Superconducting Order Parameter Fluctuations in YBCO/Ag Film Synthesized by Pulsed Laser Deposition

Abstract: YBCO/ Ag (1wt.%.) composite thin film is synthesized by pulsed laser deposition. The magneto-resistivity of the sample was investigated for 0T, 4T, 8T field. The resistivity plot showed broadening in presence of field. The onset of global superconductivity and transition temperature in the sample is observed to decrease with the application of magnetic field. The logarithmic plots of excess conductivity and reduced temperature reveals two distinct regions namely mean field region and short wave fluctuation region. Superconducting order parameter fluctuation analysis revealed dimensionality crossover from 3D to 2D at temperature above the transition temperature. Activation energy decreases with application of field.

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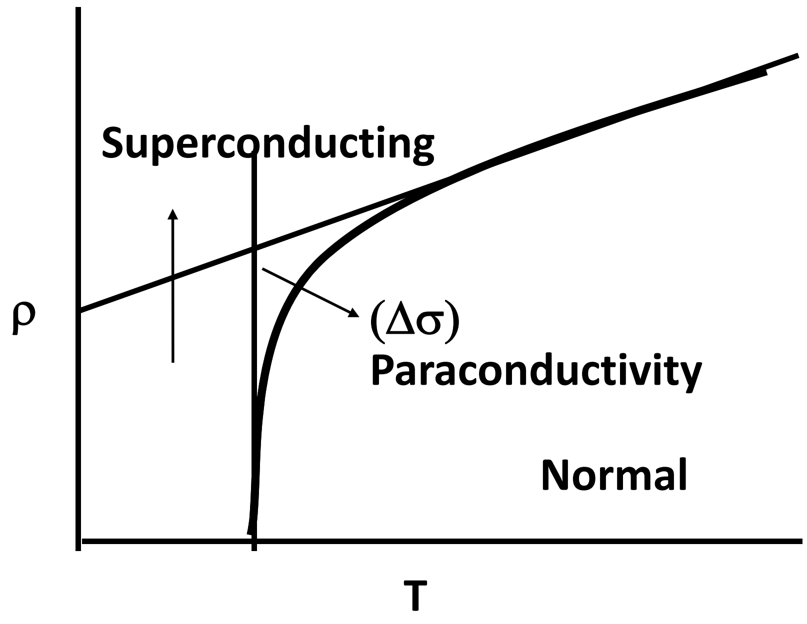
INTRODUCTION

Why excess conductivity

* Very short coherence lengths
* High operating temperatures
* Layered structure of the conducting CuO_2 planes.



Why to study excess conductivity -

- **Understand the origin of excess conductivity Δσ**
- **Obtain superconducting coherence length ξ(0 K)**
- **Obtain effective dimension of the Fluctuations**
- **Address the very mechanism of superconductivity in HTSC's**

$$\Delta\sigma\,(T) = 1/\rho_M - 1/\rho_R$$

ρ_M IS THE MEASURED RESISTIVTY AND

ρ_R IS THE REGULAR RESISTIVITY

Why silver doping ?

Does not degrade superconducting (SC) properties.

i. Improve bulk properties [1]
ii. Increases thermal conductivity [2]
iii. Increases electrical conductivity [3]
iv. Enhances mechanical properties [4]
v. J_c is improved significantly [5]
vi. Hence solves grain boundary problem

[1] E. Mendonza, T. Puig, E. Varesi, A.E. Carrillo, J. Plain, X. Obradors, Physica C 334 (2001) 7

[2] G. Krabbes, G. Fuchs, P. Schätzle, S. Gruss, J.W. Park, F. Hardinghaus, R. Hayn, S.L. Dreschler, Physica C 341-348(2000) 2289

[3] D. Behera, N C Mishra, Supercond. Sci. Technol. 15 (2002) 72.

