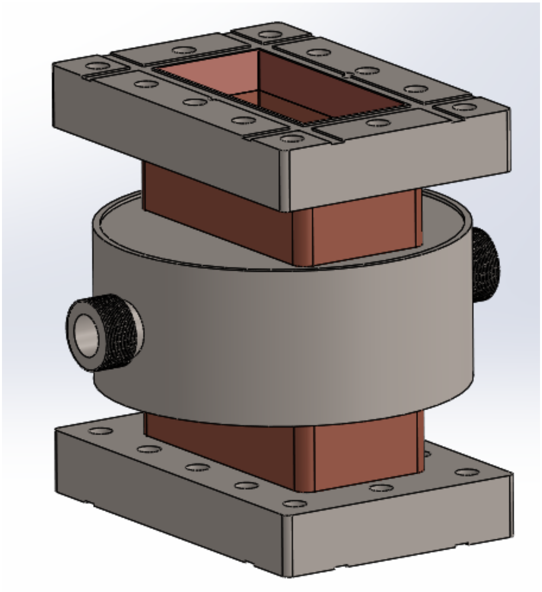


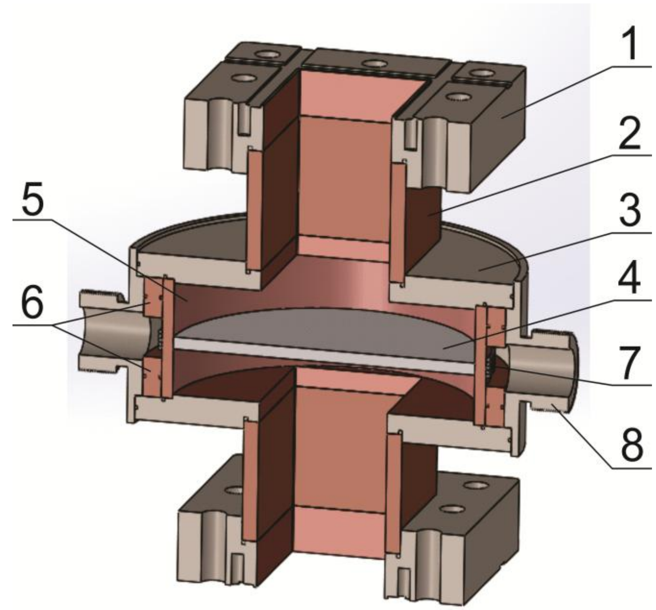
Ceramic
Mn-Mo+Ni



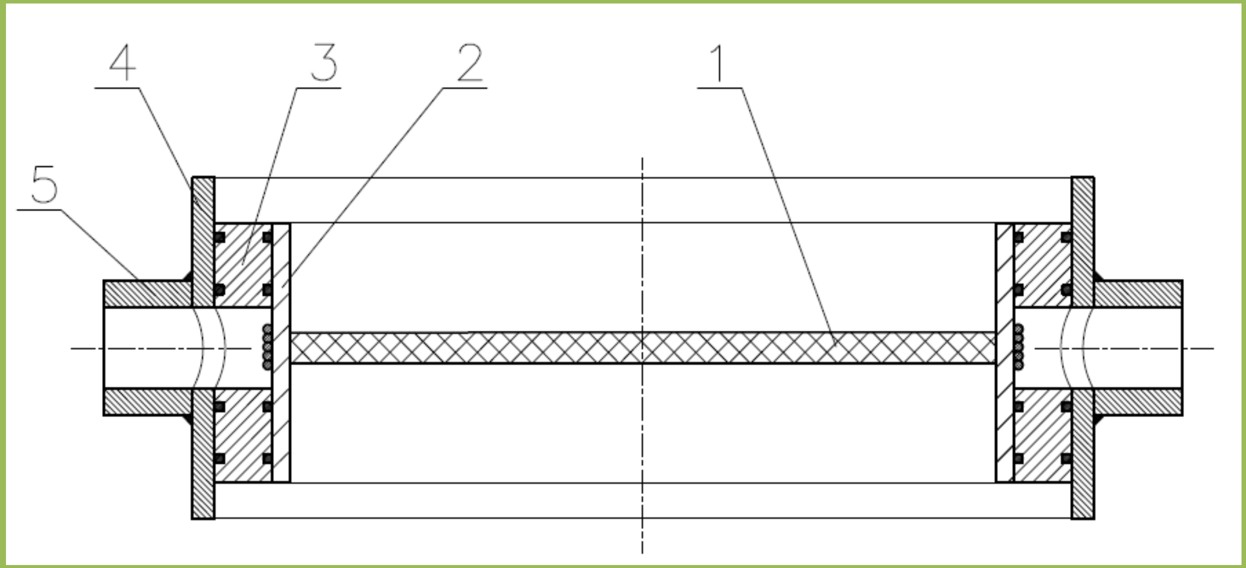
Ceramic to Cu fixation

RF Window – Mechanical Design





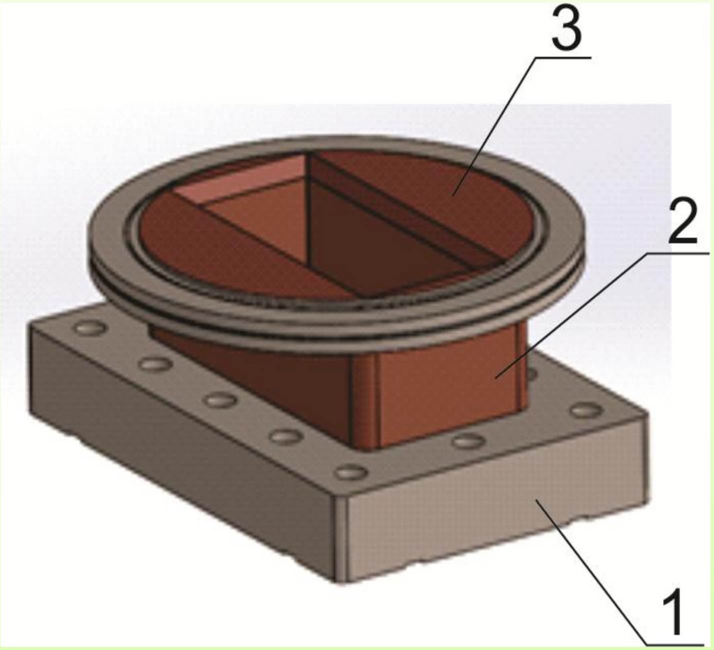
Section View of
