# Superconducting Properties of Multiple Layered Structures $(Cu,M)Ba_2Ca_{n-1}Cu_nO_{2n+2+\delta}$ (M = T*l*, C) –high $T_c$, $J_c$ and $H_{irr}$–

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## 1. High–$T_c$

Since the discovery of $HgBa_2Ca_{n-1}Cu_nO_{2n+2+\delta}$ (Hg –12*n*(*n*–1) ) by Schilling *et al.* in 1993, no superconductors with $T_c$ >130K have been synthesized. Recently, we have found that the T*l* –based superconductors with T*l*–1223 and –1234 structures show $T_c$ of 133.5 K and 127 K, respectively (Fig. 1). These $T_c$ are comparable to those of Hg–1223 and –1234. Although more than 10 years has past since the discovery of T*l*–1223 and –1234, the $T_c$ had been believed to be around 120 K. It is interesting to know the reason how and why $T_c$ have been enhanced. We have investigated the preparation conditions to obtain the high–$T_c$ samples and the mechanism of enhancement of $T_c$.

We have found several essential conditions to obtain the sample as follows 1) preparation under high pressure 2) use the precursors with low residual carbonate 3) synthesis at low temperature or from low nominal T*l* composition and 4) post-annealing in the reducing atmosphere. The samples (T*l*–1223) prepared under the above conditions show $T_c$ over 130 K with good reproducibility. The composition analysis (SEM-EDX) indicates that the grains in the high–$T_c$ samples show nearly ideal composition of T*l*:Ba:Ca:Cu=1:2:2:3 or 1:2:3:4. On the other hand, substitutions of T*l* for Ba and Ca–site have been suggested for low–$T_c$ samples, which will suppress the $T_c$ in this system.

In order to improve such performance as the critical currents density $J_c$ and the irreversibility field $H_{irr}$ of this materials, reduction of anisotropy maintaining the $T_c$ as high as possible, for example, substitution of Cu for part of T*l*–site is important.

## 2. High–$J_c$ and $H_{irr}$

$J_c$ is measured for the before/after neutron irradiated polycrystalline samples of (Cu,C) –12*n*(*n*–1) and evaluated for the intragrain limit by the Bean's model from *M–H* curves.

After irradiation with a fluence of $1\times10^{17}$ /cm², $J_c$ increases from $5.5\times10^4$ A/cm² to $7.7\times10^5$ A/cm² (0.5 T, 77 K) for (Cu,C)–1234 and from $1.2\times10^3$ A/cm² to $2.1\times10^4$ A/cm² (0.5 T, 77 K) for (Cu,C)–1245, but decreases from $2.7\times10^5$ A/cm² to $1.4\times10^5$ A/cm² (0.5 T, 77 K) for (Cu,C)–1223.

$H_{irr}$ increased toward higher field except for (Cu,C)–1223 (Fig 2). (Cu,C)–1234 is the highest $H_{irr}$ in the (Cu,C)–12*n*(*n*–1) family. $H_{irr}$(T) is described by the power law dependence of $H_{irr}(T)=H_{irr}(0)(1-T/T_c)^n$. The *n* values are 1.8 and 1.9 for (Cu,C)–1223, 2.7 and 2.0 for (Cu,C)–1234, 2.5 and 2.2 for (Cu,C)–1245) before and after neutron irradiation, respectively (Fig 3). These results indicated the possibility of the enhancement of further $H_{irr}$ for (Cu,C)–1234 and –1245.

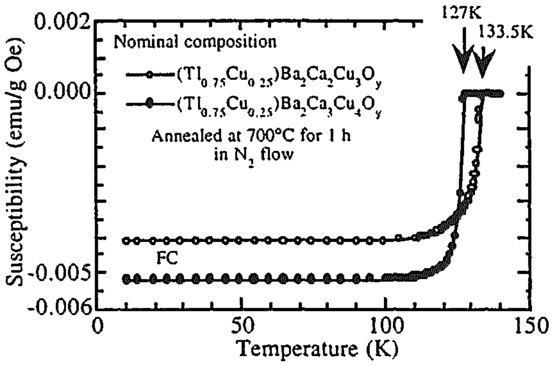


Fig. 1 Temperature dependence of susceptibility for (Cu,T*l*)–1223 and –1234.

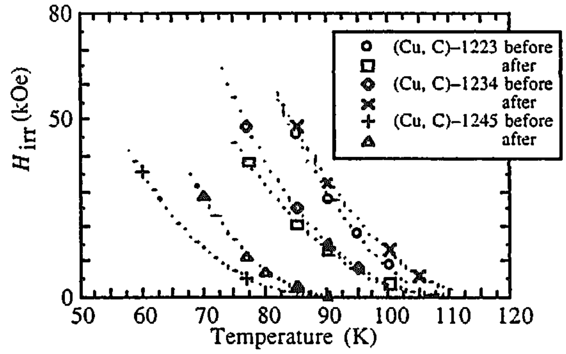


Fig. 2 Temperature dependence of $H_{irr}$ for (Cu,C)–12*n*(*n*–1) (*n*=3, 4 and 5)

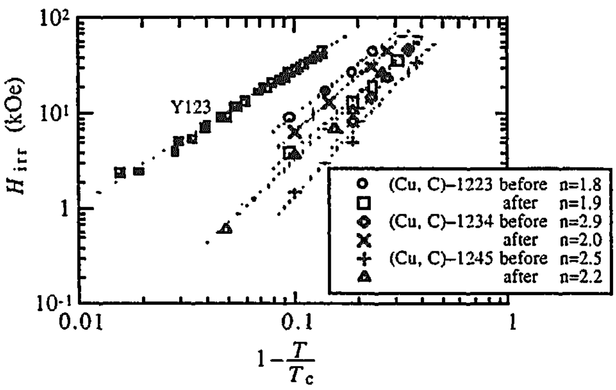


Fig. 3 The log–log plot of $H_{irr}$ for (Cu,C)–12*n*(*n*–1) (*n*=3, 4 and 5)