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Vacuum Soldering of OFHC Copper with Low Temperature Filler Material

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Abstract — Vacuum soldering is one of the advanced soldering methods, mainly used for joining of copper alloys, super conductors, photo circuit board. One of the many promising application of vacuum soldering is in electrical and electronics industries to join two or more superconductors. This work is mainly focused on vacuum soldering of oxygen free high conducting copper with copper and other super conductors like NbTi wire and BSSCO tapes by using lead tin eutectic filler metal and tin bismuth low temperature filler material. Joining of super conductor is very difficult by using conventional joining method like soldering by heater due to it's lose high conductivity. Therefore vacuum soldering is novel method of joining of superconductors without affecting their properties. The filler material and working conditions are using in this process selected in such a way that it is not affecting thermal and electrical resistivity of super conductors. Generally vacuum soldering is carried out in high vacuum resistance furnace, that can control manually as well as automatic. Temperature used in joining of high temperature superconducting leads is varies from 220 °C for SnPb and 180 °C for Sn–Bi. Vacuum level used in this process is 10^2 mbar to improve the wettability of Oxygen OFHC copper with solder alloys. Tin coating is made on the surface of having thickness 15 µm. Tin coating on the copper improve wettability and also reduced resistivity as compared to the uncoated OFHC copper. The voids, unfilled areas and other defects were nullified in the tin coating and it is delivering better results. Microstructural analysis revealed the better bonding with minimum reaction length for the selected temperature.

Index Terms — Contact angle, HTS leads, Joint resistance, OFHC copper, SCM, Super condoctors, Tin coating, Vacuum soldering

1 Introduction

Current leads are probably the first high current application of super conductors to be used on commercial basis. In many cases HTS current leads enable application that would very difficult using conventional technology. The performance requirements on high temperature superconducting material used in leads lower than for many other application, making this one of the earliest application to become both technically and economically feasible. Currently several hundred leads are incorporated in to super conducting magnet system each year. In future high temperature superconducting leads are required for other superconducting device such as transfer, fault current limiter, SMES system and generator. The 10 kA HTS lead is designed to carry a maximum current of 10 kA DC between room temperature and the 4.5 K liquid helium bath. As shown in fig. 1, it mainly consists of a resistive and a superconducting part. The resistive part operates between room temperature and about 80 K. It is conventionally cooled by nitrogen vapor, made available by a liquid nitrogen at the bottom. The high Tc superconducting part operates between 80 K. The HTS material is characterized by a low thermal conductivity and practically zero electrical resistivity at temperature below 85 K. Its integration in the colder part of the lead reduces the heat load into the liquid helium bath. The design of the HTS lead optimizes the thermal and electrical performance of both the resistive and HTS parts. The High Tc superconducting part mainly consists of A stainless steel cylinder (HTSCL12), onto which 62 stacks of BSCCO tapes are vacuum soldered. Each stack is a bunch of 2 tapes with a solder foil in between. R. Lwali [1] has focused on refining power film resistor manufacturing process in order to minimize the voids that occur within the solder joints during the soldering process. A. Klemm et al. [2] have investigated effect of X-ray on vacuum soldering processes for conventional and diffusion soldering. W. Lin [3] has done Void-free Reflow Soldering of BGA with Vacuum and proved that vacuum reflow solder technology is a valid technology for the void-free and lead-free soldering of BGA. R. W. Brown [4] has developed an infrared vacuum soldering (IVS) process for thick-film hybrid microcircuits. V. Chidambaram et al. [5] have Designed lead-free candidate alloys for high-temperature soldering based on the Au–Sn system. M. Roellig et al. [6] have done Fatigue analysis of miniaturized lead-free solder contacts based on a novel test concept.

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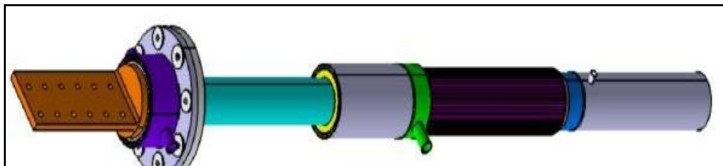

Fig. 1. CAD model of high temperature superconducting current lead

2 Experimental Investigation

2.1 Parameters of Vacuum Soldering

The parameters that effect wetting phenomenon and quality of joints are mainly temperature, time, and vacuum. Manipulation and controlling of these parameters directly affect the quality of joint. By optimizing these parameters joint properties can also be optimize.

Temperature

The temperature of soldering filler metal has an important effect on wetting and alloying action, which increases with increasing temperature. The temperature must be above the melting point of the soldering filler material and below the parent metal. Within this range, a soldering temperature that is most satisfactory overall is generally selected. Usually low soldering temperature is preferred in order to economize on the heat energy required, minimize heat effect on the base metal, minimize base filler material interaction and increase life of fixture and other tools.

Time

The time at soldering temperature also affect the wetting action particularly with respect to distance to the filler material can creep. If the filler material have tendency to creep then distance increase with time. The alloying action between parent material and filler material is function of time and temperature both. For production work both temperature and time are kept minimum consistent with good quality.

Vacuum

Soldering in vacuum atmosphere is well suited for joining heat resistant nickel, fabrication of parts of aerospace, high temperature superconducting leads for nuclear application, electronic tubes, where the metals react with chemically with a hydrogen atmosphere, or where entrapped fluxes are intolerable. The maximum tolerable pressure for successful soldering depends upon the number of factors that are primarily determined by composition of base metal. Soldering filler metal and gas remains in evacuated chamber. For soldering of OFHC Copper it should be 102 mbar.

2.2 Wettability and Method to Improve Wettability of OFHC Copper by Solder

Capillary attraction is the physical force that gives the action of liquid against solid surface in small, confined areas. Capillary flow is the dominant physical principle that ensures good soldering joint provided both flying surface to be joined are wetted by the molten soldering filler metal. The joint must be also properly spaced to permit efficient capillary action and result of surface tension between the base metal soldering filler metal, flux or atmosphere and contact between base metal and filler metal. In actual practice, soldering filler metal flow characteristics are also influenced by dynamic consideration involving fluidity, viscosity, vapor pressure, gravity and metallurgical reactions between soldering filler metal and base metal.