Pill Box Type RF Window



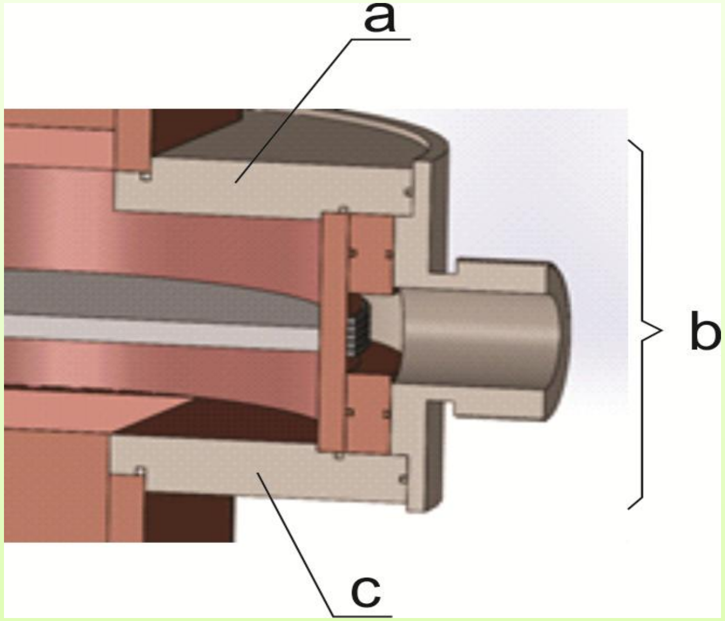
First brazing part

1. Ceramic disc
2. Cu cylinder
3. Cu ring
4. SS cylinder
5. Water in and out ports

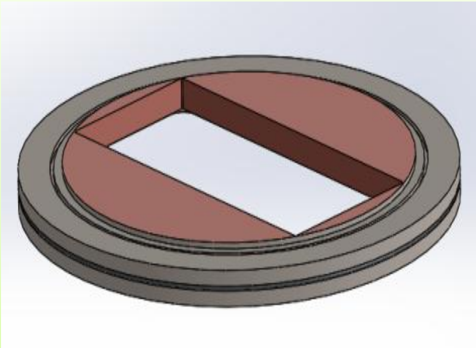
Sequence of Brazing



First Brazing Part
1- flange, 2- waveguide, 3- cylinder cover

