

2001

Comparative studies on “sandwich” rolling and flat rolling in processing Ag/Bi-2223 tapes

W. M. Chen

University of Wollongong

Y. C. Guo

University of Wollongong, yanhui@uow.edu.au

X. K. Fu

University of Wollongong

Hua-Kun Liu

University of Wollongong, hua@uow.edu.au

S. X. Dou

University of Wollongong, shi@uow.edu.au

See next page for additional authors

Follow this and additional works at: <https://ro.uow.edu.au/engpapers>



Part of the [Engineering Commons](#)

<https://ro.uow.edu.au/engpapers/51>

Recommended Citation

Chen, W. M.; Guo, Y. C.; Fu, X. K.; Liu, Hua-Kun; Dou, S. X.; and Apperley, M.: Comparative studies on “sandwich” rolling and flat rolling in processing Ag/Bi-2223 tapes 2001.
<https://ro.uow.edu.au/engpapers/51>

Authors

W. M. Chen, Y. C. Guo, X. K. Fu, Hua-Kun Liu, S. X. Dou, and M. Apperley

Comparative studies on "sandwich" rolling and flat rolling in processing Ag/Bi-2223 tapes

Wu M. Chen, Yuan C. Guo, Xue K. Fu, Hua K. Liu, Shi X. Dou and Miles Apperley

Abstract—The normal rolling method is commonly used for intermediate mechanical deformation in the powder-in-tube process to make Ag-clad Bi-based superconducting tapes. To compare the effects of different reduction processing on the superconducting properties of Ag/Bi-2223 tapes, the reduction rate dependence of the critical current densities J_c of tapes processed by three methods, including normal rolling, pressing and "sandwich" rolling, has been systematically studied. Experimental results show that J_c dependence on the reduction rate for the three processes follows the same law. There is an optimal reduction rate in each case, which gives the highest physical density and the highest J_c . When the reduction rate increases, J_c initially increases, reaches a maximum and then diminishes. The density-reduction rate follows a corresponding trend. However, the maximum J_c of the Ag/Bi-2223 tapes made using "sandwich" rolling is 35% higher than is the case for normal rolling even though the tapes in both cases have the same density of the oxide core. XRD analysis shows that the significant difference in J_c of tapes processed using the three different intermediate deformation procedures can not be attributed to the phase composition. SEM images show that normally rolled tapes have much higher density of microcracks than "sandwich"-rolled tapes. It is evident that the J_c of a tape is strongly dependent on oxide core density and deformation procedure.

Key words—core density, critical current, deformation, microcracks.

Manuscript received Aug. 18, 2000. This work was supported by Australian Research Council/Department of Employment, Education, Training and Youth Affairs financially supported the research work.

W. M. Chen is from the Department of Physics and National Laboratory of Solid State Microstructures, Nanjing University, Nanjing 210093, P. R. China, and now is with the Institute for Superconducting and Electronic Materials, University of Wollongong, Wollongong, New South Wales 2522, Australia (telephone: 61-2-4221-5798, email: chen@uow.edu.au).

Y. C. Guo is with the Institute for Superconducting and Electronic Materials, University of Wollongong, Wollongong, New South Wales 2522, Australia (telephone: 61-2-4221-5726, email: ycguo@uow.edu.au).

X. K. Fu is with the Institute for Superconducting and Electronic Materials, University of Wollongong, Wollongong, New South Wales 2522, Australia (telephone: 61-2-4221-5771, email: xf02@uow.edu.au).

H. K. Liu is with the Institute for Superconducting and Electronic Materials, University of Wollongong, Wollongong, New South Wales 2522, Australia (telephone: 61-2-4221-4547, email: hua_liu@uow.edu.au).

S. X. Dou is with the Institute for Superconducting and Electronic Materials, University of Wollongong, Wollongong, New South Wales 2522, Australia (telephone: 61-2-4221-4558, email: shi_dou@uow.edu.au).

M. Apperley is with is with Australia Superconductors, Miller St., Coniston NSW 2500 Australia (telephone: 61-2-4226-5331, email: milesa@ozemail.com.au).

