Joining of high purity copper for compact linear collider structure

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I. Introduction

The CLIC project designs and builds the next generation particle accelerator.

The present material of CLIC accelerating structure disks (cells) is high conductivity Oxygenelectronic (OFE) Cu (Fig.1a).

Current technology for fabricating the CLIC accelerating structure (disk stack) consists of diffusion bonding the Cu faces of each cell together.

Fig. 1*: Optical images (front and backside) of the initial OFE Cu cells in the CLIC accelerating structure.*

Although diffusion bonding process is more accurate towards axial alignment than brazing processes, conventional solid-state joining of Cu has been performed using high bonding forces, resulting in notable deformation of the parts [2].

Therefore, it is of interest to extend diffusion bonding towards lower bonding pressures, thereby avoiding plastic deformation of the Cu discs.

II. Direct diffusion bonding of OFE Cu- - - Process variables

Joining processes for the CLIC production must be very reproducible. Success of direct (without transient interlayer) diffusion bonding process depends on a number of adjustable variables:

After precision machining and stress-relieve operations, proper cleaning of the surfaces is a first necessity.

The bonding environment affects the joint quality. As the solubility of O_2 in solid Cu (under atmospheric conditions) is very small and reaches a maximum of about 0.03 at. % [3] at the eutectic temperature (Fig. 2a), good vacuum sublimes the surface oxides, thereby improving the material properties in the diffusion zone (Fig. 2b). Similar results can also be achieved in a reducing atmosphere, like H_2 or H_2-containing gas mixtures.

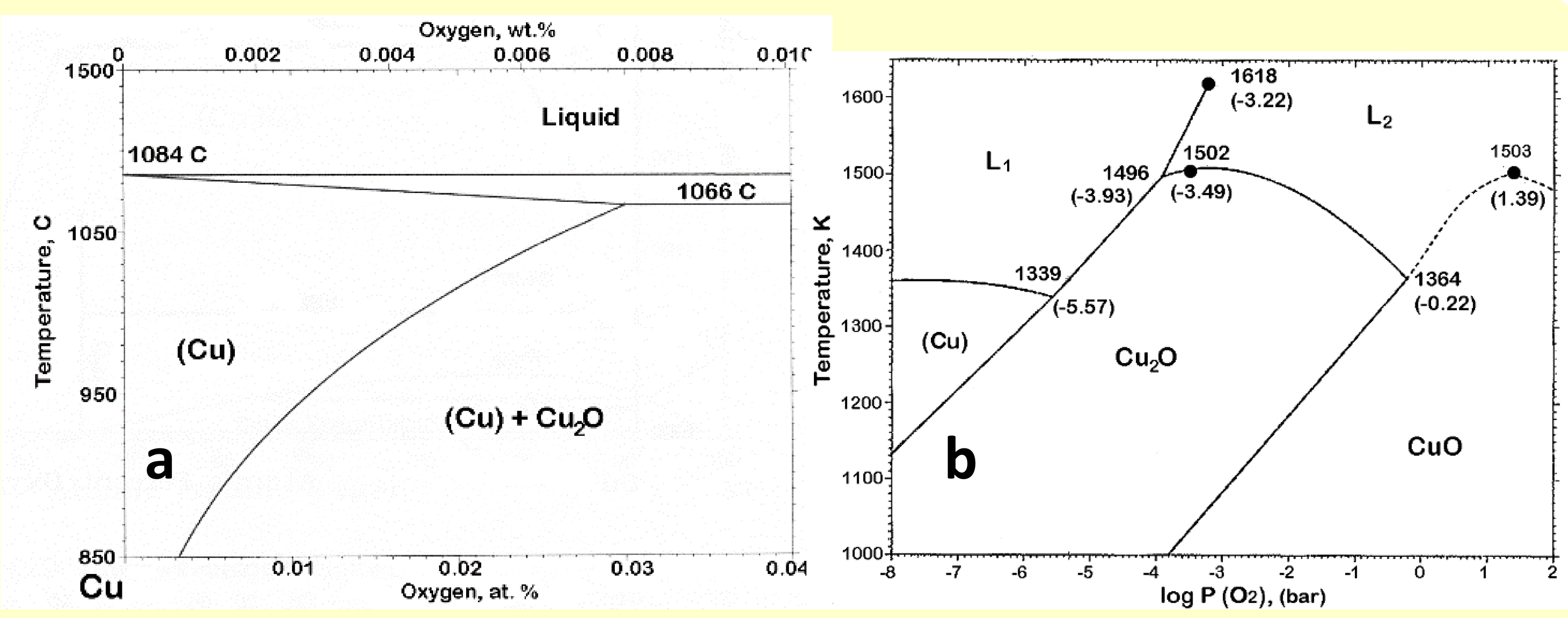

Fig. 2: *In a)Cu-rich domain on the binary Cu-O phase diagram showing solid-state solubility (solvus line) of oxygen in the FCC lattice of Cu [3]. In b) the calculated stability diagram for Cu-O system [4].*

Depending on the surface quality, bonding pressure, time and ambient, diffusion bonding is conducted usually between 0.5 and 0.7 of the homologous (absolute melting point) temperature [2].