[4] J.P. Singha1, J. Jooa1, D. Singha1, T. Warzynskia1 and R.B. Poeppela1 Journal of Materials Research (1993), 8: 1226-1231

[5] C. H. Cheng and Y. Zhao Journal OF Applied Physics 93, 4 2003

Experimental Details

- Target was prepared by solid route Y : Ba: Cu= 1:2:3
- Calcined at 880 ◦C for 36 hours with 4 intermediate grindings
- YBCO + x Ag_2O (x = 10.0 wt.%) mixed
- Pelletized
- Sintered at 930 ◦C for 12 hours
- Annealing at 500 ◦C 12 hours in an oxygen supply

Thin film preparation

- **PLD was used for thin film parameters highlighted below**

Laser	KrF excimer laser (λ=248 nm)
Target	YBCO+ Ag_2O (10 wt.%) pellet
substrate	(100)-oriented $LaAlO_3$ (LAO)
Target substrate distance	5 cm
Repetition frequency (Hz)	10 Hz
Thickness	100 nm
Laser energy	220 mJ
Substrate temperature	820 °C
Oxygen pressure (Pa)	400 mTorr

Excess Conductivity

- **Excess conductivity ($\Delta\sigma$) diverge as power-law given by AL theory[6]**
- $$\Delta\sigma = A\varepsilon^{-\lambda}$$

where, $\varepsilon = (T-T_c)/T_c$ is reduced temperature.

λ = Gaussian critical exponent depends on Dimensionality(D)

$\lambda = 2-D/2$ [7]

A = is a temperature dependent parameter [8]

For 3D $A = e^2/32\hbar\xi(0)$ and $\lambda = 0.5$

For 2D $A = e^2/16\hbar d$ and $\lambda = 1$

- **Short wave fluctuations**

Excess conductivity ($\Delta\sigma$) varies as ε^{-3} [9]

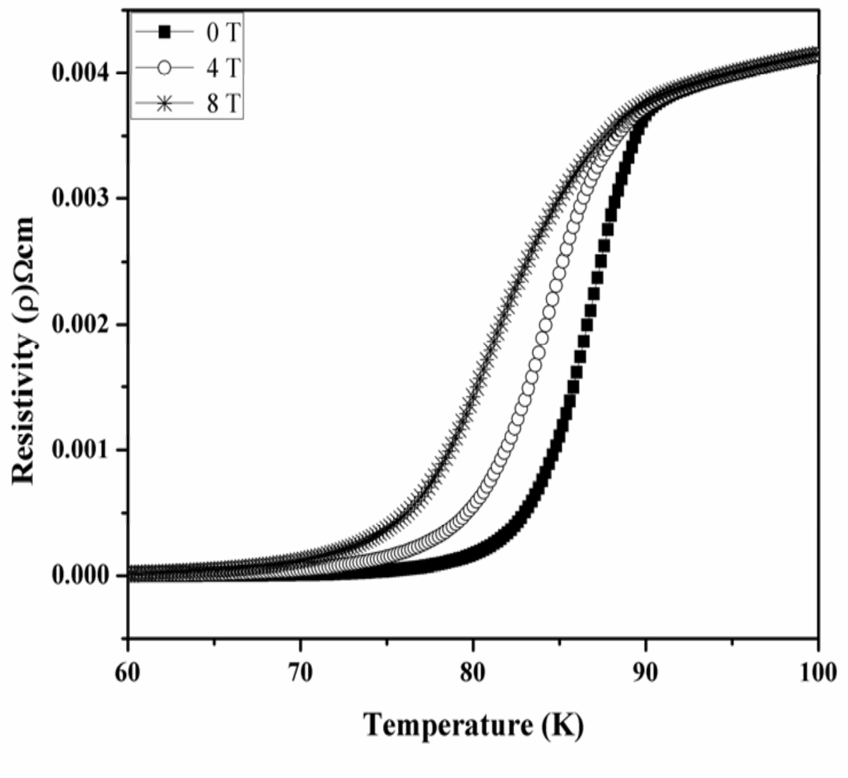
[6] L.G. Aslamazov, A.I. Larkin, Sov. Phys. – Solid State 10 (1968) 875.

[7] P. Konsin, B. Sorkin, M. Ausloos, Supercond. Sci. Technol. 11 (1998) 1.