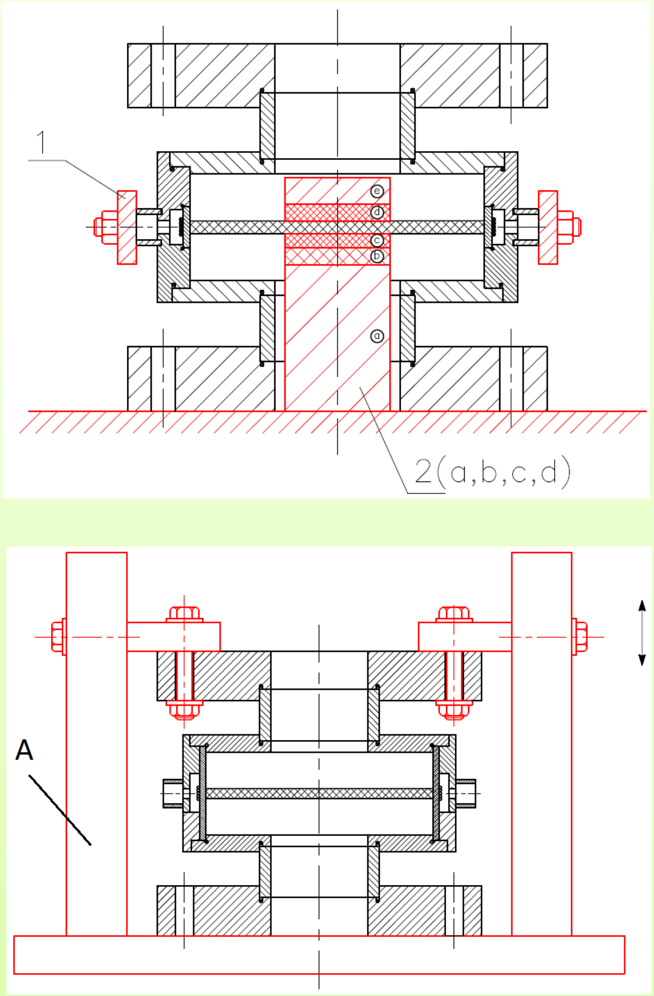


Third Brazing Part
a and c - first and b-second brazing parts

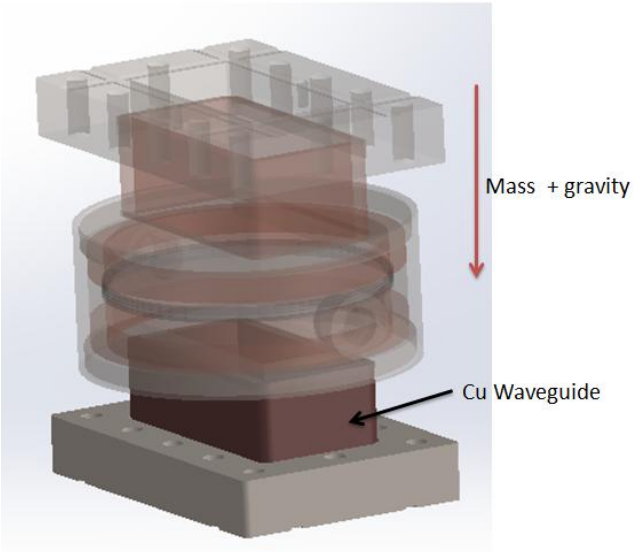


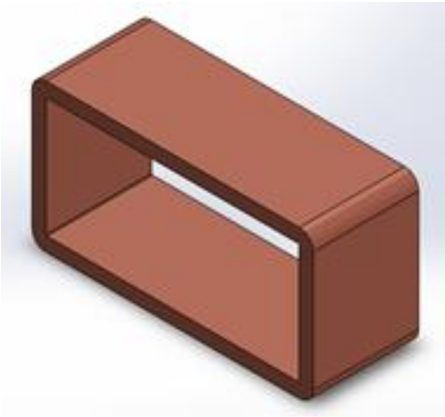
Pill-box cover
Material – stainless steel
Coated surface - Cu