I. INTRODUCTION

The processing method known as intermediate mechanical deformation is the most important method of improving the texture and critical current density J_c of Ag sheathed Bi-2223 mono- and multi-filaments tapes. Flat rolling or normal rolling is the most popular of these intermediate deformation methods to be used in making powder-in-tube tapes [1]–[5]. The pressing deformation method can reduce porosity and has thus been introduced to improve tapes' J_c [6], [7]. However, the pressing method is hardly ever used to manufacture long tapes. Another deformation mechanism called 'sandwich rolling' has been developed because it has the advantages of both normal and pressing deformation methods [8]. To compare the effects of different reduction processing on the superconducting properties of Ag/Bi-2223 tapes, the reduction rate dependence of J_c has been systematically studied using tapes produced by the three methods, including normal rolling, pressing and "sandwich" rolling. It was found that the maximum J_c of the Ag/Bi-2223 tapes made using "sandwich" rolling is 35% higher than for normal rolling even though the tapes in both cases have the same density of the oxide core [9].

II. EXPERIMENTS

Ag/Bi-2223 multi-filamentary tapes were fabricated by a powder-in-tube process that included an intermediate mechanical deformation between two sintering processes [1], [8], [10]. All samples used in this experiment were of identical length. They were cut from the same green tape and sintered at 840 °C for 50h in air and then furnace-cooled to room temperature. The samples were subjected to different amounts of deformation, ranging from a reduction in thickness from 0% to about 35%, using the processes of normal rolling (NR), pressing (P) and 'sandwich' rolling (SR). SR was performed with the short samples sandwiched between two 0.9 mm thick spring-steel plates. The samples and plates were then rolled between two rollers. After the reduction, the samples were sintered again in air at 840 °C for 30 hours, and this was followed by an annealing procedure at 825 °C for 30 hours.

The critical current was measured by the four-probe method and recorded using the normal criterion of 1 μ V/cm. X-ray diffraction (XRD) analysis was used to determine the phase compositions. Scanning Electron Microscopy (SEM) was also applied to observe the crystal morphology and the grain texture of the samples.

To determine J_c as a function of the density of the core

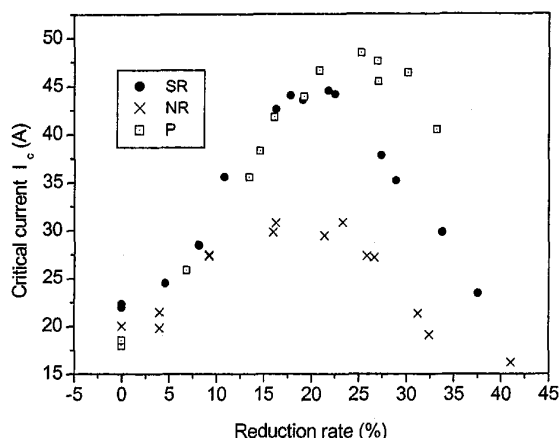


Fig. 1 Reduction rate dependence of I_c . I_c strongly depends on the deformation rate and is maximised at an optimal value. P, NR and SR processed tape have the largest, the second largest and the lowest optimum I_c , respectively.

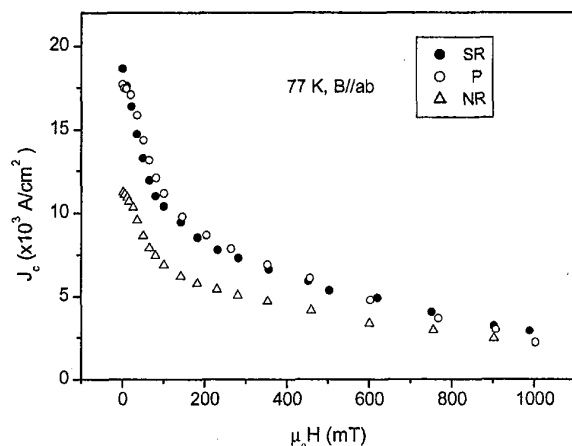


Fig. 2 J_c vs magnetic field μ_0H for SR, NR and P tapes processed at the optimum reduction rate. For $\mu_0H = 0$ T, the maximum J_c of SR processed tape is the same as that of P and 35% higher than that of NR.

mass, the relative core density was determined as follows. The length, width and thickness of as-sintered samples were measured and the volumes of the tapes were calculated. The core mass density is easy to obtain by dividing the mass by the volume if core mass of a sample is known. Noting that all the original samples have same amount of core mass because they were cut to the same length from the same green tape, the relative density of a deformed sample may be determined, by dividing its reciprocal volume by the reciprocal volume of the undeformed sample.