2.3 Wetting Angle between Solid and Liquid by Sessile Drop Experiment.

Experimentally it has been observed that liquid placed on solid surface usually do not completely wet, but rather remains as drop that has a definite contact angle between liquid and solid phases. Low contact angle less than 90° shows high wettability and contact angle greter than 90° shows low wet ability and complete wetting occurs when contact angle become 0° as the droplet turns in to flat puddle. Ideally the shape of liquid droplet is determined by surface tension of liquid. In pure liquid, each molecule of liquid in bulk is pulled equally in every direction by neighboring molecules resulting net force to zero. However molecules exposed at the surface do not have neighboring molecules in all direction to provide a balance net force. Instead of, that are pulled by neighboring molecule, creating an internal pressure. As a result liquid voluntarily contact it surface to maintain the lowest surface free energy.

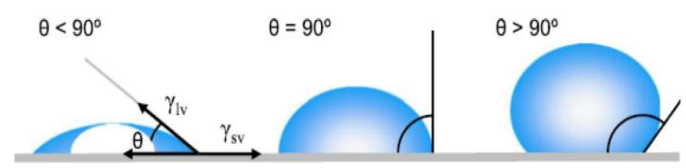

Fig. 2. Illustration of contact angle formed by sessile liquid drop on smooth homogeneous solid surface.

$$\gamma l_v \cos \theta Y = \gamma s_v - \gamma sl \quad (1)$$

Where

γlv, γsv, and γsl represent the liquid-vapor, solid-vapor, and solid-liquid interfacial tensions, respectively, and θY is the contact angle shown in fig. 2. Above equation is called young equation. From Young's equation applied to a specific liquid-solid system, three thermodynamic Parameters γlv, γsv, and γsl determine a single and unique contact angle θY.

2.4 Soldering of Complicated/Complex Assembly

As shown in fig. 3, vacuum soldering of complex shape like copper braided cable with copper block and BSSCO tapes with copper is very difficult to solder. These component are highly sensitive can't resist too much mechanical force. Assembling and soldering of this component is not easy because absence of proper force between tapes and base metal and also if these component are compressed by more force then get distorted before soldering. So in this case of soldering it is very important to maintain uniform temperature to minimize thermal stress. Design of fixture should be in such a way, it can maintain vertical alignment and also able to apply sufficient force so that BSSCO tapes and copper should be always in contact during soldering. Fixture used in this type of soldering is made of stainless steel because having thermal conductivity is less than the Copper and Bismuth strontium calcium copper oxide (BSSCO) tapes. Assembling of soldering material and BSSCO tapes follow sequence like first soldering material, then BSSCO Tapes again soldering material again BSSCO Tapes.

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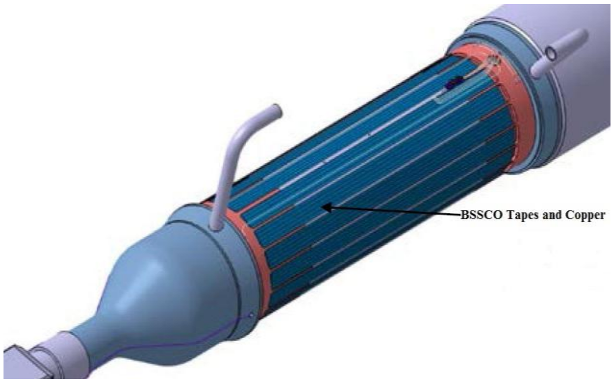

Fig. 3. CAD model of BSSCO tapes with Copper before vacuum soldering

3 Experimental Procedure

3.1 Materials Selection and Preparation

Base metal preparation

Oxygen free high conducting copper has been developed with 99.3% purity. The base metal was taken in cold drawn stage in the form cylindrical rods of OFHC copper and cold forged stage in the form of big rectangular section blocks.

Processing History

OFHC Copper was cast in vacuum furnace in the form of cylindrical blocks. These cast cylinders were hot extruded and subsequently cold drawn to get require shape and hardness. Filler material Sn-Pb (63% - 37%) was also casted in the vacuum induction furnace in form of thick slab. This slab was rolled to required thickness in the form of strips by subsequent cold rolling and annealing. The cold drawn cylindrical pieces of Copper were taken and soldering surfaces polished on 200 grades emery paper, so as to obtain some surface roughness, which would in turn create capillary holes on the surface. These specimen were cleaned with water to remove sand particle after over during polishing.

Alloy preparation

The majority of alloys are prepared by mixing metals in the molten state as shown in fig. 4. Then the mixture is poured into metal or sand molds and allowed to solidify. Generally the major ingredient is melted first, then the others are added to it and should completely dissolve. Difficulty of making Sn-Pb soldering alloy is due to difference in melting points. Lead melts at 325°C and tin melt at 232 °C so in making alloy if we just put piece of Lead and Tin in a crucible and heated above 325°C both the metals would certainly melt. But at that high temperature the liquid Tin will also boil away and the vapour would oxidize in the air. The method adopted in this case is to heat first the metal having the higher melting point, namely lead. When this is molten, the solid Tin is added and is quickly dissolved in the liquid lead before very much Tin is boiled away. Even so making of soldering alloys allowance has to be made for unavoidable Tin loss which amounts to about one part in twenty of the Tin.

Fig. 4. Soldering alloy preparation in induction furnace

Consequently, in weighing out the metals previous to alloying, an extra quantity of tin has to be added. Another difficulty in preparation of soldering alloy is due to smaller quantity of higher melting point metal like SnPb. In this case alloying is done in two stage. First an intermediate 'hardener alloy' is made containing 50% of a lead and 50% of Tin which alloy has a melting point lower than the melting point of lead, in fact below the Tin. Then Tin is melted and correct amount of hardened alloy is added to make the proportion (63% - 37%) Sn-Pb. The particular alloy is known as the 'eutectic' alloy and the freezing temperature (183˚C) is called eutectic temperature.

