Temperature dependent noise in $\text{YBa}_2\text{Cu}_3\text{O}_y$ thin film

H.E. Horng^a, J.M. Wu^a, S.Y. Yang^a, H.C. Yang^b and J.D. Chern^b

^aDepartment of Physics, National Taiwan Normal University, Taipei 117, Taiwan

^bDepartment of Physics, National Taiwan University, Taipei 106, Taiwan

We measured the noise power spectral density at a constant current (3 mA in this report) and various temperatures to study the origin of the noise in the high- T_c superconducting $\text{YBa}_2\text{Cu}_3\text{O}_y$ thin film. The range of the measuring temperature T was from 11 to 90 K. It is found that the noise power spectrum curves all overlap and decrease smoothly as the frequency f increases for $T < 84.3$ K whereas a transition begin to develop as $T \geq 84.3$ K, then drop after $T > 85.6$ K. Furthermore, the temperature dependent noise power density at $f = 0.2$ Hz can be fitted to the thermal fluctuation model. This result suggests that the noise may come from the resistance fluctuation which is caused by the thermal fluctuation. The causes will be also discussed in terms of the flux motion of the high- T_c superconductors.

1. INTRODUCTION

It is interesting to study the noise in the superconductors for the noise power larger than in the metals and semiconductors. Testa et al. investigated the $1/f$ noise in a bulk $\text{ErBa}_2\text{Cu}_3\text{O}_y$ superconductor and found a sharp noise peak near the transition temperature[1]. They interpreted the result as the effect of the thermal fluctuation. Later, Song and co-workers measured the noise in the YBCO single crystal and found that the $1/f$ noise power spectral density was independent of the resistivity in the normal state while it was not observed in the superconducting transition region [2]. It was suggested that the $1/f$ noise was come from the twin boundaries in YBCO single crystal. All the above noise measurements were studied in a wide frequency range, the low frequency noise ($f < 5$ Hz) is still to be studied.

In this report, we measured the temperature dependent noise at low frequency range (100 Hz in this report) on the YBCO thin film to study the origin of noise in the superconducting mixed state.

2. EXPERIMENTAL DETAIL

The YBCO thin film was fabricated by RF

magnetron sputtering and patterned into a meander line by chemical etching. The thickness of the sample is 2500 Å and the width of the line is 50 μm. All the temperature dependent noise measurements were preceded as following: At first, the temperature T was raised to $T = 100$ K to expel the existing flux and then cooled down to the measuring T . The current I (=3 mA) was applied after the temperature being stabled and then the noise voltage was fed into the Hp3562A power spectrum analyzer by coaxial cable. For the noise measurement under the applied magnetic field H ($H=0, 10$ and 20 Gauss), H was applied after I being applied.

3. RESULTS AND DISCUSSION

The temperature dependent noise power spectrum was plotted in figure 1. The detailed plot for the noise power spectrum $S_v(f)$ at high frequency region ($f > 5$ Hz) was shown in the inset with the normal scales and it reveals a white noise which may be the Johnson noise. In the low frequency region ($f < 5$ Hz), the behaviors of $S_v(f)$ were the same when $T < T_{c, \text{zero}}$ (=84.3 K), while an abrupt increasing in $S_v(f)$ was obtained for the sample at each temperature in the mixed state. If we examine the figure more detail, it was also found that the noise

Figure 1. The noise power spectrum at $H = 0$ Oe and $I = 3$ mA for various temperatures in YBCO thin film (2500 Å). The inset plot the detailed $S_v(f)$ at high frequency region.

power at low frequency region was increased at first as raising the temperature and then decreased after reaching a maximum value at $T = 85.6$ K. The behavior of temperature dependent noise power at low frequency might be the result of the resistance fluctuation in the mixed state and was discussed as the following:

In figure 2, the noise power S_v at frequency 0.2 Hz was plotted as a function of T and the solid line $(dR/dT)^2$ was obtained from the $R(T)$ curve. It was found that the shape of $S_v(T, f=0.2 \text{ Hz})$ is in good match with that of $(dR/dT)^2$. According to the theory of temperature fluctuation[3], the noise power spectrum is proportional to $(dR/dT)^2$ at a constant frequency ($f=0.2 \text{ Hz}$ in this plot). Therefore, the low frequency noise power in the mixed state most likely come from the resistance fluctuation which is caused by the effect of temperature fluctuation.

With the magnetic fields, the temperature dependent noise power at $f = 0.2 \text{ Hz}$ were shown in

Figure 2. The noise power $S_v(T, f=0.2 \text{ Hz})$ under $H = 0$ Oe and $I = 3$ mA for YBCO thin film (2500 Å). The solid line $(dR/dT)^2$ is obtained from the $R(T)$ curve.

Figure 3. The noise power $S_v(f=0.2 \text{ Hz})$ vs T for various H in YBCO thin film (2500 Å).

figure 3 to investigate the effect of H on the noise power spectrum. From the plot, two results were obtained: (1). the noise power increased as increasing the applied magnetic fields and (2). all the peaks of temperature dependent noise power at $f = 0.2 \text{ Hz}$ were appeared at the same temperature ($T = 85.5 \text{ K}$). The first result suggested that the extra noise under the applied magnetic field in the mixed state may be caused by the flux motion and the latter one implied that the temperature magnetic field affected the noise power spectrum independently.

4. CONCLUSION

The temperature dependent noises were measured at $I = 3 \text{ mA}$ and various applied magnetic fields to study the origins of noises. It was found that the noise power spectrum at high frequency region ($f > 5 \text{ Hz}$) may be the Johnson noise and the noise at low frequency region ($f < 5 \text{ Hz}$) in the mixed state may be derived from the resistance fluctuation which is caused by the effect of temperature fluctuation. It was also observed that the low frequency noise power in the mixed state were enhanced by the magnetic field and the effect of temperature and magnetic field on the noise power spectrum were independent.

REFERENCES

1. J.A. Testa, Y. Song, X.D. Chen, J. Golben, Sung-Ik Lee, B.R. Patton and J.R. Gaines, Phys. Rev. B 38, 2922 (1988).
2. Y. Song, A. Misra, P.P. Crooker and J.R. Gaines, Phys. Rev. Lett. 66, 825 (1991).
3. R.F. Voss and J. Clarke, Phys. Rev. B 13, 556 (1976).