III. RESULTS AND DISCUSSION

The reduction rate dependence of critical current (I_c) for tapes processed by the three intermediate deformation

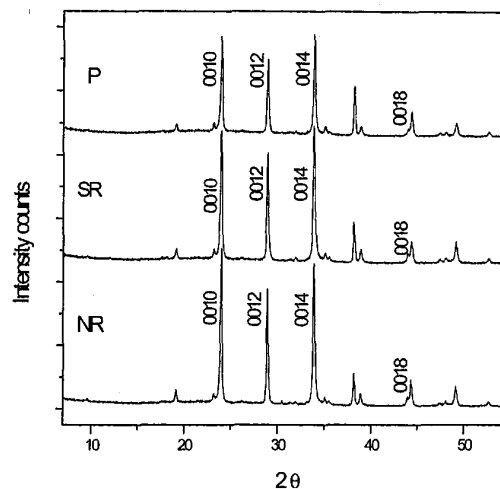


Fig. 3 XRD patterns of P, SR and NR processed tapes. XRD analysis shows that all P, NR and SR processed tapes have the same composition of the major phase Bi-2223 and the same fraction of the secondary phase Bi-2212.

methods including NR, P and SR is shown in Fig. 1. In all three cases, I_c vs reduction rate shows a similar curve: for lower reduction rates I_c increases with increasing reduction rate, but reaches a maximum I_c at an optimal reduction rate in each case. Taking the core mass density of the undeformed sample as 1, the relative core densities of all deformed samples were calculated. The highest core densities were seen in tapes deformed by P, while tapes deformed by NR had the lowest core densities. SR tapes were of intermediate density, but very close to the densities seen for P. The maximum core density is found at a reduction rate of 25% for P, 23% for SR and 22.5% for NR.

Figure 2 shows the magnetic field dependence of the critical current density J_c for NR, SR and P tapes produced using the optimum reduction rate for J_c (22%, 23% and 25%, respectively). Note that the NR reduction rate is slightly different from that needed to maximise core density. At zero field, the optimal reduction for pressed tape (25%) is slightly higher than that for sandwich-rolled tape (23%). It is interesting to note that the maximum J_c for sandwich-rolled tape is the same as for pressed tape, but J_c for both the sandwich-rolled and pressed tapes is 35% higher than for normal rolled tape.

Fig. 3 shows the XRD patterns of three tapes processed using NR, SR and P at similar reduction rates. It is found that all the tapes have similar diffraction patterns, showing that the composition of the major phase consisting of Bi-2223 is the same and that the fraction of the secondary phase Bi-2212 is also the same. There are no obvious differences in XRD patterns for tapes processed using different reduction rates. Therefore, the three intermediate deformations have no obvious effects on the crystal structure and phase assemblages of Ag/Bi-2223 tapes.

Fig. 4 shows the SEM morphologies of the cores of NR, SR and P tapes. It is evident that tapes processed by P, SR

and NR have the highest, the second highest and the lowest core densities, respectively. The results coincide with the calculated core densities. SR and NR tapes produced using large reduction rates (beyond the optimum) were also studied in order to explore the reason why J_c is reduced for such tapes. Fig. 5 shows SEM images of overly deformed tapes. It can be seen that filaments of SR tape processed at a reduction rate of 34% are of better quality than filaments of NR tape processed at a reduction rate of 32%. In particular, there are numerous large and small microcracks found in the image field of the NR tape, but not the SR tape. It is believed that microcracks can break the current circuit in filaments and thus cause lower J_c .

IV. CONCLUSIONS

From XRD analysis, the significant differences seen in J_c of tapes processed using three different intermediate

deformation methods is not attributable to the phase composition.

All three J_c curves of tapes processed by SR, NR and P show a maximum at an optimal reduction rate. It can be concluded that a proper reduction rate is important for any type of deformation processing. It is noted that among the three cases P tapes have the highest core density and J_c , but SR tapes have the same J_c as P tapes, 35% above the best J_c for NR tapes. This shows that SR is definitely a promising deformation process for enhancing J_c of Ag/Bi-2223 tapes.

A strong association was observed between microcracks generated through excessive deformation and large reductions in critical current of Ag/Bi-2223 tapes. Limiting the production of microcracks during mechanical deformation is likely to be of great value in maximising J_c .