3.2 Pretreatment in Vacuum Soldering

Pickling

Pickling is a metal surface treatment process by using acid to remove impurities, oxide layer and tarnish films etc. The objective of pickling is chemically clean and shiny surface. Surface must be clean and completely free from dirt, grease and oil before soldering. Pickling agent used for copper is generally chromic acid solution. OFHC copper is placed in the solution of chromic acid for 10 to 20 min. After that piece is washed by water and the clean by acetone. In case of soldering pickling is done to improve the solder ability of OFHC Copper by soldering alloys.

Pretreatment for bonding

The wetting and absorption capacity of OFHC copper is increased by suitable pretreatment to be joined. Pretreatment has objective of cleaning the surface and increasing the effective surface area by fine roughing of surface. Thereby improving activity of bonding. The easiest way of removing oxide layer and creating effective roughness by mechanical means using metallic bushes. Surface roughness should not increase 30 μm. These specimen were then cleaned with acetone to remove oil, grease or any other particles from the surface of the metal.

Assemble for soldering

Soldering filler material is cut in to form of strips having thickness was point 5 mm is inserted in the dummy after cleaning for vacuum soldering and assemble component was placed in the furnace for joining operation.

3.3 Experiment 1: Soldering By Filling of OFHC Copper Dummy (With Cavity) With Solder Alloy Sn-pb (63% - 37%) Without Flux

Heating cycle

The furnace is a resistance heating type furnace shown in fig.5. As shown in fig. 6, at initial stages, the furnace is slowly heated with temprature of 1°C per min up to 70 °C, to prevent thermal shocks of heating metal. At 70°C the temperature is held for 10 min (soaking) so that a uniform temperature is obtained in the heating chamber. From 70°C to 150 °C the furnace chamber is heated 1°C per min and held at 150°C for 30 min to maintain uniform heating and required vacuum level. After that from 150°C to 240°C it is heated and held at 2 hrs (soaking). After 2 hrs soaking furnace heating element was switched off and cooling was carried out in vacuum atmosphere. The whole cycle was carried out in the vacuum.

TABLE 1
SOLDERING PARAMETERS FOR EXPERIMENT 1

Parent material	Oxygen free high conductive copper
Soldering alloy	Sn – pb (63% - 37%)
Vacuum	10^{-2} mbar
Working temperature	210 ± 10˚C
Cycle time	4-5 hrs

Fig. 5. High Vacuum Resistance Furnace

3.4 Experiment 2: Soldering By Filling of OFHC Copper Dummy (With Cavity) With Solder Alloy Snbi (50% - 50%) Without Flux

Steps involved in vacuum sooldering

Steps involved are same as the experiment 1. Fig. 7 shows vacuum soldering cycle of OFHC copper by Sn-Bi.

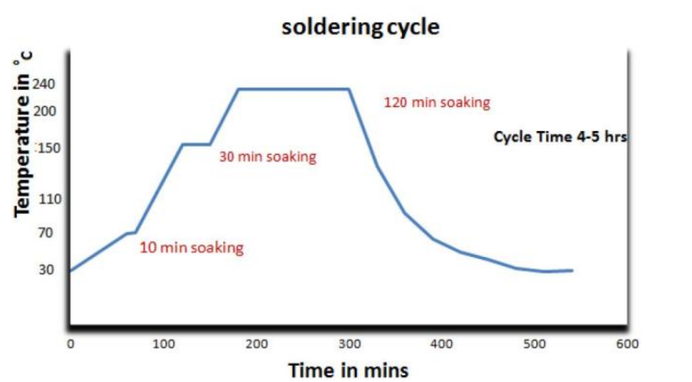

Fig. 6. Vacuum soldering cycle of OFHC Copper without flux using Sn-Pb alloy

TABLE 2
SOLDERING PARAMETERS FOR EXPERIMENT 2

Parent material	Oxygen free high conductive copper
Soldering alloy	Sn – Bi (50% - 50%)
Vacuum	10^{-2} mbar
Working temperature	210 ± 10˚C
Cycle time	4-5 hrs

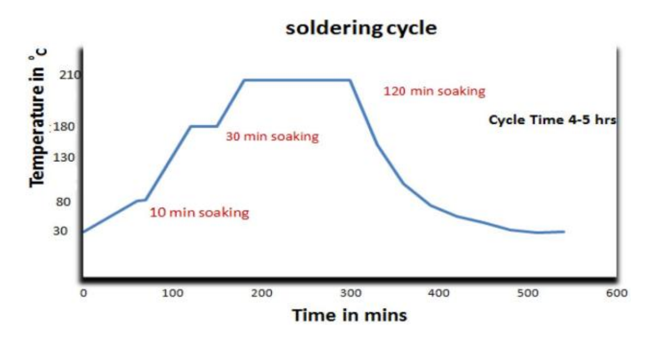

Fig.7.Vacuum Soldering Cycle of OFHC Copper by Sn-Bi (50% - 50%)

3.5 Experiment 3: Soldering By Filling of OFHC Copper Dummy (With Cavity) With Solder Alloy Snbi (50% - 50%) With Flux

Steps involved in vacuum soldering

Sample preparation: A slot/cup was made on the surface of OFHC copper.

Cleaning of base metal

Fig. 8 shows soldering cycle of OFHC Copper with rosin flux by Sn-Bi. The specimen of final shape, were dipped in acid bath (chromic acid) from 30 sec to 5 min depending upon the oxide layer formed on the surface. The operation was done just before the soldering operation, to avoid the further formation of oxide layer on the metals. After pickling, they were cleaned with water and acetone to remove the acid from the surface of the metal.

