Effect of sintering temperature on the nature of weak links and flux pinning mechanism in $La_{1.85}Sr_{0.15}CuO_4$ superconductor

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Effect of sintering temperature on the nature of weak links and flux pinning mechanism in $La_{1.85}Sr_{0.15}CuO_4$ superconductor

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Abstract. *AC* and *DC* susceptibility study is carried out to investigate the granular nature of $La_{1.85}Sr_{0.15}CuO_4$ superconductor. Presence of weak links and flux pinning phenomena are two important implications of granular type II high temperature superconductors. Weak links manifested as Superconductor-Insulator-Superconductor (SIS) / Superconductor-Normal metal-superconductor (SNS) Josephson Junctions are investigated from the temperature and field dependence study of *AC* susceptibility. On the other hand, *DC* susceptibility measurement is used to study the flux pinning mechanism. Mechanism of flux pinning is dependent on the nature and size of the pinning centres as well as on the microstructure wavelength. Thus, the nature of grain boundaries plays an important role in determining the nature of pinning mechanism of flux lines. In the present work, effect of sintering temperature on the nature of weak links and flux pinning mechanism in the bulk polycrystalline sample of $La_{1.85}Sr_{0.15}CuO_4$ superconductor is studied.

1. Introduction
The type II high temperature superconductors (HTS), specially the cuprate superconductors till date are the best potential candidates to be used for generating high magnetic fields, lossless electrical transmission, transportation based on magnetic levitation and so on. But, even after the completion of the twenty five years of their discovery, they have still not been able to put into use extensively. Presence of weak links and poor flux pinning in these materials are among the major grounds of their restricted practical applications.

Cuprate superconductors belong to the class of type II as well as HTS which have a peculiar property of being granular in nature. In granular superconductors, the superconducting grains are separated by non-superconducting grain boundaries which may be either conducting or insulating. Superconducting state in such granular materials is established by tunnelling of cooper pairs between the grains. The grain boundaries act as weak links between the grains, as they tend to decouple them in the presence of ample magnetic field. Therefore, the grain boundaries (weak links) act as Superconductor-Insulator-Superconductor (SIS) / Superconductor-Normal metal-Superconductor (SNS) tunnel or Josephson Junctions [1] assisting the flow of super currents.

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In the presence of magnetic field, the flux lines tend to enter inside such superconducting materials in the form of vortices. The motion of vortices causes dissipation of energy which is undesirable for superconductor applications. Therefore pinning of the flux lines or vortices is of utmost importance in polycrystalline bulk type II HTS.

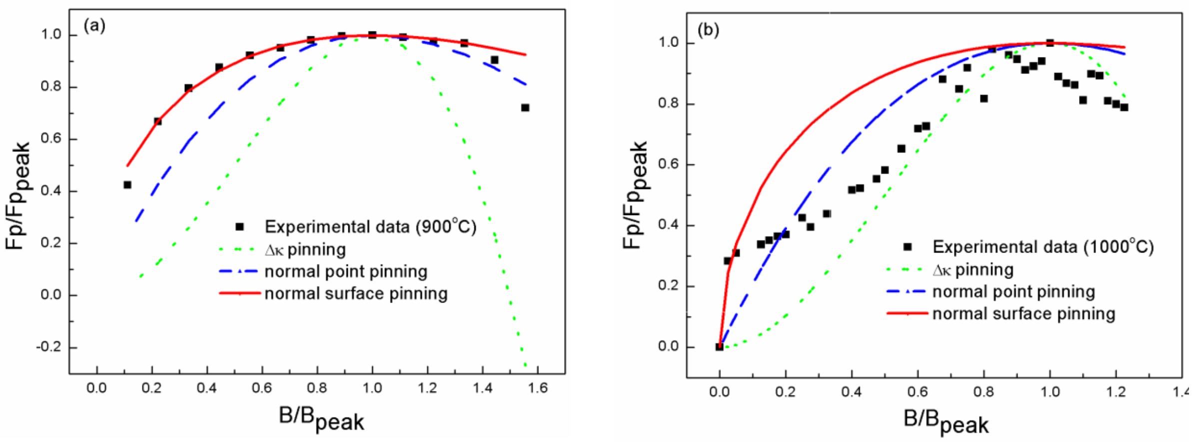
AC susceptibility (ACS) and *DC* susceptibility (DCS) [2] are non-destructive magnetic measurement techniques used for the characterisation and study of superconducting samples. In *AC* (*DC*) susceptibility measurement, sample is magnetised by varying (constant) magnetic field and the induced time dependent (independent) magnetic moment is measured. In the present work nature of weak links/grain coupling and flux pinning mechanism of $La_{1.85}Sr_{0.15}CuO_4$ superconductor is studied using ACS and DCS respectively.