[8] J. Rosenblatt, P. Peyral, A. Raboutou, C. Lebeau, Phys. B 152 (1988) 95.

[9] L. Reggiani, R. Vaglio, A. A Varlamo, Phy. Rev. B 44(1991) 435.

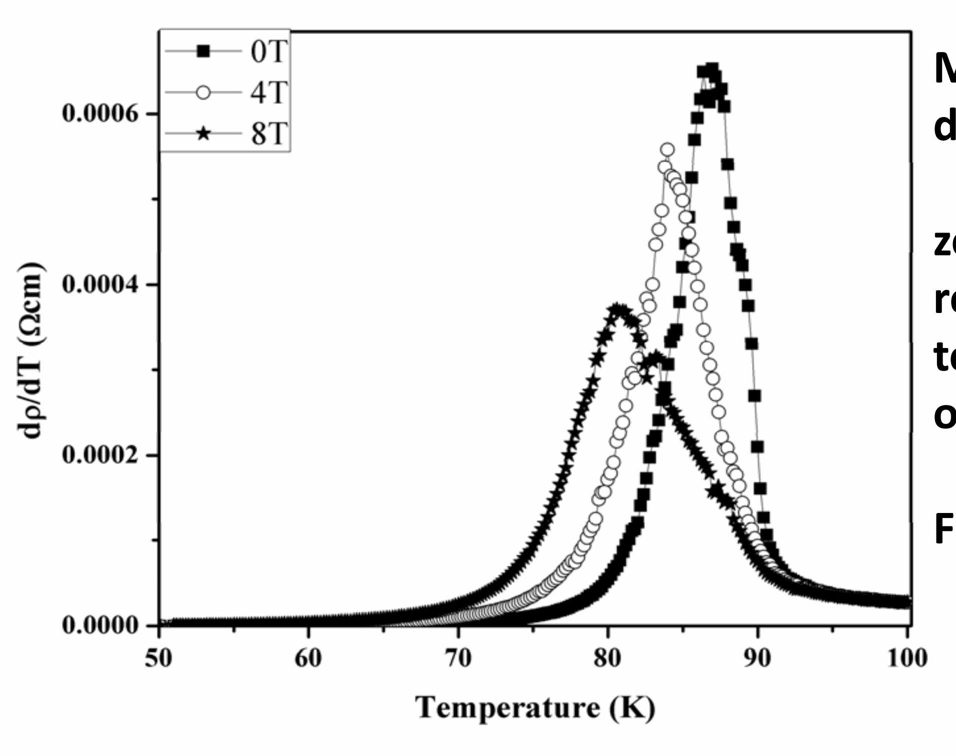
Result and discussion



- **Onset of superconducting transition temperature (T_c) is ~ 92K which remains unaffected with application of field.**

- **Field results in broadening of resistive transition.**

Temperature dependence of the electrical resistivity for silver doped YBCO sample under magnetic field application.



