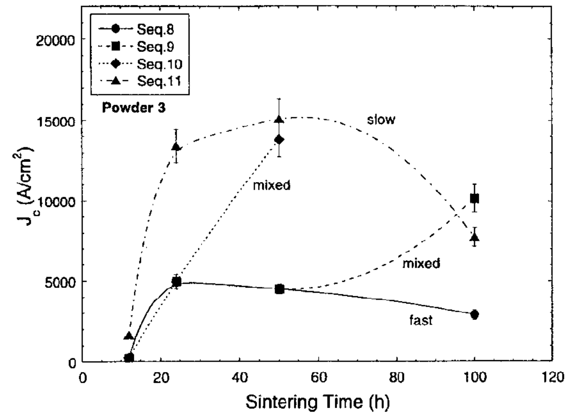

Figure 10. Variation in J_c with accumulated sintering time for PIT tapes containing powder 3 and subjected to treatments listed in experimental set C.

savings in time. Results from tapes containing powder 3 and processed using treatment schedules listed in set C are shown in figure 10. The J_c behaviours of these tapes are essentially identical to that of powder 2 (figure 9) except for the higher J_c values in all the sequences after 24 h of heat treatment reflecting the faster formation of Bi-2223 in the precursor with larger amount of Cu addition.

Microstructures of these conductors were examined by SEM/EDS, and samples subjected to slow cooling either in the final step or throughout all the steps are virtually indistinguishable from one another. Scanning electron micrographs of peeled high-J_c powder 2 PIT tapes subjected to 25–50–25 and 25–25–50 treatments with slow cooling in the final step are shown in figures 11(a) and (b), respectively. It can be seen from these figures that the samples are composed of well aligned Bi-2223 grains with a small amount of Bi-2212 phase distributed within the Bi-2223 matrix. Also, secondary phases such as CuO, Sr_2O_3 and Pb_2O_4 have been identified by EDS in most of the tapes examined. Figures 12(a) and (b) show the etched surfaces of the Bi-2223 cores, i.e., the Ag/HTS interfacial areas of powder 2 PIT tapes that were subjected to all fast-cooling and all slow-cooling steps, respectively. Both these samples show a high degree of Bi-2223 grain alignment. However, the minor difference in grain size seen between these two samples is not significant enough to explain the large difference in their J_c values.

By comparing results presented for the above four cases, some general conclusions can be made. Slow cooling has a beneficial effect on J_c where the enhancement can be as high as three to four times that of similarly processed samples subjected to fast cooling only. This enhancement in J_c cannot be explained purely by the minute increase in resident time the samples spent above 800 °C. As proposed by Parrell *et al* [22], it is likely that J_c enhancement in the aerosol precursor PIT tapes examined in this study is due to improved pinning by either defects or minor secondary phases such as $Pb_{3-x}Bi_xSr_{2+y}Ca_{2+y}CuO_z$ (Pb-3221) [24], $Pb_4Sr_5CuO_{10}$ [25] or $(Ca,Sr)_2PbO_4$ that resulted from partial decomposition during slow cooling. In addition, the oxygen content of Bi-2223 is likely to increase during slow

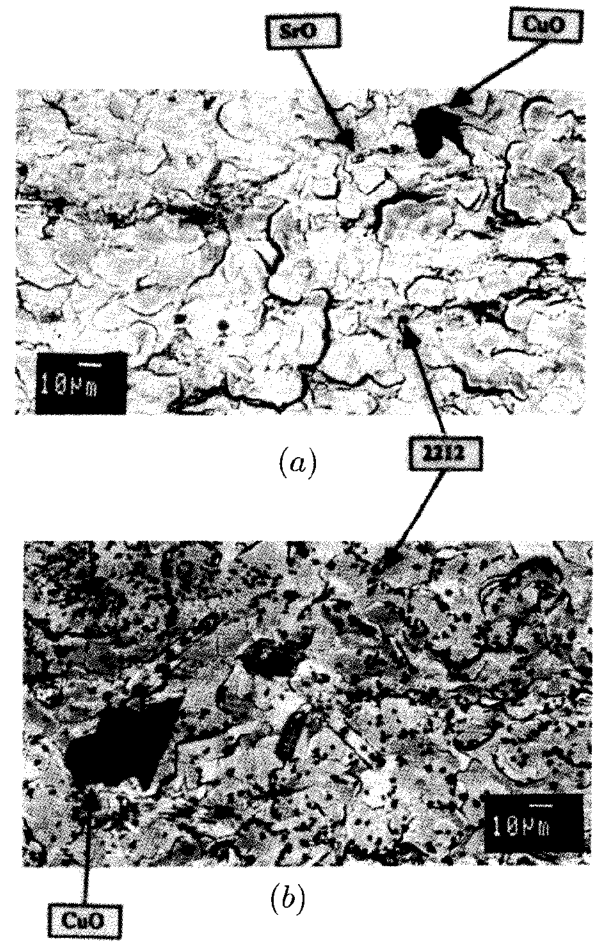

Figure 11. SEM micrographs of peeled PIT tapes containing powder 2 and treated for (a) 25–50–25 h and (b) 25-25-50 h with slow cooling performed in the final sintering step.

cooling [26] which may also result in J_c enhancement as reported in studies on two-step final annealing treatments [26, 27]. The optimum treatment developed based on fast cooling in a previous study served as a good guideline to design the treatments for slow-cooling stages. However, depending on the precursor composition and the frequency of slow cooling, the pressing/sintering schedule will have to be adjusted accordingly. In the present study where excess Cu is added to the precursor material, it is generally sufficient to obtain high J_c by employing an early pressing schedule and a total sintering time of 50 h with slow cooling during the final step. Sizeable savings in time may also be obtained by identifying the highest possible termination temperature of the slow-cooling step so as to eliminate the temperature range that is not operative in providing the J_c enhancement.

4. Summary

Cooling rate and precursor Cu content of PIT tapes fabricated using aerosol powders have been varied to establish their effects on Bi-2223 phase evolution and J_c