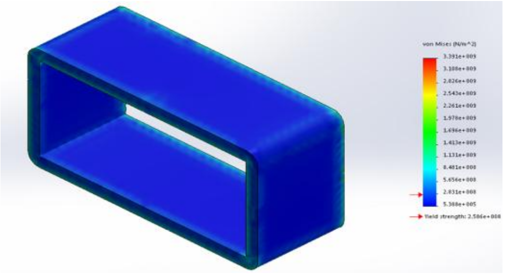
Sequence of Brazing

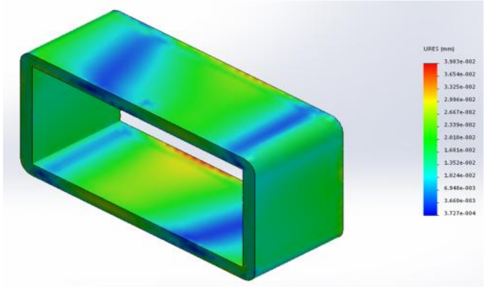


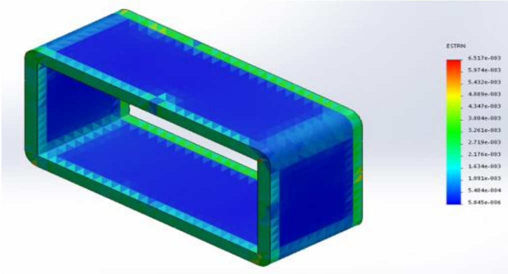
Fixation methods for Diffusion Brazing







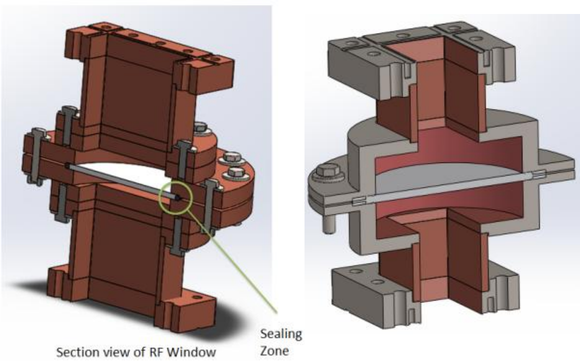




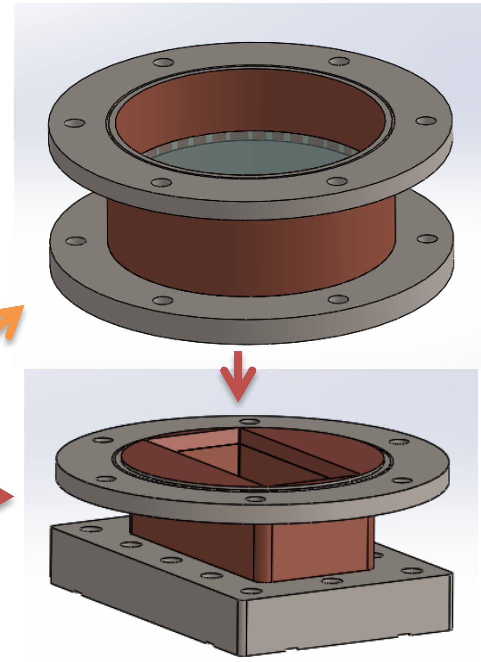
Pressure - 15kg.
Temperature -800 ^{0}C

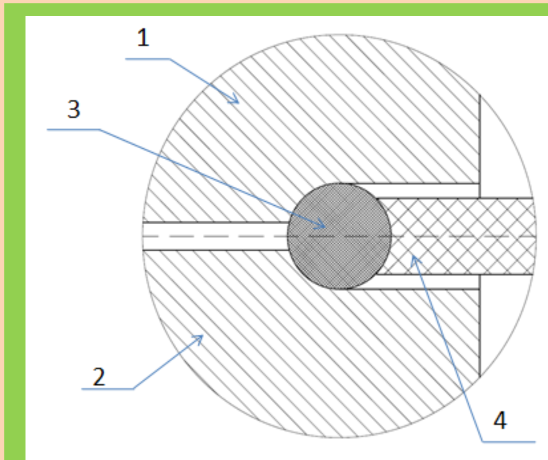
Weight of RF window is 3.5 kg

RF Window Test Stand

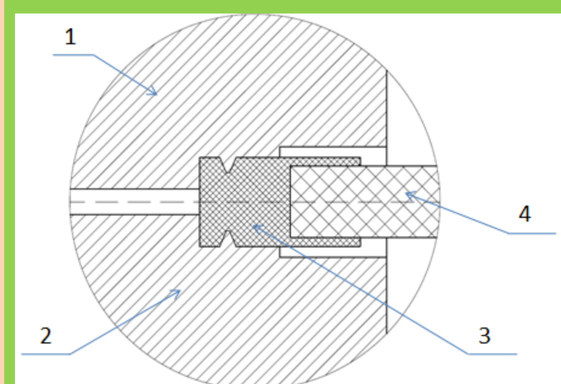


For testing Ceramic to metal, metal to metal technologies for RF windows

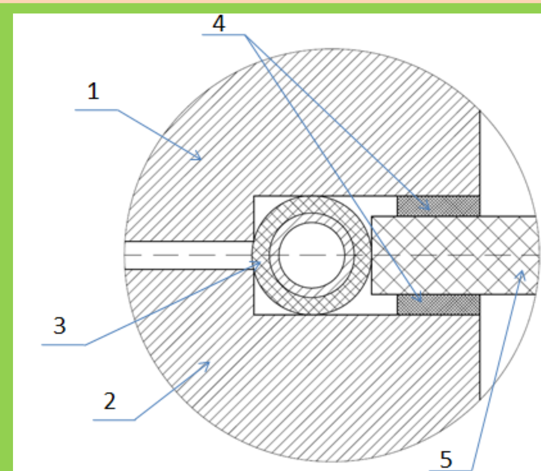




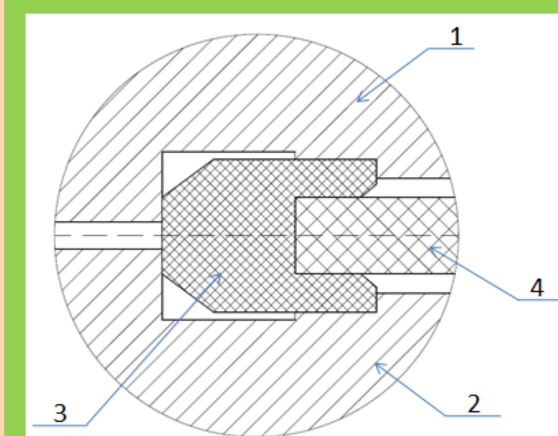
1-flange 1, 2-flange 2, 3-viton or teflon, 4-ceramic