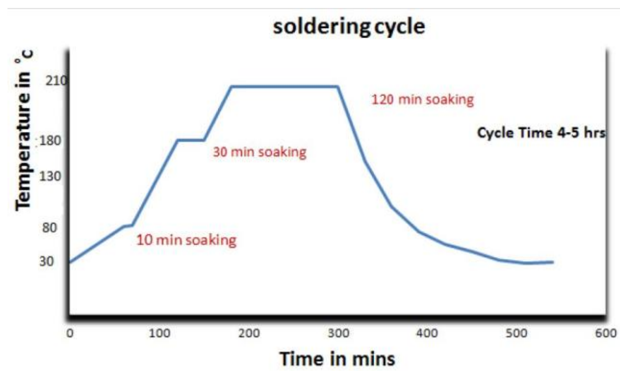

Fig. 8. Vacuum soldering cycle of OFHC Copper with Rosin flux by Sn-Bi (50% - 50%)

Cleaning of joint after soldering

After completion of vacuum soldering component was taken outside the furnace to remove the excessive filler material comes out side and clean by using acetone.

TABLE 3
SOLDERING PARAMETERS FOR EXPERIMENT 3

Parent material:	Oxygen free high conductive copper
Soldering alloy:	Sn – Bi (50% - 50%)
Vacuum	10^{-2} mbar
Working temperature	210 ± 10˚C
Cycle time	4-5 hrs

3.6 Experiment 4: Soldering of OFHC Copper by Snpb (63% - 37%) By Using Flux

Steps involved in vacuum soldering

Sample preparation

A slot/cup was made on the surface of OFHC copper.

Degreasing: After cleaning by acid acetone is used to clean the oil and dirt present on the surface. Because in presence of the organic contamination flux does not effectively work.

Flux the parts: Before assembling flux is applied on the sample. The major role of flux is to remove the tarnish layer initial stage of soldering process. There by permitting the molten solder to react with the parent metal and to spread. However flux does not effectively displace organic contamination. So poor solder ability. A degreasing step should precede flux application. The flux has to additional functions like, (1) one is its lower the surface tension of solder allowing it to more readily fill gaps and hole by capillary action. (2) Flux coating protect the metal surface protect the metal surface from reoxidation during the heating step just prior to soldering. Fig. 9. Shows soldering cycle wth rosin flux by Sn-Pb.

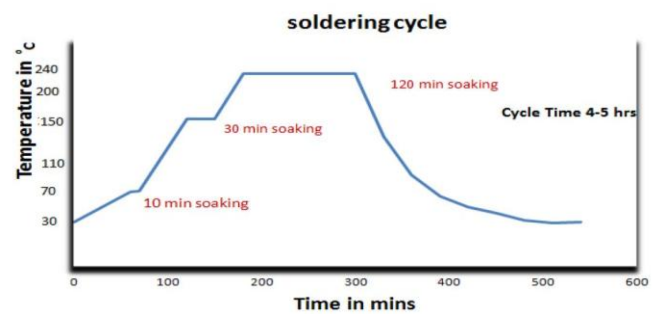

Fig. 9. Vacuum Soldering Cycle wth Rosin Flux by Sn-Pb (63% -37%)

TABLE 4
SOLDERING PARAMETERS FOR EXPERIMENT 4

Parent material:	Oxygen free high conductive copper
Soldering alloy:	Sn – pb (63% - 37%)
Vacuum	10^{-2} mbar
Working temperature	210 ± 10˚C
Cycle time	4-5 hrs

3.7 Experiment 5: Soldering Of OFHC Copper With Nbti Wire Using Tin Coating On Metal By Snpb (63% - 37%).

Steps involved: All the steps involved are same as the previous experiment. Only tin coating is added.

Fig. 10. Tin coated and without coated sample

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Coating: Prior to tin coating dirt, grease and other organic impurities should be carefully remove from the OFHC Copper surface. As shown in fig. 1, Tin coating was made on the sample. Because copper lose their solder ability too quickly after cleaning due to formation of oxide layer and become very difficult to solder. To prevent the formation of oxide layer tin coating is applied on the copper sample before soldering. Thickness of tin coating varies from 1 to 3 µm.

TABLE 5
SOLDERING PARAMETERS FOR EXPERIMENT 5

Parent material:	Sn coated OFHC copper
Soldering alloy:	Sn – Pb (63% - 37%)
Vacuum	10^{-2} mbar
Working temperature	210 ± 10˚C
Cycle time	4-5 hrs

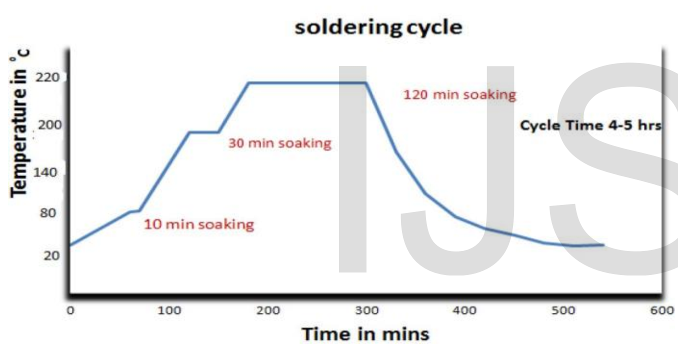

Fig.11. Vacuum soldering of Tin coated OFHC copper by Sn-Pb (63% - 37%)

3.8 Experiment 6: Soldering of Sn Coated Sample With Nbti Wire Using Snbi (50% - 50%) Soldering Alloy.

Steps involved: All the steps involved are same as the previous experiment.

TABLE 6
SOLDERING PARAMETERS FOR EXPERIMENT 6

Parent material:	OFHC copper
Soldering alloy:	Sn –Bi (50% - 50%)
Vacuum	10^{-2} mbar
Working temperature	170 ± 10˚C
Cycle time	4-5 hrs

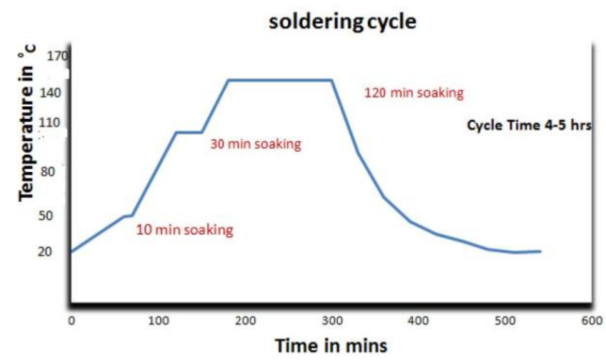

Fig.12. Vacuum soldering cycle for Tin coated OFHC Copper by Sn-Bi (50% 50%)

3.9 Experiment 7: Wetting angle Measurement

As shown in fig. 14, a set up equivalent to sessile drop experiment was created to measure and prove the betterment of wettability of without coated sample OFHC Copper. It comprises a vacuum chamber with from side covered with glass so as to view the samples at hot zone. Fig. 13 shows furnace used in vacuum soldering for wettability.