Minimizing deformation is our first choice and, therefore, the bonding pressures used were kept intentionally low, and deformation (either through creep or actual yielding) of the Cu around the contact area during joining should be tightly controlled.

Depending on bonding temperature, the surface quality and ambient, diffusion bonding can, in principle, be accomplished at bonding pressure as low as 3.5 kPa [5].

III. Bonding of OFE Cu components using a transient interlayer

Joining of the OFE Cu disks is also possible through bonding in vacuum or in H_2 or H_2-containing gas mixtures using a thin interlayer of pure Ag [5, 6].

A few microns layer of Ag can be deposited on the mating surfaces by sputtering (PVD) or by a plating process.

Bonding of the plated disk stack can be conducted in “a two-step process”:

Heating below eutectic temperature of the binary Ag-Cu system, i.e. below 780 ºC (Fig. 3) under an external load to achieve some diffusion bonding of the components.

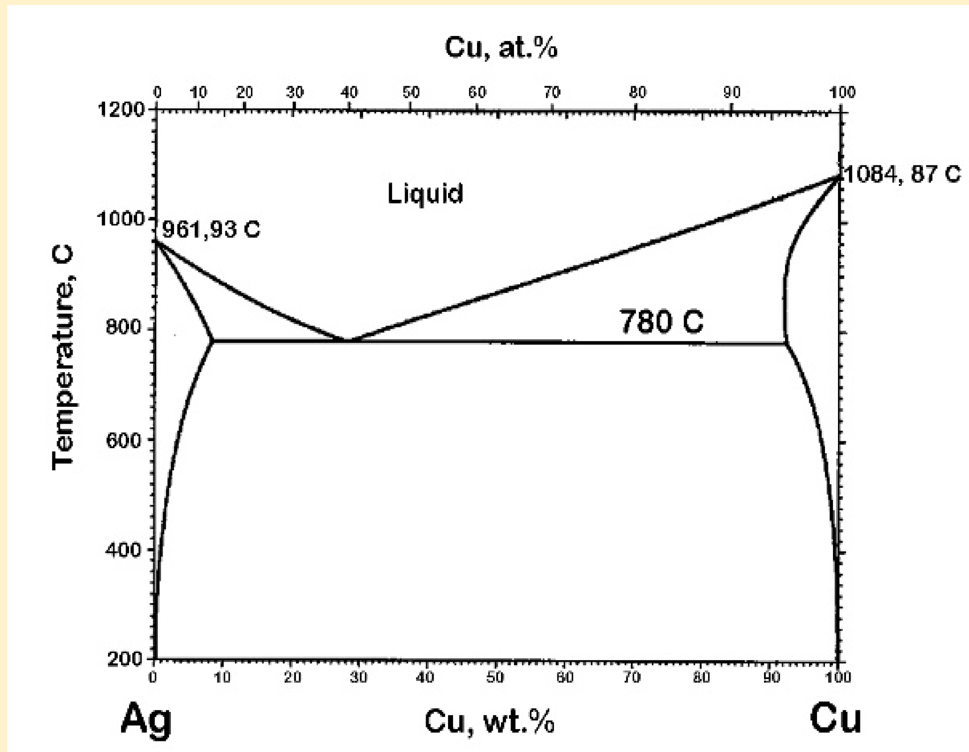

Fig. 3: *The binary Ag-Cu system [3].*

Subsequent heating above the Ag-Cu binary eutectic (but within the two-phase field, e. g. at 800 ºC) ensures a vacuum tight seal and provides additional strength to the finished assembly.

The product stack is cooled slowly to minimize distortion and residual stresses.

IV. Concluding Remarks

Joining of the precision machined, stress-free OFE Cu disks (cells) can be accomplished by direct low-pressure diffusion bonding in vacuum or in H2-containing gas mixtures as well as through a transient interlayer of pure Ag.

A thin Ag-layer can be applied on the mating surfaces by sputtering (PVD) or by using a plating process.

The bonding pressures used should be kept as low as possible in order to minimize deformation of the Cu around the contact area of the joint.

The proposed joining processes are to be optimized and fine turned.

V. References

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