1-flange 1, 2-flange 2, 3-viton or teflon, 4-ceramic

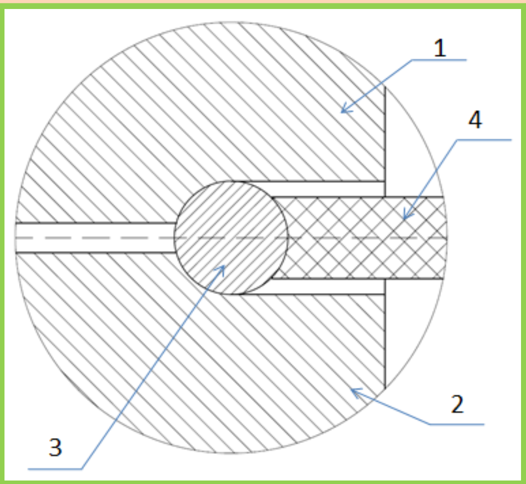


1-flange 1, 2-flange 2, 3-viton or teflon with metals, 4-ceramic

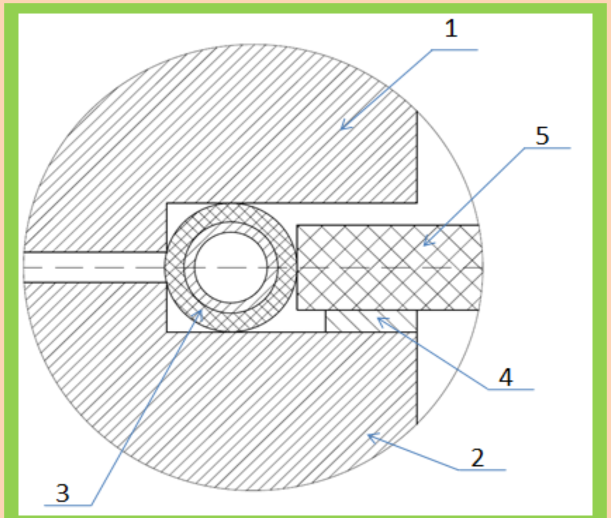


1-flange 1, 2-flange 2, 3-viton or teflon, 4-ceramic

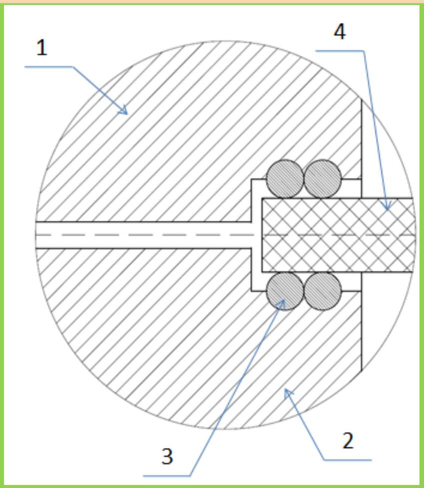
RF Window Test Bench



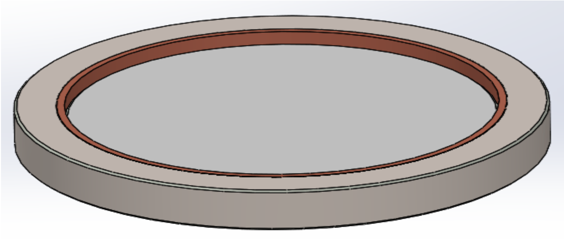
1-flange 1, 2-flange 2, 3-metal, 4-ceramic



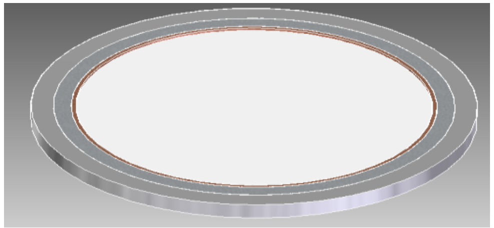
1-flange 1, 2-flange 2, 3-metal, 4-compensator, 5-ceramic disc



1-flange 1, 2-flange 2, 3-metal, 4-ceramic



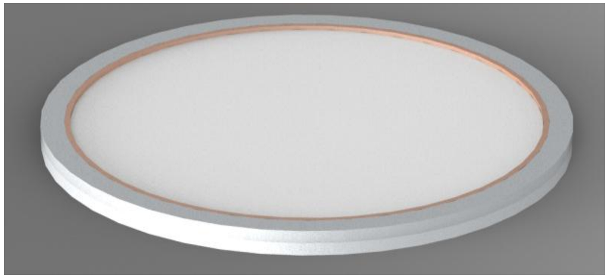
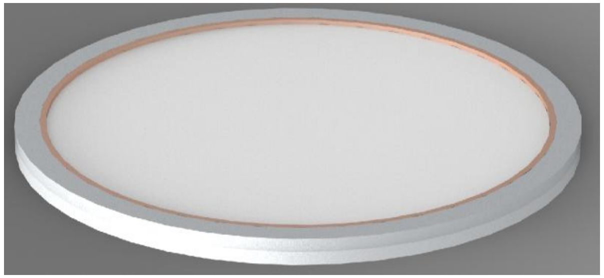
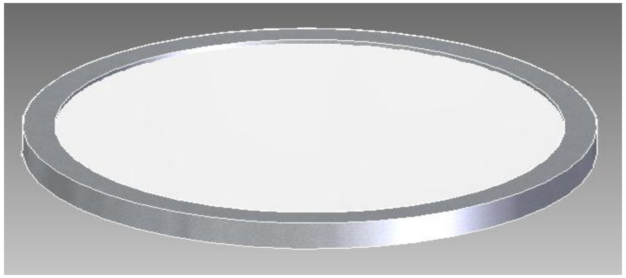
Ceramic- Cu-Mo ring



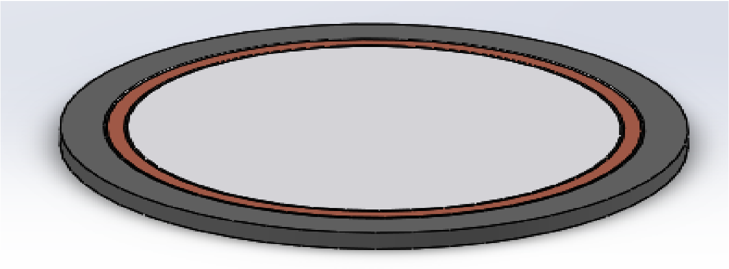
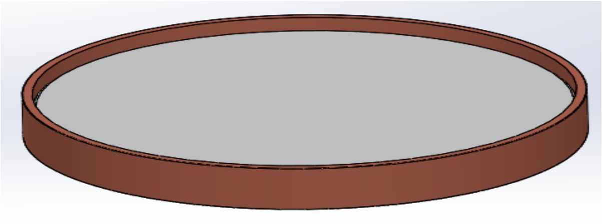
Ceramic- Cu-SS-Mo ring

