Figure 11. SEM micrograph of a PIT tape treated for a total of 100 h with three intermediate pressings.

addition, the core density is increased, which facilitates further precursor reaction. Moreover, a liquid phase is available to heal the microcracks that form as a result of pressing-induced stresses. As the Bi-2223 conversion nears completion, however, insufficient precursor is left to provide the necessary liquid phase to heal the cracks if any mechanical pressing is performed. Consequently, pressing is not advisable during the later stages of thermomechanical treatment. In sequence 1 of this study, the initial short pressing steps facilitate higher reaction rates. Unfortunately, this leads to insufficient liquid to heal the cracks induced during the last pressing step, resulting in a decrease in J_c. Similarly, the sintering duration of sequence 6 (10 h) is too small for pressing-induced cracks to be completely healed during sintering. It is believed that the partially healed microcracks are propagated during subsequent pressing and lead to a smaller maximum J_c. Additional pressing resulted in cracks that can no longer be healed owing to a lack of liquid phase. In contrast, the lower J_c values in sequences 4 and 5 are believed to be due to insufficient pressing. In the case of sequence 9, the rate of Bi-2223 formation decreases as the reaction proceeds (stage 3 of classical reaction kinetics S-curve) and requires longer sintering duration in the final thermomechanical treatment steps for Bi-2223 conversion and crack healing. This accounts for the larger maximum J_c value in sequence 9 when compared with sequences 7 and 10. Consequently, for a thermomechanical schedule that consists of two pressing steps and 100 h total sintering time, a third sintering duration of 50 h is better than 25 h. On the other hand, a typical second sintering interval usually lies within the second stage of a classical reaction kinetics S-curve, i.e. the reaction rate is high. Hence, a shorter sintering interval between pressings will provide a higher J_c. This can be seen by comparing the J_c behaviours of samples in sequence 9 (second sintering duration 25 h) and sequence 10 (second sintering duration 50 h).

In this study, the best J_c values are obtained for a total sintering time of 100 h, with a processing schedule of 12–12–26–50 (sequence 2) for three pressing steps and a schedule of 25–25–50 (sequence 9) for two pressing steps. Briefly, results of the three sets of experiments show that a shorter sintering duration between pressings should be employed during the initial stages of thermomechanical treatment, a long sintering duration should be used during the later stages and pressing should not be performed once the Bi-2223 fraction has reached approximately 90%. With an optimum choice of thermomechanical processing schedule and the utilization of a low cooling rate during the last sintering step, which has been shown to increase J_c by a factor of 3–4 [2, 13], PIT conductors with practical J_c values can be obtained. Some of the observations made in this discussion can be verified by microstructural analysis, which is presented in the following section.

3.3. Microstructure of PIT tapes

3.3.1. Optical microscopy. Figures 9(*a*)–9(*c*) show the microstructural development of samples in sequence 2. It can be seen in figure 9(*a*), which is obtained from a sample that has been heat treated for 12 h without pressing, that the HTS core is porous with widely distributed secondary phases. After one pressing and an additional 12 h of heat treatment (figure 9(*b*)), the density of the core has increased and the amount of the Bi-2223 phase (dark matrix) is now substantial. In comparison with the sample in figure 9(*a*), the amount and size of the second-phase particles have been reduced. In figure 9(*c*), which shows a sample that has been heat treated for a total of 50 h with two intermediate pressings, the HTS core is found to be further densified, and only a very small amount of secondary phase is seen. The variation in J_c value with processing as seen in figure 6 is in excellent agreement with the microstructural development observed here. Interestingly, microstructural observations on different sample sequences revealed that tapes pressed for the same number of times have similar microstructural features, rather than tapes sintered for the same amount of time. This indicates that the phase development and hence the superconducting properties of PIT tapes are heavily dependent on intermediate pressings. In each of the sequences, as thermomechanical processing proceeds, the HTS core density and the Bi-2223 fraction are found to increase, and the size and amount of second-phase particles are found to be reduced.

3.3.2. Scanning electron microscopy. In order to identify the secondary phases and to obtain a better estimation of their size and distribution, scanning electron microscopy (SEM) analysis was performed using both secondary and backscattered electrons on mounted longitudinal and transverse cross-sections of the tapes. Figures 10(*a*) and 10(*b*) compare the backscattered electron images of samples treated for 12 h without pressing and 50 h with two intermediate pressings, respectively. Compositions of the different constituents are estimated using energy-dispersive spectrometry (EDS) analysis, where the grey blocky precipitates embedded within the matrix are identified as CuO. The small dark distribution of acicular features, on the other hand, is composed of voids, alkaline earth cuprates or calcium plumbates. From these micrographs, it is seen that, as the processing proceeds, the amount and size of secondary