2. Experimental

The superconducting polycrystalline samples of $La_{1.85}Sr_{0.15}CuO_4$ are prepared by sol gel method as described in reference [3]. Three samples are obtained by sintering the precursor powder at 900, 1000 and 1050°C respectively. Phase purity is checked from X-ray diffraction pattern [3] obtained using Rigaku X-ray diffractometer with Cu K_α (λ=1.54Å) at room temperature. Temperature dependent *AC* and *DC* susceptibility measurements are carried out in susceptometer employed in Physical Property Measurement System (PPMS). The amplitude of magnetic field is varied from 0 to 10Oe in the temperature range of 5 to 50K at 333 Hz for ACS study, while DCS measurement is carried out at 5K temperature in the field range of 0 to 30kOe.

3. Results and Discussion

DC susceptibility measurement is carried out to obtain magnetisation (M-H) curves at 5K as described in our earlier report [3]. Flux pinning density curves are obtained from these loops using,



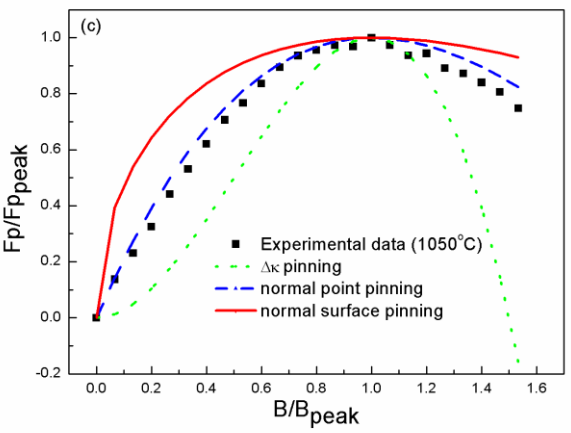


Figure 1. Normalized pinning force F_P/F_{Ppeak} as a function of B/B_{peak} for samples sintered at (a) 900, (b) 1000 and (c) 1050°C fitted to theoretical models given by equation (1), (2) and (3) by green (dot), blue (dash) and red (solid) lines respectively.

J_c(H)=[20×ΔM(H)]/[a(1-a/3b)] [3,4] and F_P=J_c×B [4]. Figure 1 shows fitting of the flux pinning curves using three theoretical models commonly used for HTS [5]:

$$F_p(B) = 3B^2(1-2B/3) \quad \text{; for } \Delta\kappa \text{ pinning} \quad (1)$$
$$F_p(B) = 9/4\,B(1-B/3)^2 \quad \text{; for normal point pinning} \quad (2)$$
$$F_p(B) = 25/16B^{-1/2}(1-B/5)^2 \quad \text{; for normal surface pinning} \quad (3)$$

It is clearly visible that sample sintered at 900°C exhibits normal surface flux pinning while that sintered at 1050°C shows normal point pinning. The sample sintered at 1000°C does not follow any single pinning mechanism. It can be concluded that the basic mechanism, i.e. normal pinning mechanism remains same for all the samples but the difference arises due to the change in the size of pinning centres [6] owing to different sintering temperatures.

Figure 2 shows the temperature dependence of imaginary part of *AC* susceptibility for the three samples measured at different field amplitudes with 333 Hz frequency. It is clearly visible that for sample sintered at 900°C, high inter granular coupling peak has suppressed the intra granular coupling peak. Also the separation of the intra and inter granular dissipation peak decreases with decrease in