Ceramic- SS ring

RF Window Test Bench

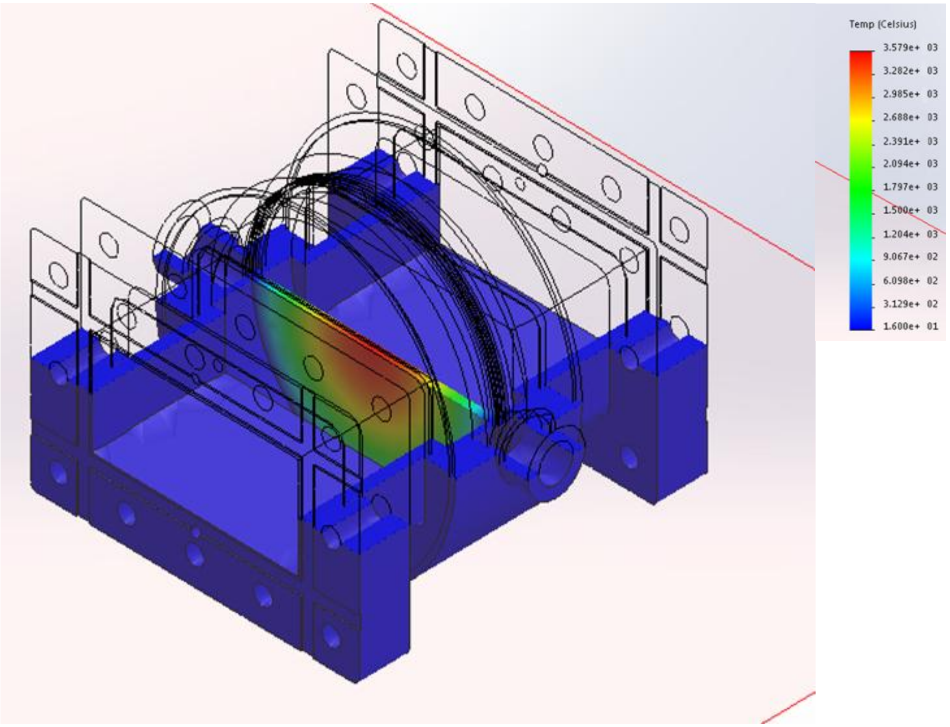




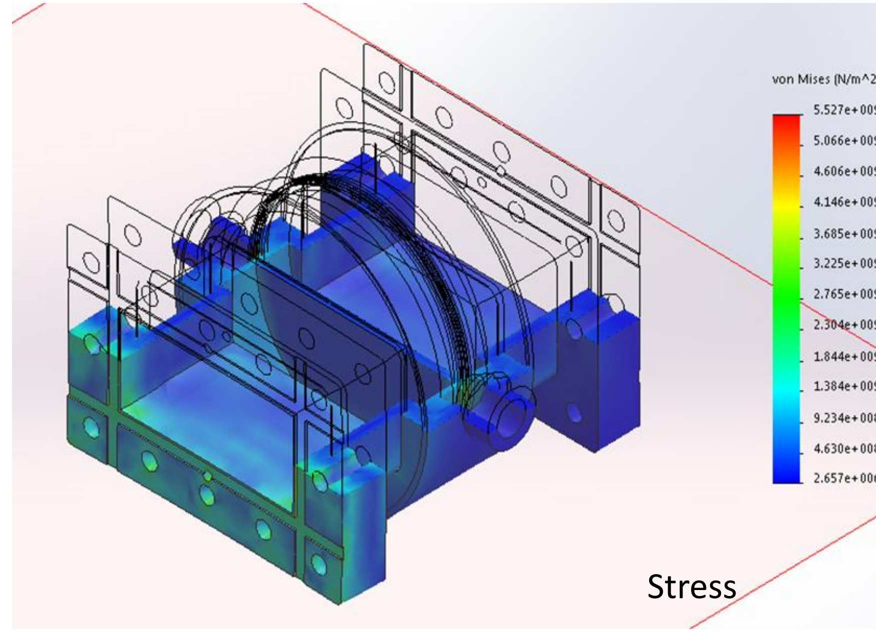
Cearamic - Ti

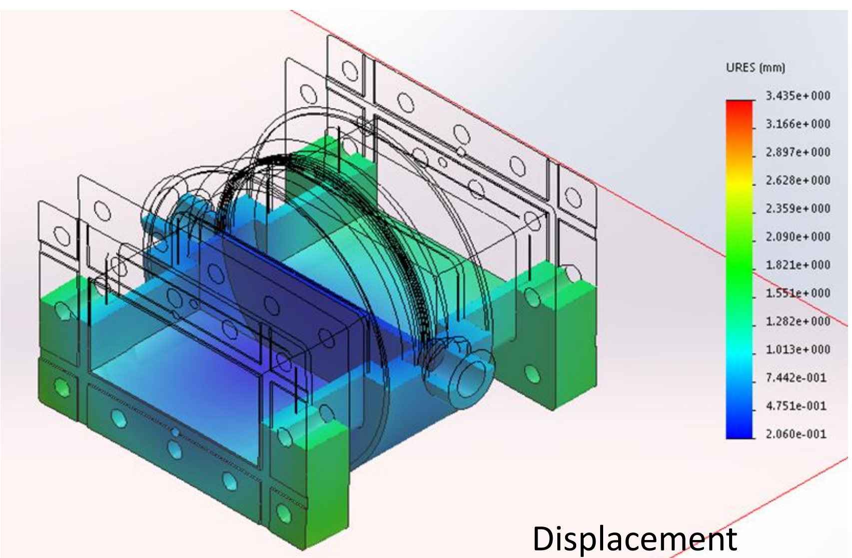



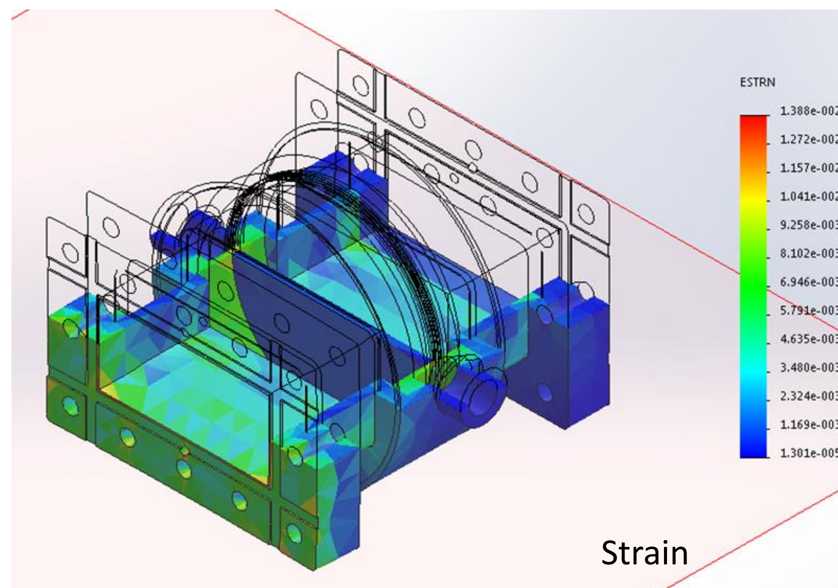
Ceramic - Cu

Thermo-mechanical Simulation of RF windows

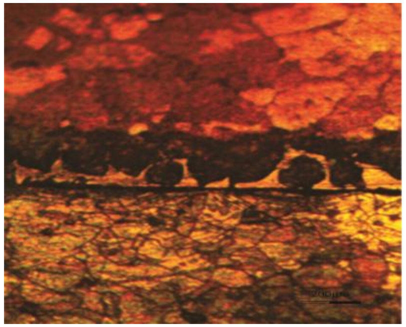


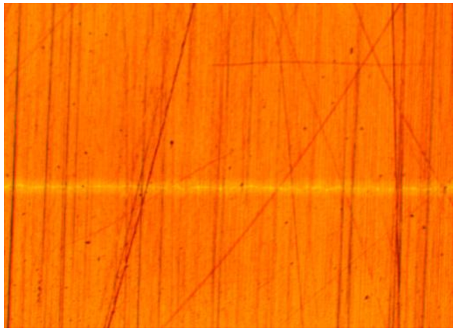






Metals Brazing Technology for RF windows



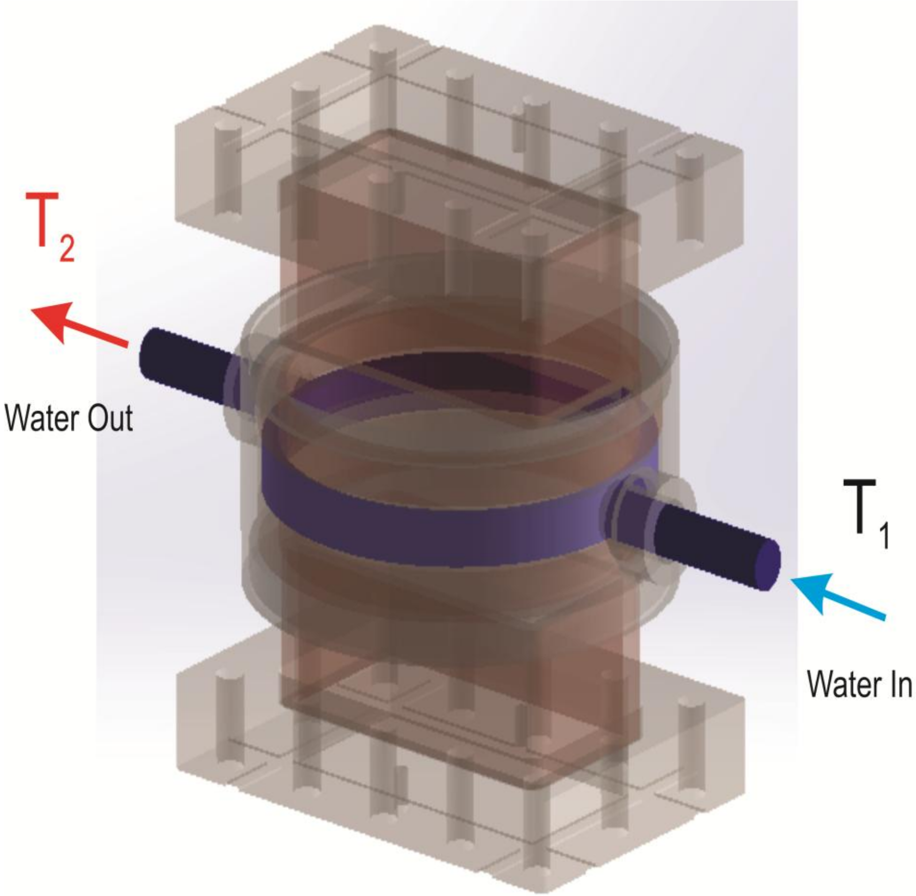


Cu to SS

Cu to Cu

SS – Stainless Steel

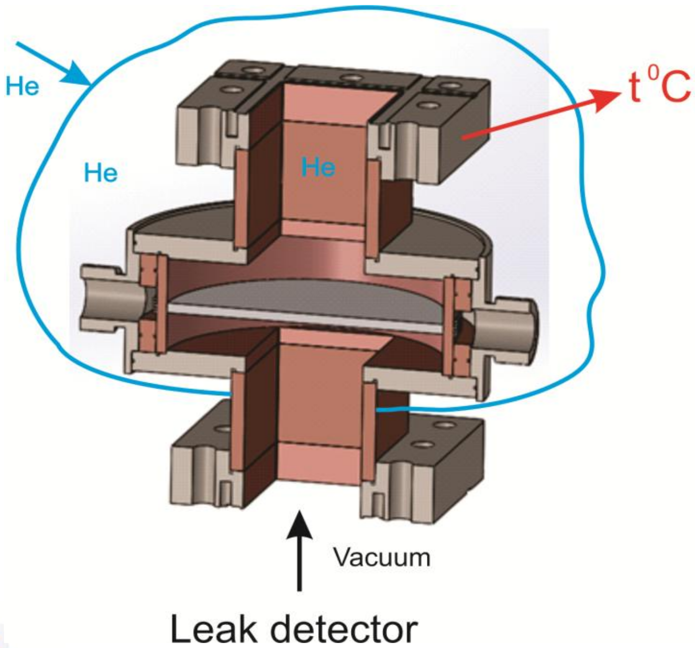
Thermoregulation for RF window

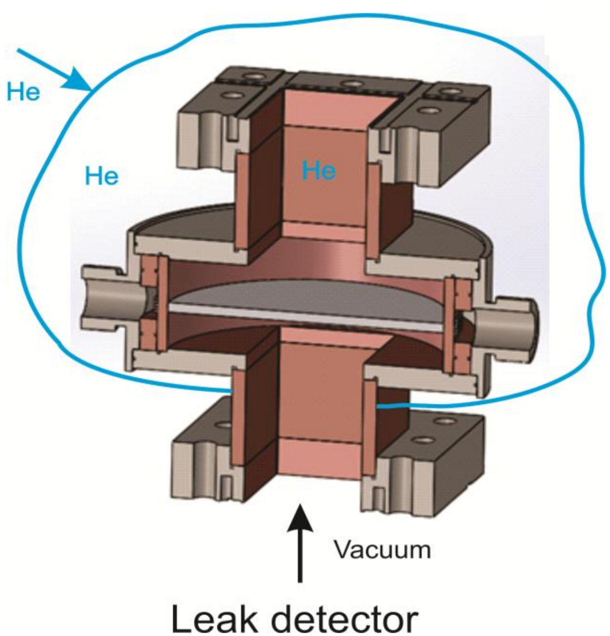


Coolant – deionized water

Testing technologies for mechanical design of RF windows

- Thermal tests;
- Vacuum tightness tests;
- Mechanical Tests;
- Vibration tests;
- Outgassing tests;
- Electro-mechanical tests;
- Humidity tests;
- Roughness measurement;
