Synopsis

The A15-based Nb_3Sn and V_3Ga superconducting compounds are an integral part of synchrotrons and magnetic fusion reactor technology, especially where a magnetic field higher than 10 T is required, which lies beyond the limit of conventional Nb-Ti superconductors (~8 T). These brittle intermetallic compounds are difficult to manufacture in the form of wires, required for the application purpose, using the traditional wire-drawing process. Hence, bronze technique is adopted to fabricate such filamentary wires. This is based on the solid-state diffusion where A_3B compound (A=Nb or V, B=Sn or Ga) forms during the interaction of Cu(B) and A. The operation of pure superconducting wires gets restricted to the field of 12 T, however, the ever-increasing demands for an improved efficiency have promoted the development of these A15 wires with the addition of alloying elements such as Ti and Zr. Many important physical and mechanical properties of such wires depend on the growth behavior of these compounds. Therefore, understanding the growth of such compounds necessitates an in-depth analysis on diffusion behavior of various elements in both bronze-based solid solutions as well as A15-intermetallics.

Estimation of diffusion parameters makes use of the most commonly used diffusion couple technique. There are mainly three methods available for the estimation of the interdiffusion coefficients, proposed by Matano-Boltzmann (MB), Den Broeder (dB), same as Sauer-Freise (SF) and Wagner. Among these three, MB treatment is known to be the least accurate method, especially when there is a deviation of molar volume in a system from the ideality. At the same time molar volume might affect the estimation process differently for dB and Wagner's approach. MB method is still being used neglecting the actual molar volume variation. On the other hand, the implementation of dB or Wagner's approach for

the estimation remains to be random. For the first time, we have critically examined the role of molar volume on estimated diffusion parameters and indicated the more accurate approach. Similar analysis for the estimation of the intrinsic diffusion coefficient is conducted considering Heumann and van Loo's methods. Furthermore, the discussion is extended to the estimations of various diffusion parameters considering the measured composition profile in the V-Ga system.

A detailed diffusion study has been conducted on Cu(Ga) and Cu(Sn) solid solutions to examine the role of the vacancy wind effect on interdiffusion. The interdiffusion, intrinsic and impurity diffusion coefficients are determined to facilitate the discussion. It is found that Ga and Sn are the faster diffusing species in the respective systems. The trend of the interdiffusion coefficients is explained with the help of the driving force. Following that, the tracer diffusion coefficients of the species are calculated with and without consideration of the vacancy wind effect. We found that the role of the vacancy wind is negligible on the minor element in a dilute solid solution, which is the faster diffusing species in this system and controls the interdiffusion process. However, consideration of this effect is important to understand the diffusion rate of the major element, which is the slower diffusing species in this system.

Major drawback of studying diffusion in multi-component systems is the lack of suitable techniques to estimate the diffusion parameters. In this study, a generalized treatment to determine the intrinsic diffusion coefficients in multi-component systems is developed utilizing the concept of pseudo-binary approach. This is explained with the help of experimentally developed diffusion profile in the Cu(Sn, Ga) solid solution.

Based on an interdiffusion study using an incremental diffusion couple in the V-Ga binary system, we have shown that V diffuses via lattice, whereas Ga does so via grain

boundaries for the growth of the V_3Ga phase. We could estimate the contributions from two different mechanisms, which are, usually, difficult to delineate in an interdiffusion study. Available tracer diffusion studies and the atomic arrangement in the crystal structure have been considered for a discussion on the diffusion mechanisms. Diffusion–controlled growth rate of V_3Ga at the Cu(Ga)/V changes dramatically because of a small change in Ga content in Cu(Ga). One atomic percent increase in Ga leads to more than double the product phase layer thickness and a significant decrease in activation energy. Kirkendall marker experiment indicates that V_3Ga grows because of diffusion of Ga. Role of different factors influencing the diffusion rate of Ga and high growth rate of V_3Ga are discussed.

The growth of Nb_3Sn by bronze technique on two different single crystals and deformed Nb is studied. The grain boundary diffusion-controlled growth rate is found to be different for each of these three specimens. The difference is explained on the basis of the grain size of Nb_3Sn.

Elemental additions such as Ti and Zr to either bronze or metal are found to improve the superconducting properties. We have examined their effects on the growth rates of A15-phase formed in Cu(B,*x*)/A and Cu(B)/(A,*x*), where *x* is Ti or Zr. In either cases Ti and Zr-additions result in an improved growth rate of the product phase and reduces activation energy with increase in alloying addition; however few precipitates are formed in the interdiffusion zone for Cu(B,*x*)/A. Wavelength dispersive spectrometry (WDS)-mapping reveals these to be *x*-rich. Scanning transmission electron microscopy (STEM)-analysis suggests having composition gradient inside a single precipitate. TEM-diffraction demonstrates these to be Ti(A) solid solution crystallizing as BCC-structure for Cu(B,Ti)/A. These are located on grain boundaries of A15-phase. Electron back-scattered diffraction (EBSD)-analysis demonstrates grain morphology of product phase and found the average

grain size to exhibit a decreasing trend with increasing *x* content. Columnar grains, on Ti and Zr addition tend to form as equiaxed ones. Based on the morphology and grain size pattern, the role of grain boundary diffusion is speculated to have a dominant effect with increase in elemental additions. The texture evolution of the product phase is also investigated and found the product phase to grow as a strongly textured one with the elemental additions. A peculiar pattern is observed for the texture of the product phase and its adjacent A or A(*x*) grains.