Furnace used in vacuum soldering

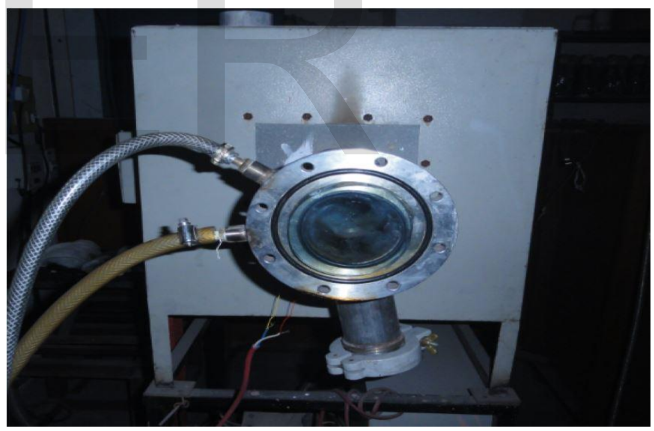

Fig. 13. Furnace used in vacuum soldering for wettability

TABLE 7
SOLDERING PARAMETERS FOR EXPERIMENT 7

Parent material:	OFHC copper
Soldering alloy:	Sn – Pb (63% - 37%)
Vacuum	10^{-2} mbar
Working temperature	210 ± 10˚C
Cycle time	4-5 hrs

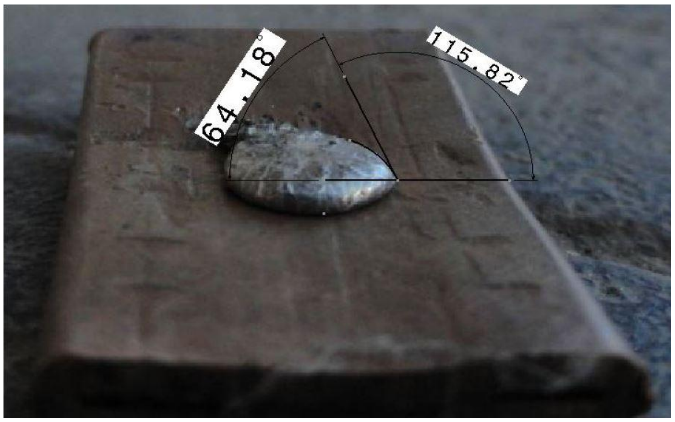

Fig. 14. Sample after vacuum soldering for contact angle measurement

3.9 Experiment 8: Wetting Angle Measurement of Tin Coated Sample

Set up as same as previous experiment. Tin coating is made on the OFHC Copper.

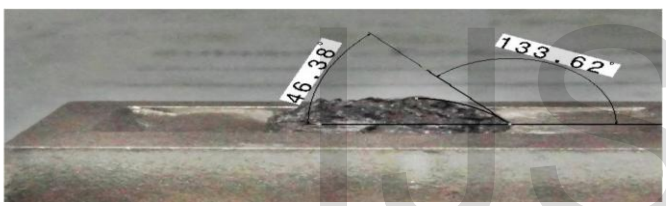

Fig. 15. Tin coated sample after vacuum soldering for contact angle measurement

Electrical resistivity measurement

Digital multimeter also known as a VOM (VoltOhm meter), is an electronic measuring instrument that combines several measurement functions in one unit. A typical multimeter would include basic features such as the ability to measure voltage, current, and resistance. Soldered joint resistance is also measured by using digital multimeter. Digital multimeters (DMM, DVOM) display the measured value in numerals, and may also display a bar of a length proportional to the quantity being measured.

4 Result and Discussion

4.1 Visual Inspection and Sample Preparation

Objective of visual inspection of soldered joint were:

1) To seek out discontinuities defined in quality standards or codes

2) To obtain clues to the classes of irregularities in the fabricating process

Every soldered joint was examined visually. Visual inspection may be effective in evaluating external evidence of voids, porosity, surface cracks, fillet size and shape, noncontinuos fillets, base metal erosion, surface imperfection, roughness, liquidation, and general solder appearance. presence of fillets on both side of joint, even if continuous does not guarantee complete filling of solder joint, such as taped flux, porosity, lack of fill, and internal cracks. To avoid misinterpretation, the inspection should be provided with samples, photos or sketches showing the precise visual condition that are acceptable and unacceptable.

Sample preparation

Rough grinding: The sample that was cut from the block, was first made flat by rough grinding and polishing operation. The specimen was moved perpendicular to the already existing scratches. This allows identifying the old deep scratches that must be replaced by new and shallower scratches.

Intermediate polishing: The specimen was polished on a series of emery paper containing successively finer abrasives. The specimen was rubbed on the emery paper very gently and cares fully to avoid any deviation from the flat surface. The care taken at this stage reduces the effort required in final polishing.

Fine polishing: The final approximation to the flat, scratch free mirror like surface was obtained in this process by use of wet rotating wheel covered with a velvet cloth that was charged with small abrasive particles. Polishing was first done on a diamond polisher on which diamond paste and lubricant are applied. Water was not used while polishing on a diamond polisher. The final surface finish obtained after this process was about 0.5 microns.