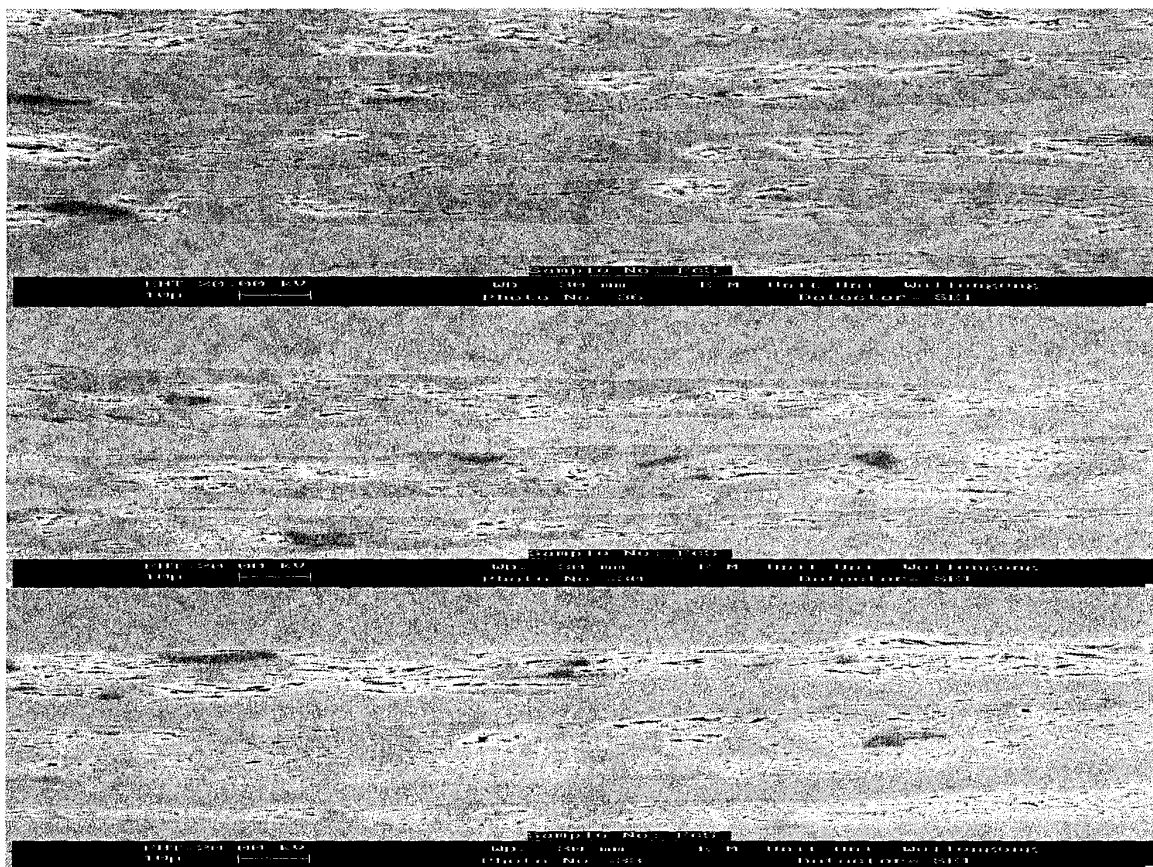


Fig. 4 The SEM morphologies of filaments of tapes produced using P, SR and NR deformation methods. The density of the P sample (the highest micrograph) is obviously the greatest, followed by the density of the SR sample (the middle one). The NR sample (the lowest one) exhibits the lowest density.