- Hardness measurement;
- Rotation test.





Conclusions

- The thermoregulation systems have been designed and fabricated for electromagnetic vacuum devices and systems of AREAL linear accelerator at CANDLE Synchrotron Research Institute – thermoregulation system for RF gun, thermoregulation system for klystron and cooling system for solenoid magnet.
- The UHV test bench has been designed and fabricated for developing UHV systems – testing and design of UHV pumping system, vacuum tight joints, etc.
- Ceramic-metal joints have been designed and experimented based on moly-manganese, active brazing and gluing technologies.
- Vacuum diffusion brazing technologies, machining, cleaning and investigation (including metallurgical microscopy) technologies have been developed and designed for vacuum-tight ceramic-metal joints.
- New diffusion brazing method for dissimilar items in difficult geometry has been developed and designed - AM 20140053.
- New diffusion bonding method for bonding of cylindrical dissimilar items has been developed and designed - AM 20170070.
- Thermo-mechanical simulations have been done for RF window.

Conclusions

- Different fixation methods have been investigated and developed for vacuum tight ceramic-metal joints – including thermo-mechanical simulations.
- Pill box type vacuum RF window has been investigated and mechanically designed.
- Based on reviews of scientific articles and other materials of RF test stand, for testing ceramic and ceramic-metal brazing systems in different conditions, has been mechanically designed.
- Different testing methods have been mentioned for evaluating the quality of vacuum-tight ceramic-metal joints.

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- CANDLE SRI Staff

Thank You for Your Attention