Etching: Etching is generally done to reveal the structural characteristics of a metal or alloy. Different parts of the microstructure must be clearly differentiated. For this purpose an etching reagent was applied on the polished surface of the specimens. These reagents attack preferentially over some regions, thus revealing the structure. There are so many etching reagents used for specific metals and alloys. The etching reagents used for copper specific metals and alloys. There are so many reagents are used for specific metals and alloys. The etching reagents used for copper is 5cc.

$$FeCl_3 + 10cc\ HCL + 100cc\ H_2O$$

4.2 Metallographic Examination

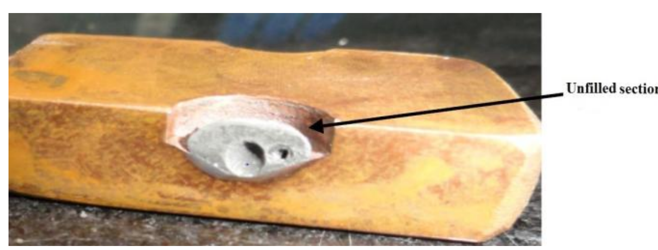

Fig. 16. Sample of vacuum soldering by Sn-Pb

The specimen, polished and etched properly, was observed under a metallurgical microscope. Essentially a metallurgical microscope is composed of two distinct and separate optical system the objective and the eye piece, whose primary purpose, when appropriately used together, is to reveal details in an object that are too small in size to be normally seen with unaided eye. A metallurgical microscope in comparison to a biological microscope differs in the manner by which specimen is illuminated, owing to the inability of visible radiation to propagate through a metallographic specimen, however small it may be. Metallographic examination of each experiment is explained below.

Sample of vacuum soldering by Sn-Pbfor experiment is shown in fig. 16. It is easily seen that joint was not as per the requirement because formation of spheroids and unfilled section. This happens due to improper cleaning of sample and absence of flux. Which liable to suffer from oxide formation. Due to formation of oxide soldering alloy cannot wet and fill properly in the joining area and cause unfilled section.

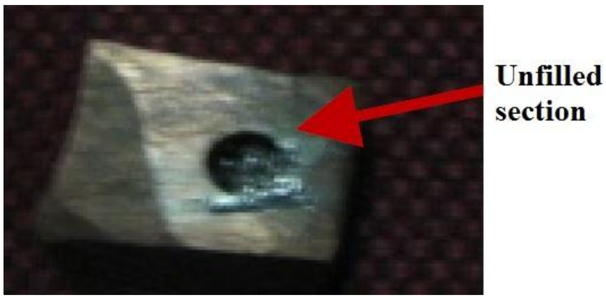

Fig. 17. Sample after vacuum soldering by Sn-Bi

Fig. 17 shows sample after vacuum soldering by Sn-Bi for experiment 2. Unfilled section is present due to formation of oxide layer and so low wettability. Because flux could not remove the oxide layer.

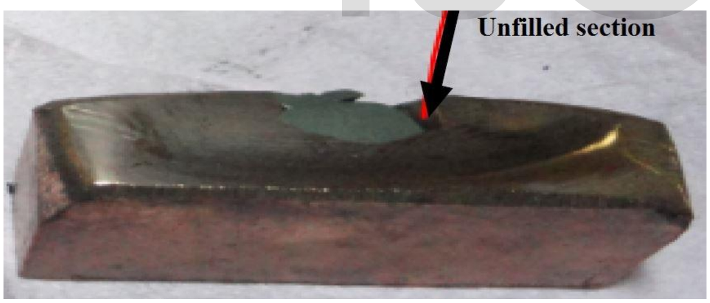

Fig. 18. Sample with Rosin flux by Sn-Pb

Fig. 18. Shows Sample with Rosin flux by Sn-Pb for experiment 3. A small portion was not filled due to presence of oxide because temperature is high and at this high temperature flux is no more activated and cause formation of oxide layer which reduce the solder ability.

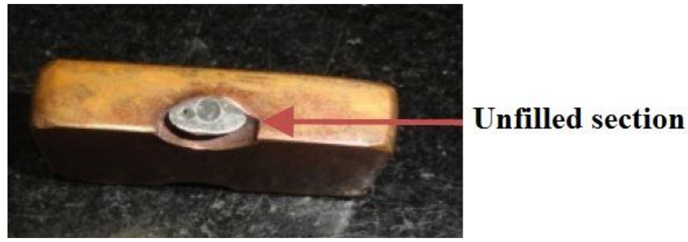

Fig. 19. Sample with flux by Sn-Bi (50% - 50%)

Fig. 19 shows sample with flux by Sn-Bi for experiment 5. There is small improvement but still unfilled area is seen.

Fig. 20 shows sample after soldering and microstructure of sample. The wettability improve and its clearly seen in the picture area/volume is completely filled with solder alloy**.** As the results are up to expectation in this experiment this particular sample is taken for metallographic analysis. By metallographic very smooth transition has taken place between parent material and soldering alloy joining area has been completely filled by the alloy. It means that Sn coating has improved wettability by reducing contact angle between soldering alloy and filler material. Fig. 21 show microstructure view of joint interface with 100 X.

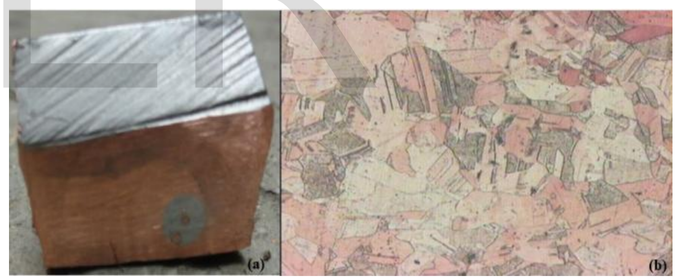

Fig. 20. (a) Sample after soldering, (b) Microstructure of sample after soldering

As shown in fig. 22, Wettability improved by Sn coating and join its clearly seen in the picture. Area/volume is completely filled with solder alloy Sn-Bi. As the results are up to expectation in experiment 7, this particular sample is taken for metallographic analysis. By metallographic very smooth transition has taken place between parent material copper and SnBi soldering alloy joining area has been completely filled by the alloy. It means that Sn coating has improved wettability by reducing contact angle between soldering alloy and filler material.

