## §15. Studies on Advanced Superconductors for Fusion Device

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### i) Fabrication of New $Nb_3Sn$ Superconductors for High-Field Use

The bronze-processed $Nb_3Sn$ with small amount of Ti addition is being widely used for high-field generation, however, a superconducting magnet capable of generating fields over 20T at 4.2K has not yet been realized. A new process to fabricate $Nb_3Sn$ conductor has been developed starting from $Nb_6Sn_5$ intermediate compound powder[1]. The $Nb_6Sn_5$ fine powder can be synthesized by the melt diffusion process of Sn using Nb and Sn powders. The $Nb_6Sn_5$ intermetallic compound powder is mechanically mixed with Nb powder, and then tape conductors are fabricated using mixed powder of Nb/$Nb_6Sn_5$ encased in a Ta tube. The fabrication can be performed without intermediate annealing. Fig.1 shows the cross-section of the specimen with outer layer of Cu stabilizer.

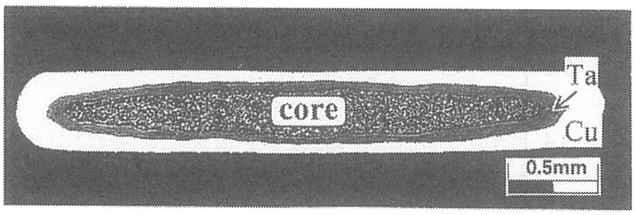


Fig.1. Cross-section of the present $Nb_3Sn$ specimen.

The upper critical field $Bc_2$ of present $Nb_3Sn$ reaches 24.7T at 4.2K, which is nearly 5T higher than that of bronze-processed pure $Nb_3Sn$. The normal state resistivity $\rho_n$ of the present $Nb_3Sn$ is about three times larger than that of bronze-processed $Nb_3Sn$ which may be account for the high $Bc_2$ in the present $Nb_3Sn$[2]. In this study the effect of small amount of Ge addition to the $Nb_3Sn$ conductor fabricated by the new process has been studied[3]. The Ge is added to $Nb_6Sn_5$ compound at the time of the melt diffusion.

The SEM structures taken on the cross-section of the specimen indicate that the small amount of Ge addition appreciably reduces the grain size of $Nb_3Sn$ after the heat treatment. Fig.2 illustrates the critical current $I_c$ and critical current density $J_c$ at high magnetic fields for different specimens heat treated at quoted conditions. The Ti addition to $Nb_3Sn$ improves high-field performance as described in the last report. The small amount of Ge addition produces more significant enhancement in $J_c$ at high fields than the Ti addition does. The optimum amount of Ge addition is found to be 0.5-1.0wt%. The composition slightly richer in Sn, i.e. $Nb_{2.9}Sn$, is more favorable to obtain improved high-field performance. The composition slightly richer in Sn yields the increase in $\rho_n$ value of $Nb_3Sn$. The significant enhancement in $J_c$ at high-fields seems to be attributed to the grain refinement of $Nb_3Sn$ by the Ge addition described above. A $J_c$ value of over 30000A /cm$^2$ has been realized at 21T and 4.2K by the Ge addition. The present result is much encouraging for the development of $Nb_3Sn$ conductor capable of generating fields over 20T at 4.2K.

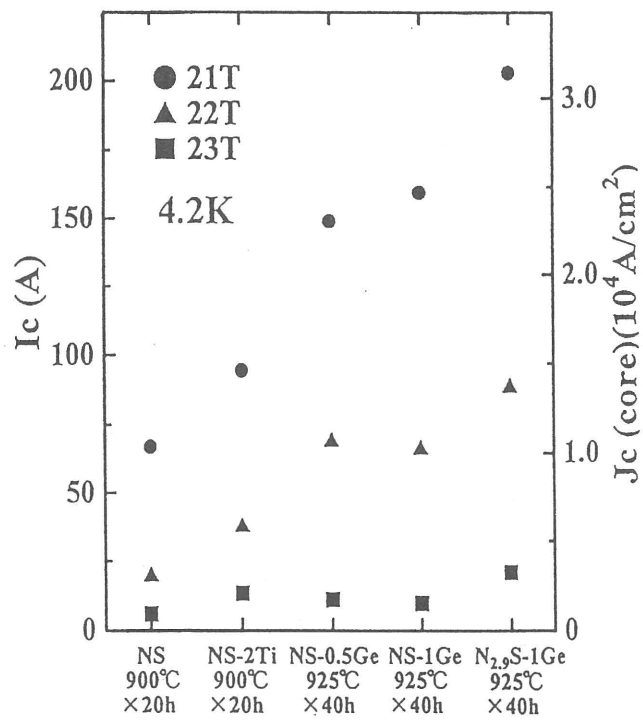


Fig.2. $I_c$ and $J_c$ at 4.2K in fields of 21, 22 and 23T for different specimens. NS:$Nb_3Sn$.

ii) Investigation on the Present Status of Advanced Metallic Superconductors other than $Nb_3Sn$.

A comprehensive report on the development of $Nb_3Sn$ was published as NIFS-MEMO-20 in last year[4]. Present study covers the progress so far achieved in the research and development of advanced metallic superconductors other than $Nb_3Sn$[5]. Among different A15 crystal-type compounds, $Nb_3Al$ has been fabricated into cables with large current-carrying capacity referring its smaller sensitivity to mechanical strain than $Nb_3Sn$. Other high-field A15 superconductors, e.g. $V_3Ga$, $Nb_3Ge$ and $Nb_3(Al,Ge)$, have been also fabricated through different novel processes. Meanwhile, B1 crystal-type NbN and C15 crystal-type $V_2(Hf,Zr)$ superconductors are characterized by their excellent tolerance to mechanical strain and neutron irradiation. Chevrel-type $PbMo_6S_8$ compound has gained much interests due to its extremely high $Bc_2$ value. In addition, this study includes the recent progress in ultra-fine filamentary Nb-Ti wires for AC use, and that in Nb-Ti/Cu magnetic shields necessary in the application of high magnetic field. The data on the decay of radioactivity in a variety of metals relating to fusion superconducting magnet are also included. This report might contribute substantially as a useful reference for the planning of fusion apparatus of next generation.

References


1) Tachikawa, K., Natuume, M., Kuroda, Y. and Tomori, H., Cryogenics, 36 (1996) pp 113-117.
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5) Tachikawa, K., Yamamoto, J. and Mito, T., Research Report NIFS-MEMO-22 (March,1997) pp 1-132.