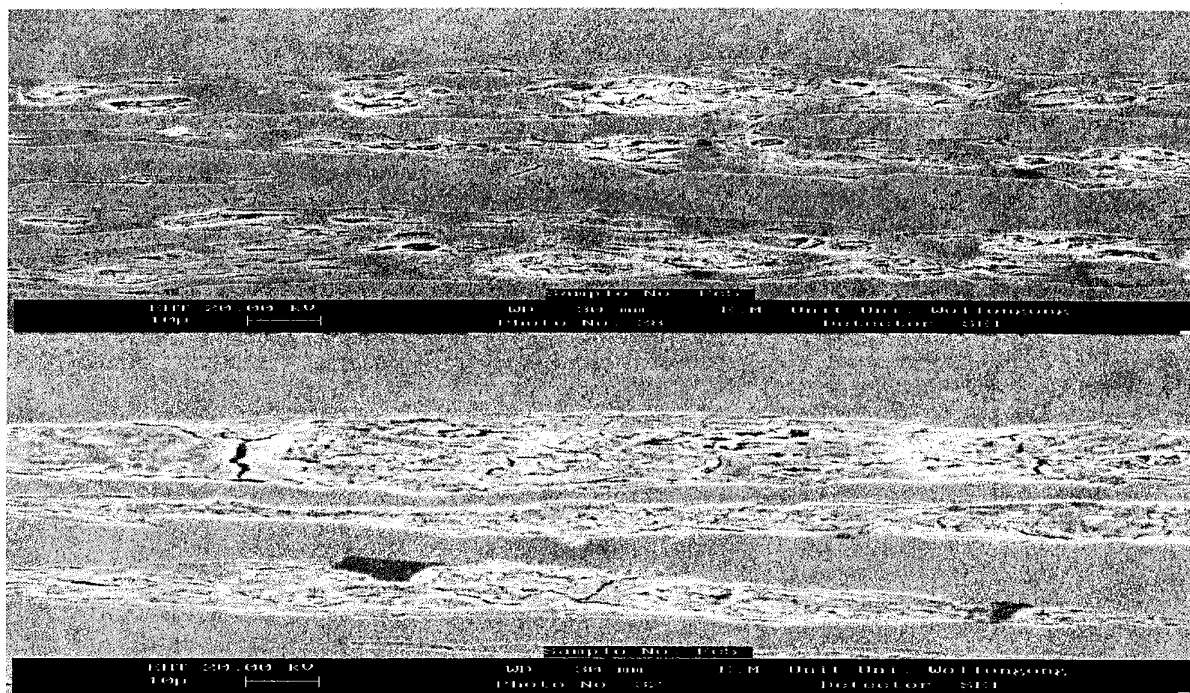


Fig. 5 SEM images of tapes with excessive reduction rates. Upper and lower microphotographs show filaments of SR and NR tapes processed at reduction rates of 34% and 32%, respectively. It is found that the SR filaments are of superior quality. Note the numerous large and small microcracks appearing in the image of NR. These microcracks are associated with reduced J_c .

REFERENCES

- [1] N. N. Merchant, J. S. Luo, A. K. Fischer, V. A. Maroni, E. R. Podtburg, W. L. Carter, Q. Li, A. Otto, M. W. Rupich and G. N. Riley Jr, *Supercond. Sci. Technol.*, 12 (1999)pp. 327.
- [2] Y. L. Liu, W. G. Wang, H. F. Poulsen, and P. Vase, *Supercond. Sci. Technol.*, 12 (1999)pp. 376.
- [3] P. Kovac, P. E. Richens, P. Bukva, H. Jones, and I. Husek, *Supercond. Sci. Technol.*, 12 (1999)pp. 168.
- [4] Q. Li, G. N. Riley Jr, R. D. Parrella, S. Flesher, M. W. Rupich, W. L. Carter, J. Q. Willis, J. F. Bingert, V. K. Sika, J. A. Parrell, and D. C. Larbalestier, *IEEE trans. On Appl. Superconductivity* 7, No 2, (1997)pp. 2026.
- [5] J. W. Anderson, J. A. Parrell, P. V. P. S. S. Sastry, and D. C. Larbalestier, *IEEE trans. On Appl. Superconductivity* 7, No 2, (1997)pp. 1422.
- [6] Z. Han, P. Skov-Hansen and T. Freltoft, *Supercond. Sci. Technol.*, 10 (1997)pp. 371.
- [7] Y. T. Zhu, P. S. Baldonado, J. F. Bingert, T. G. Holesinger, J. O. Willis and D. E. Peterson, *Supercond. Sci. Technol.*, 12 (1999) pp. 540.
- [8] W. G. Wang, H. K. Liu, Y. C. Guo, P. Bain and S. X. Dou, *Applied Superconductivity* 3, No 11/12 (1995)pp. 599.
- [9] W.M. Chen, Y.C. Guo, G. McCaughey, H.K. Liu and S.X. Dou, accepted by ICMC 2000 and will be published in *Physica C*.
- [10] F. Marti, G. Grasso, Y. Huang, and R. Fluekiger, *IEEE trans. On Appl. Superconductivity* 7, No 2, (1997)pp. 1051.