Fig. 21. Microstructures of joint interface at 100X

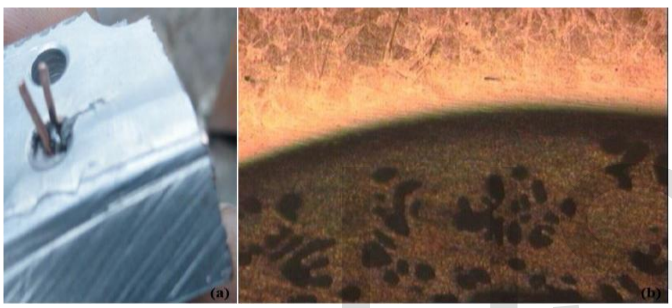

Fig. 22. (a) Sample after soldering, (b) joint microstructure after soldering at 100X

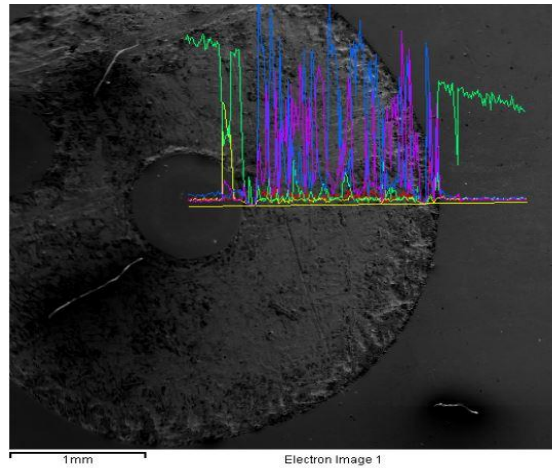

Fig. 23. SEM analysis of Sample after vacuum soldering using Sn-Pb alloy

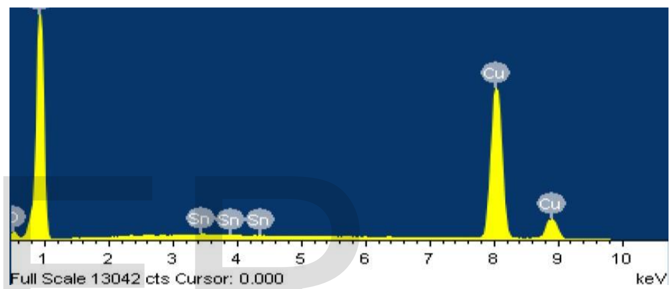

Fig. 25. Mapping at joint interface

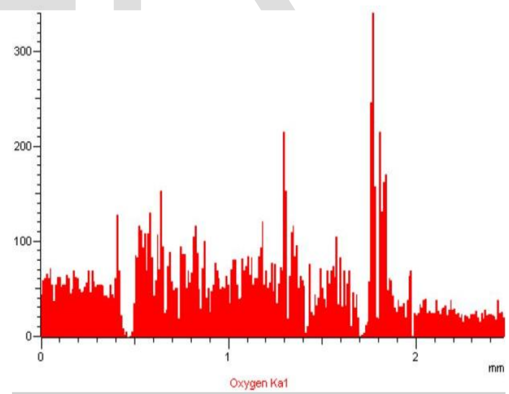

Fig. 24. Available oxygen at joint interface

4.3 SEM analysis

Scanning electron microscope analysis is carried out to determine the diffusion of soldering alloy in to base metal for Sn coated sample using Sn-Pb (63% - 37%) and Sn-Bi (50-50). For that line scan SEM EDS was carried out.

SEM analysis of Sn coated copper sample using Sn-Pb alloy

Diffusion length (solder alloy inside copper and vice versa) is limited to approximate 100 microns. So conductivity drop of joint will not be affected much and it is proved from line scan SEMEDS analysis as shown in fig 23 (diffusion length is as minimum as possible approximate 200 microns).

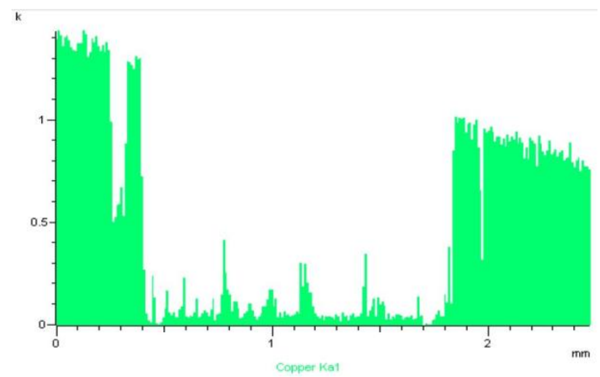

Fig. 26. Available copper at the joint interface

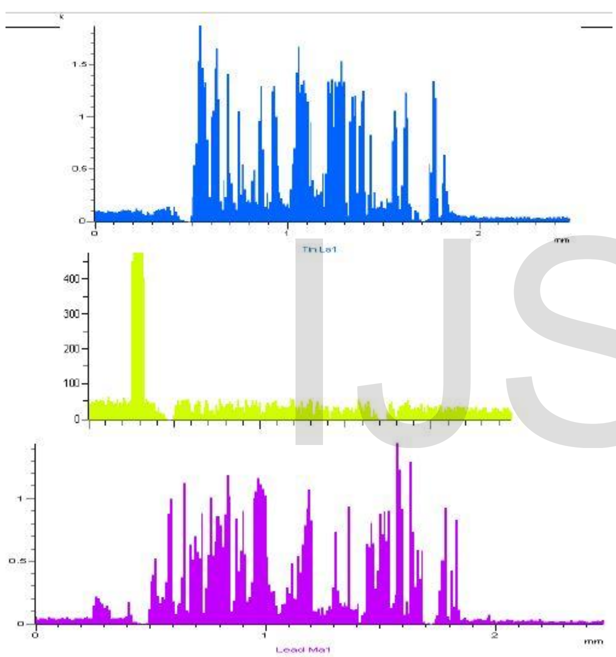

Fig. 27. Available tin and lead at joint interface

Fig. 24. Shows SEM of availability of oxygen at joint interface. Similarly Fig. 25 and Fig. 26 shows availability of copper and tin-lead at joint interface. Comparision of all three figures reavels that percentage of oxygen is moderate at joint interface but availability of copper is negligible at joint interface. Where as presence of tin and lead is comperatively higher than copper and oxygen.

