2P2-1
Proceedings of Symposium on Ultrasonic Electronics, Vol. 34 (2013) pp. 209-210
20-22 November, 2013

Ultrasonic strain effects on Bi2223 cuprate superconductors

Kunihiko Irie[1], Masaki Mito[1†], Takuma Nagano[1], Kazuki Tsuruta[1], Sho Nobukiyo[1]
([1]Fac. of Eng., Kyushu Inst. of Tech.)

1. Introduction

Cuprate superconductor $Bi_2Sr_2Ca_2Cu_3O_x$ (termed Bi2223) has the superconducting transition temperature (T_c) of 110 K, and it has been paid much attention as a material of transmission cable made of high-temperature superconductors (HTS). The physical properties of cuprate superconductors have been controlled through the high-pressure experiments using pressure apparatus [1] or strain experiments using piezoelectric substrates [2, 3]. However, their manipulation of the phase transition is stationary (independent of time), and it is unfavorable for the intentional high-speed manipulation. Thus we are attempting to manipulate the phase transition by the use of dynamic stress with high frequency (here, we term it "ultrasonic strain"). We expect that the development of this experimental skill might enlarge the possibility of application of piezoelectric devices as the switching device in the system of the transmission of electricity constructed by HTS cables. Thus, as a new approach, we use the piezoelectric device as the source of time-dependent stress used as the external field .

2. Experimental

A material piece of Bi2223 was extracted from DI-BSCCO (Type ST) HTS wire, developed for the transmission cable by Sumitomo Electric Industries, Ltd. The average thickness of the HTS wire is 0.3 mm, and the critical current at 77 K is more than 70 A. The peace of Bi2223 was mounted on the piezoelectric ceramics with the resonating frequency of about 1 MHz, whose scale of the surface is 5×6 mm^2. In the magnetic measurement as a function of temperature, the resonating frequency of the piezoelectric device was tuned at the minimum temperature of the measurement. The piezoelectric device had the sufficient thermal contact with a copper plate in order to release the heat due to the resonation to the copper plate (i.e. a kind of thermal bath). Ac voltage source was connected to the piezoelectric device, and further the oscilloscope was connected to the circuit in the series style. The magnitude of the strain is evaluated with the output voltage from the ac voltage source (V). Ac magnetic susceptibility was measured under ac magnetic field of 4 Oe and 10 Hz by using a commercial SQUID (Superconducting Quantum Interference Device) magnetometer (Quantum Design Japan, Inc.) equipped with an ac option.

3. Experimental Results

Figure 1 shows the temperature dependencies of the in-phase of ac magnetic susceptibility for Bi2223. Without dynamical stress, the Meissner signal was observed below 110 K, and we defined the temperature of the onset (shown by arrow in each measurement) as T_c. By applying dynamical stress with the frequency of 1 MHz, the Meissner signal shifted toward low temperature side. At the situation of V = 7.1 Vrms, T_c exhibited the reduction of about 23 K.

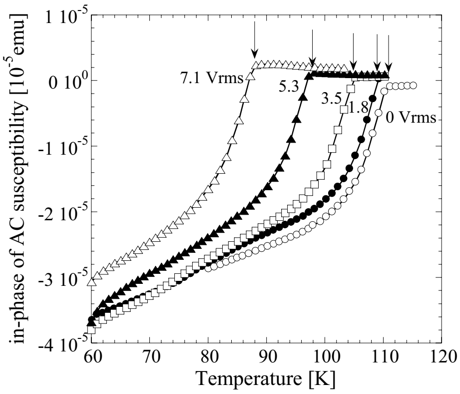

Fig. 1 Temperature dependencies of the in-phase of ac magnetic susceptibility of Bi2223 under ultrasonic strain.

Figure 2 shows the V^2 dependence of T_c for Bi2223. The T_c decreases in proportion to the square of V. This is attributed to the fact that the magnitude of ultrasonic strain is proportional to the power consumed at piezoelectric device. The present result suggests that at V = 8.5 Vrms, T_c might become less than 77 K (liquid nitrogen temperature). If we could do the manipulation of T_c across 77 K, the phenomenon would be favorable for new type of transmission switching based on the manipulation of phase transition by dynamical stress, instead of heat switching.

We consider that the attractive

E-mail: mitoh@tobata.isc.kyutech.ac.jp

condensed-state due to the many-body effects of electron on the lattice is disturbed by the dynamical perturbation, and it would play a role of inserting the dislocation to the sample. We are planning to perform similar experiments in the situation of changing the frequency of ultrasonic strain.

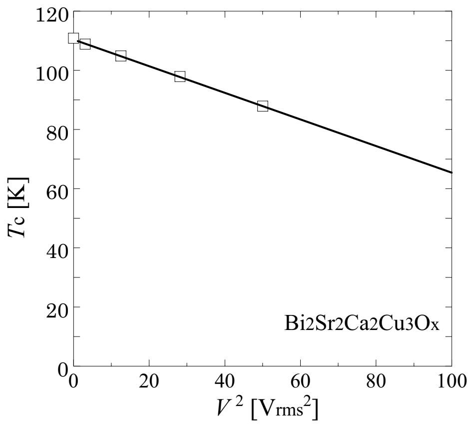

Fig. 2 Strain dependence of T_c for Bi2223. The magnitude is evaluated with the output voltage from the ac voltage source (V), and the horizontal axis stands for the square of V.

4. Conclusion

We investigated the effects of ultrasonic strain on the cuprate superconductor Bi2223. By applying the dynamical stress with the frequency of 1 MHz, we could manipulate the superconducting transition temperature effectively. The shift overcame 20 K, and it is expected that this effect obtained by using piezoelectric devices could be applied in the field of switching device.

Acknowledgment

This work was supported by the Grand-in-Aid for Scientific Research on Innovative Areas, 'Bulk Nanostructured Metals' (KAKENHI 25102709).

References

1. J. S. Schilling: *in Handbook of High-Temperature Superconductivity*, ed. J. R. Schrieffer (Springer, New York, 2007) p. 427.
2. G. L. Belenky, S. M. Green, A. Roytburd, C. J. Lobb, S. J. Hagen, R. L. Greene, M. G. Forrester and J. Talvacchio: Phys. Rev. B **44** (1991) 10117.
3. S. Trommler, R. Hühne, K. Iida, P. Pahlke, S. Haindl, L. Schultz and B. Holzapfel: New J. Phys. **12** (2010) 103030.