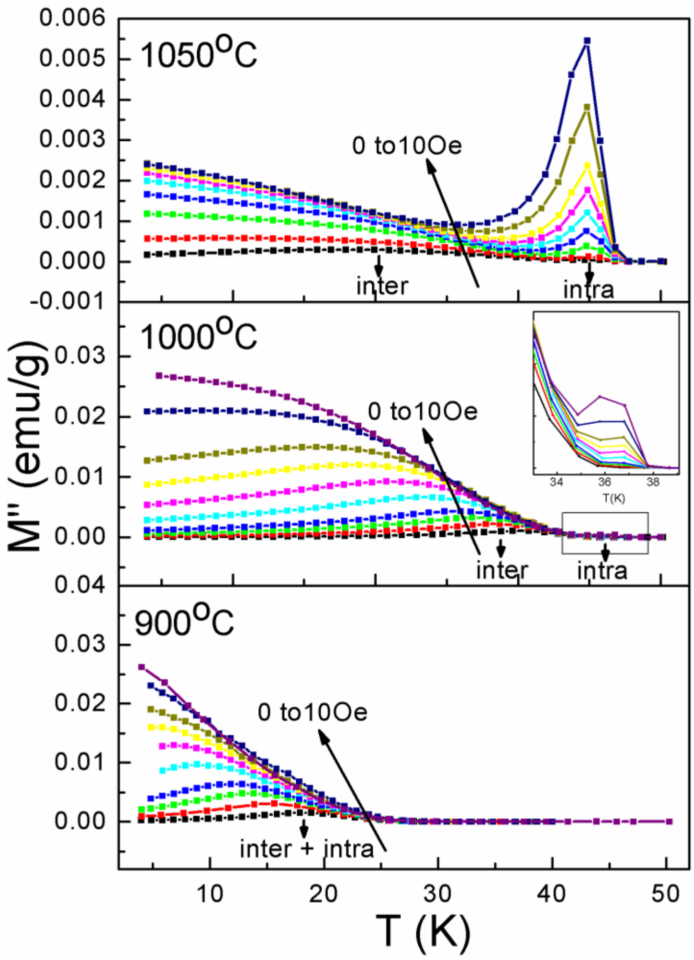


Figure 2. Temperature dependence of imaginary component of *AC* susceptibility for various samples in the applied field ranging from 0 to 10Oe at 333 Hz. The inset in the middle figure is the magnified view of the intra granular loss peak identified in the figure with rectangular box.

sintering temperature, implying improvement in grain coupling. Improvement in grain coupling with decrease in sintering temperature is also evident from the analysis of the field dependence of inter granular dissipation peak appearing at temperature T_p as shown in Figure 3. According to Herzog *et al* [7], using a critical state model the critical current density (J_c) for thin bar shaped sample at T_p is given by $H_p = J_c d/\pi[1+\ln 2a/d]$, where '$a$' and '$d$' are width and thickness of the sample respectively. Therefore, Figure 3 can be considered as the temperature dependence of J_c which clearly shows linear behaviour as per equation, $J_c = J_c(0)(1\text{-}T/T_c)^n$ where, T_c is the superconducting critical temperature. The value of "n" shows that the nature of weak links are of SNS type (n=2) [8] for sample sintered at 900°C and SIS (n=1) [9] for that at 1000°C. Sample sintered at 1050°C is not analysed, since the inter granular loss peak appears below measured temperature range.

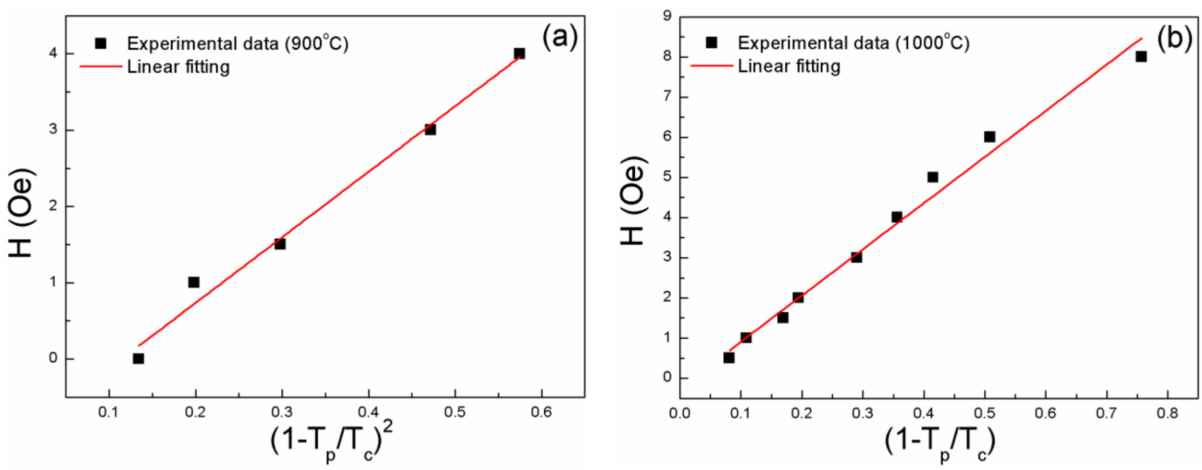


Figure 3. Variation of peak temperature with field as $(1\text{-}T_P/T_c)^n$ for samples sintered at (a) 900 and (b) 1000°C.

4. Conclusion

AC and *DC* susceptibility measurements have been carried out to study the effect of sintering temperature on the nature of weak links and flux pinning mechanism in $La_{1.85}Sr_{0.15}CuO_4$ superconductor. It is found that with increase in sintering temperature from 900 to 1050°C, coupling between the grains decreases with their nature changing from SNS to SIS type Josephson Junctions. Also, the flux pinning mechanism changes with sintering temperature due to the change in the size of the pinning centres, though basic mechanism remains same.

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