A.17: Development of a ductile niobium-316L stainless steel brazed joint for superconducting RF cavities

Choice of stainless steel (SS), type 316L, instead of titanium, as a material for the helium vessel of superconducting niobium (Nb) cavities is recently becoming popular since it makes the associated fabrication cost effective. However this requires a reliable, ductile and high strength transition joint between niobium and SS. The existing and globally accepted vacuum brazing practice (developed by CERN) to form Nb-SS transition joints, employs pure copper as the braze filler. The resultant transition joints, in spite of meeting operational requirements, reportedly suffer from brittleness due to formation of a layer of brittle Nb-Fe intermetallic compounds on Nb/braze interface. In an in-house brazing scheme developed recently, strong and leak tight Nb-316L SS transition joints were formed. The approach adopted to suppress the formation of brittle layer of Nb-Fe inter-metallic compounds involved use of a lower temperature braze filler CuSil-ABA® (63Ag/35.25Cu/1.75Ti) along with a diffusion barrier (Ni plating) on SS part. The brazed joints, made with CuSil-ABA®, displayed no brittle intermetallic layers on any of its interfaces, but instead carried well-distributed intermetallic particles (formed due to reaction between titanium present in the braze filler with copper and nickel) in the Ag-rich ductile matrix.

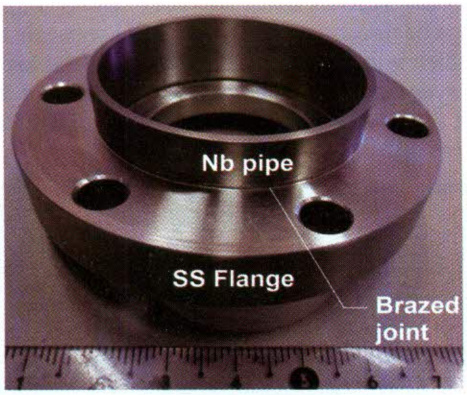

Fig. A.17.1: Vacuum brazed Nb-SS assembly

A subsequent related study demonstrated the establishment of strong and ductile Nb-SS brazed joints, free of brittle intermetallic compounds. Noteworthy feature of the new brazing scheme were: (i) first time use of BVAg8 braze filler (72Ag/28Cu; T_M = 780 °C) for joints involving Nb (due to its poor wettability on Nb surface) and (ii) use of Ni plating as diffusion barrier on SS part. The specimen, selected for verifying wettability in capillary brazing and helium leak testing, comprised of an Nb pipe brazed to a SS flange (Fig.A.17.1). Fig.A.17.2 presents transverse cross-section of Nb-SS brazed joint. The transition joints displayed tensile and shear strengths of 150 -190 MPa and 100 - 120 MPa, respectively with ductile mode of fracture in the brazed joint (Fig. A.17.3). Vacuum brazed specimens did not show any He leak with a He background less than 1 x 10^{-10} mbar.lit/s at room temperature as well as at LN_2 temperature. The joint also withstood ten-hour degassing heat treatment at 873 K and ten numbers of thermal cycles between 300 K and 77 K without any degradation in the hermeticity of the joint at room temperature and LN_2 temperature.

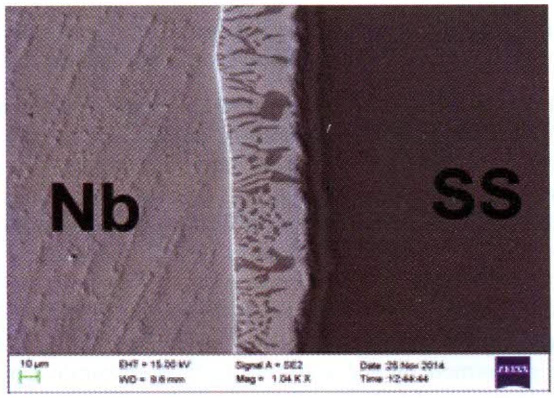

Fig. A.17.2: Cross-section of Nb-SS brazed joint

Important contributing factors for establishment of strong and ductile Nb/type 316L SS transition joint included (i) use of Ti-free braze filler and (ii) use of Ni-plating as a diffusion barrier to suppress iron migration from SS part towards Nb and (iii) excellent wettability of nickel-plated SS surface, which compensated for poor wettability of Nb surface.

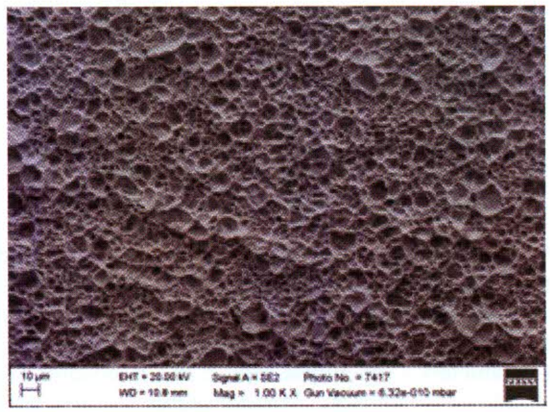

Fig. A.17.3: Ductile fracture surface of tensile tested Nb-SS brazed specimen

On the basis of the results of this study, a new lower temperature brazing route is proposed to form Nb-316L SS transition joints, with improved micro-structure and ductility, for application in superconducting RF cavities.

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