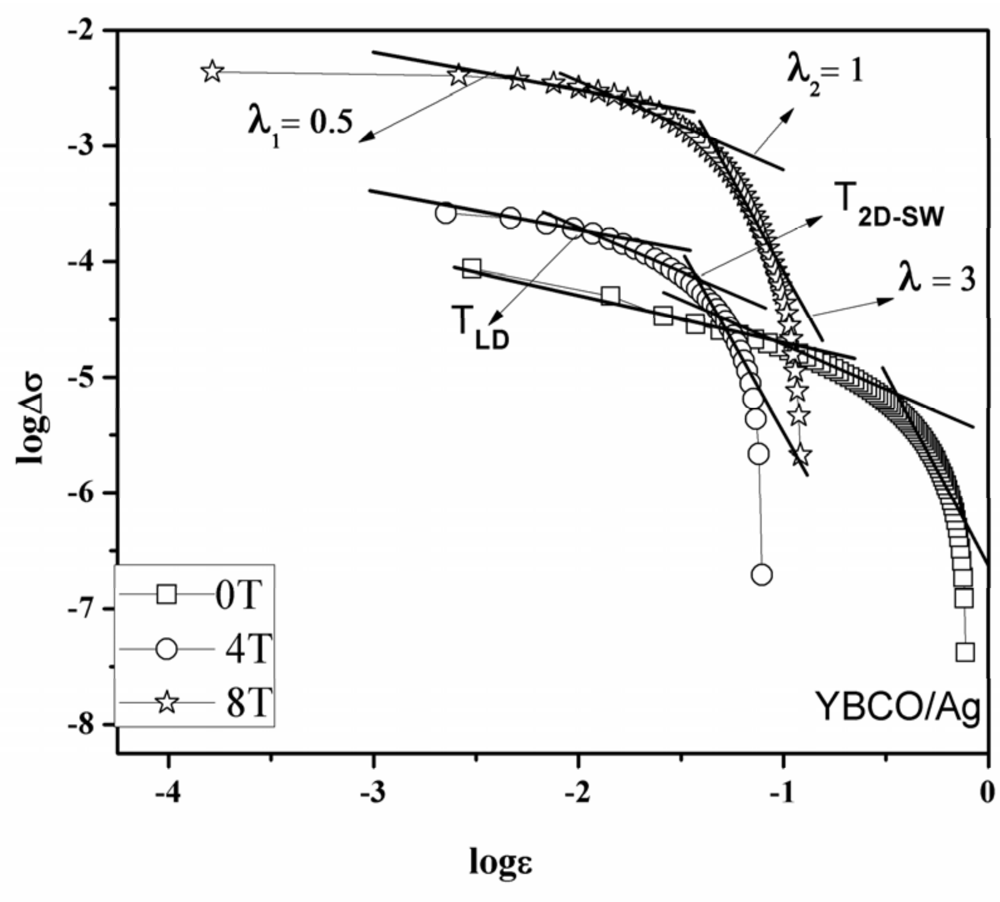
Mean field transition temperature (T_{cmf}) decreases with field.

zero resistance temperature or global resistivity (T_{co}) also decreases since these temperatures are comparable to irreversibility or depinning temperatures .

Field also plays a major role in decreasing T_{co}

Plot of dρ/dT versus temperature (K)

Plot of excess conductivity versus reduced temperature



- ❖ Excess conductivity for 4 T and 8 T shows and upward shift.
- ❖ Mean field region and the shortwave fluctuation region.
- ❖ T_{LD} temperature is lowered indicates that intragranular region has been modified as SCOPF is largely dependent on the intragranular contribution.
- ❖ Dimensional fluctuation occurring from 2D to 3D sets in faster for pristine (109.76 K - 94.87K)
- ❖ Field hampers the motion of activated cooper pairs in 3D

Field dependence of different ransition temperatures (zero resistance, mean field, Lawrence–Doniach and shortwave fluctuation).

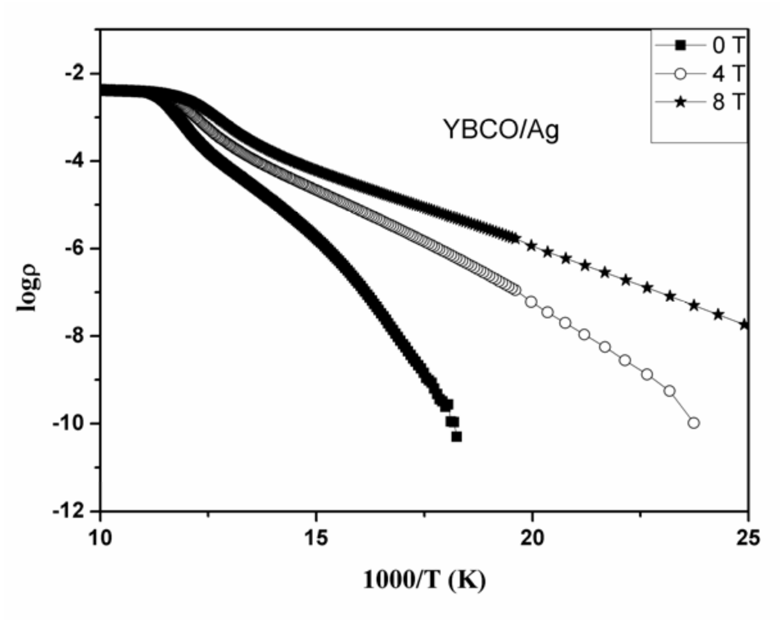
Field (T)	T_{c0} (K)	T_{cmf} (K)	T_{LD} (K)	$T_{2D\text{-}SW}$ (K)
0.0	70.89	87.60	94.87	109.76
4	64.26	84.01	85.59	124.47
8	57.25	80.79	82.84	126.99