SEM analysis of Sn coated copper sample using Sn-Bi alloy

Diffusion length (solder alloy SnBi inside copper and vice versa) is limited to approximate 150 microns. So conductivity drop of joint will not be affected much and it is proved from line scan SEM EDS analysis as shown in fig. 28 (diffusion length is as minimum as possible approximate 200 microns).

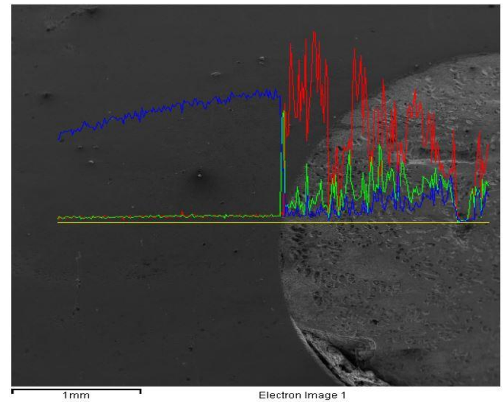

Fig. 28. SEM analysis of Sample after vacuum soldering using Sn-Bi alloy

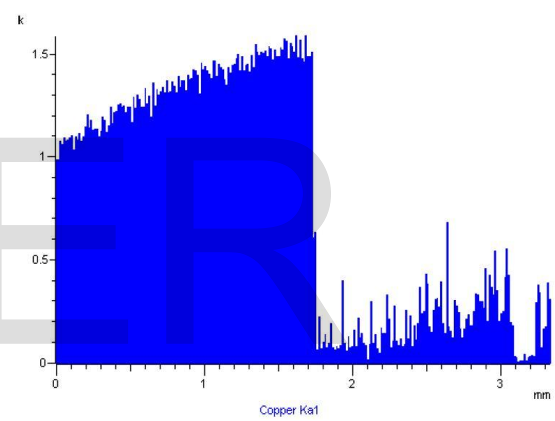

Fig. 29. Available copper at the joint interface

Fig. 29 and fig. 30 shows availability of copper and tin-bismuth at joint interface. Comparision of both figures reveals that, nearer to center presence of tin-bismuth is comperatively higher and as radius increases, copper makes its presence higher than tin and bismuth.

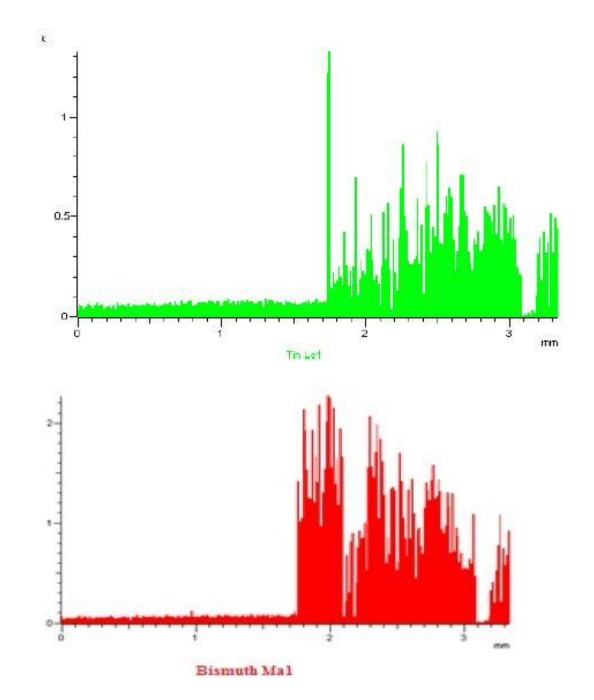

Fig. 30. Available Tin and Bismuth at the joint interface

TABLE 8
OBSERVATION TABLE BEFORE SOLDERING

Sr. No.	I(amp)	V(mv)	R(mΩ)	P = R×A/L
1.	0.5	0.18	0.36	0.38
2.	1.0	0.375	0.37	0.39
3.	1.5	0.510	0.34	0.36
4.	2.0	0.643	0.32	0.34
5.	2.5	0.834	0.31	0.35
6.	3.0	0.966	0.32	0.34
7.	3.5	1.261	0.31	0.33

TABLE 9
OBSERVATION TABLE AFTER SOLDERING WITHOUT COATED

Sr. No.	I(amp)	V(mv)	R(mΩ)	P = R×A/L
1.	0.5	0.770	1.55	1.6
2.	1.0	1.41	1.41	1.5
3.	1.5	2.18	1.45	1.5
4.	2.0	2.90	1.36	1.4
5.	2.5	3.34	1.39	1.4
6.	3.0	4.18	1.43	1.5
7.	3.5	5.72	1.38	1.4

TABLE 10
OBSERVATION TABLE AFTER SOLDERING OF COATED SAMPLE

Sr. No.	I(amp)	V(mv)	R(mΩ)	P = R×A/L
1.	0.5	0.479	0.95	1.0
2.	1.0	0.592	0.59	0.63
3.	1.5	0.751	0.50	0.53
4.	2.0	0.829	0.41	0.44
5.	2.5	0.975	0.38	0.40
6.	3.0	1.34	0.44	0.47
7.	3.5	1.49	0.42	0.45

4.5 measurement of electrical resistivity of Tin coated sample and without tin coated sample

A sample of OFHC copper of size A = 90 mm2 L = 84.4 mm. Resistivity of sample is measured before soldering, after soldering without coating, soldering with Tin coating. On the basis of these result tin coated sample is showing less resistivity as compared to without coated sample.

5 Summary and Conclusion

On the basis of experiments it is concluded that for better wettability (solder Ability) and minimum joint resistance, Tin coating on the copper base metal is required. The temperature of the soldering cycle should be in the range of be 220 ± 10 ℃ for Sn-Pb soldering alloy. The temperature of soldering cycle should be in the range of 170 ± 10 ℃ for lead bismuth. Important note is the component should clean a moment before the soldering operation. In-situ tin coating in recommended for complex shape where conventional coating cannot be done. Tin coating thickness should be 15 µm.

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