Activation energy

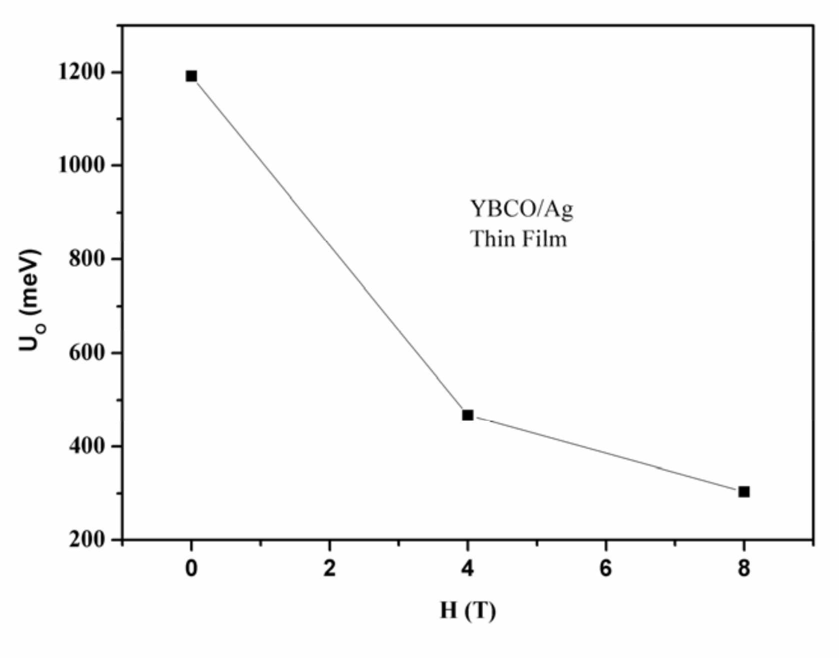
- The activation energy is evaluated through resistive broadening with varying measurement magnetic field from 0 to 8 T.

$$\rho(B, T) = \rho_0 \exp [-U(B,T)/KT]$$

- This slope of the straight line in the curve $\ln(\rho/\rho_0)$ vs 1/T gives the activation energy $U_0(T,H)$ for the flux lines at different magnetic fields.
- The activation energy decreases with increasing magnetic field. Pinning energy decreases with increasing the applied magnetic field.



Arrhenius plot of YBCO/Ag thin film



Magnetic field dependence of the activation energy(Uo) for YBCO/Ag film.

- ✓ A scaling relation as a power-law dependence
- ✓ Data near T_c ($\rho = 0$) interpreted in terms of the thermally activated flux-creep model.
- ✓ $U_0(H)$ obeys the power law of the form $U0(H) \sim H^{-\alpha}$
- ✓ Exponent varies as 0.49 ±.02
- ✓The activation energy decreases for the YBCO composites.

Conclusions

- **Well developed grains oriented in all direction is seen.**
- **Resistive broadening in silver doped YBCO thin film**

- **We observe the different fluctuations regimes with**

(a) Mean Field Region : Exhibiting 2 slopes

(i) λ= 0.5 (3D fluctuations)

(ii) λ = 1 (2D fluctuations)

(b) Short wave fluctuations λ = 3

- **Excess conductivity reveals an upward shift for 4T and 8T field.**
- **onset of 3D Guassian fluctuation is delayed with field.**