# ENHANCEMENT OF FLUX PINNING IN $YBa_2Cu_3O_{7-\delta}$ + Ag NANOCOMPOSITES

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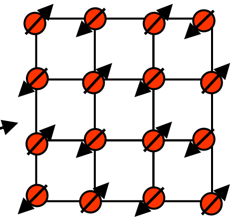
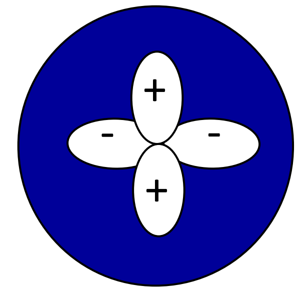
# Way of my Presentation

- Introduction
- Excess conductivity
- Need of Composite
- Experimental
- Result and Discussion
    - Electrical Transport property
    - Magnetic Transport property
- Conclusions

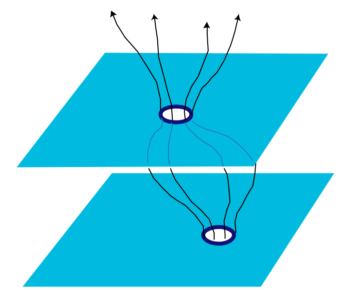
# Signature features of cuprate superconductors



1. Strong Correlation

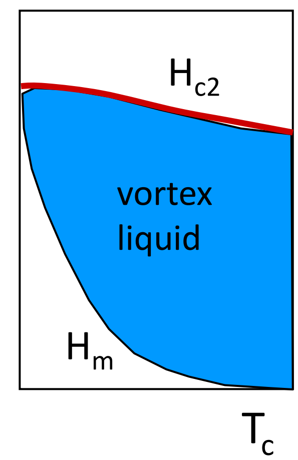



2. Quasi-2D anisotropy



3. *d*-wave pairing, very short $\xi$

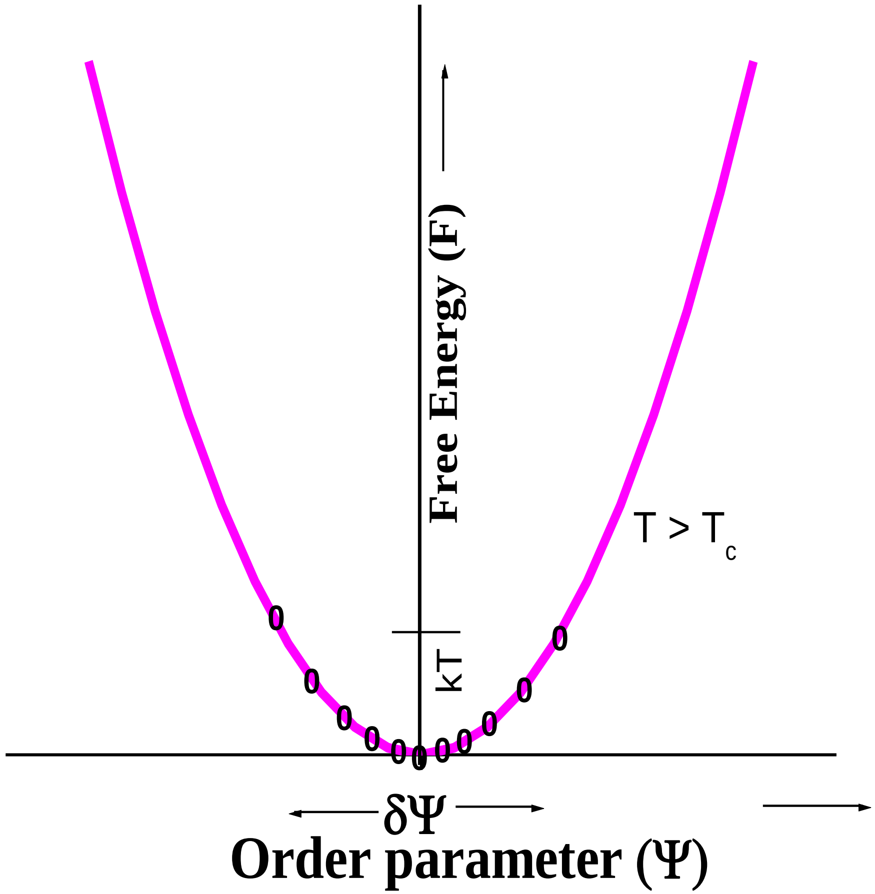
4. Spin gap, spin-pairing at T*

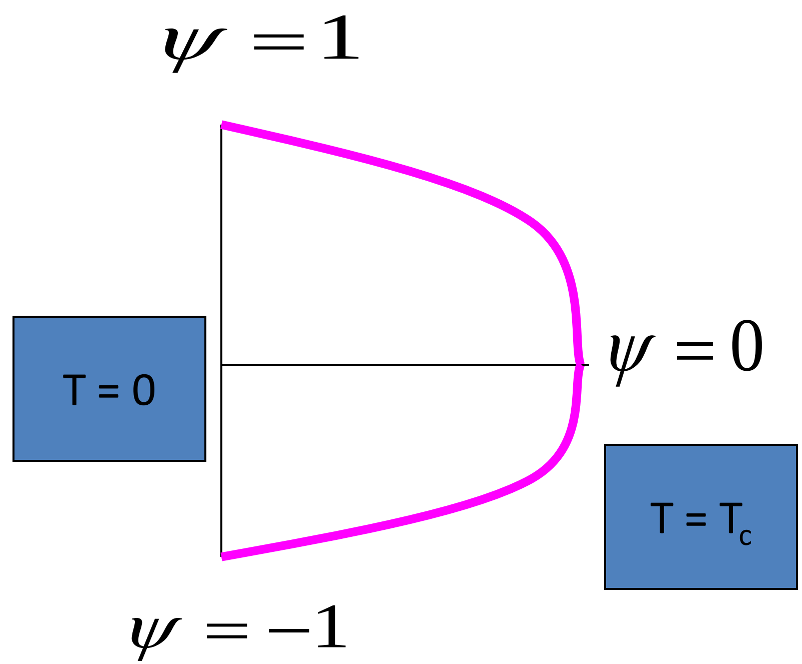



5. Strong fluctuations, vorticity

6. Loss of phase coherence at Tc

# SCOPF (Sperconducting Order Parameter Fluctuation)

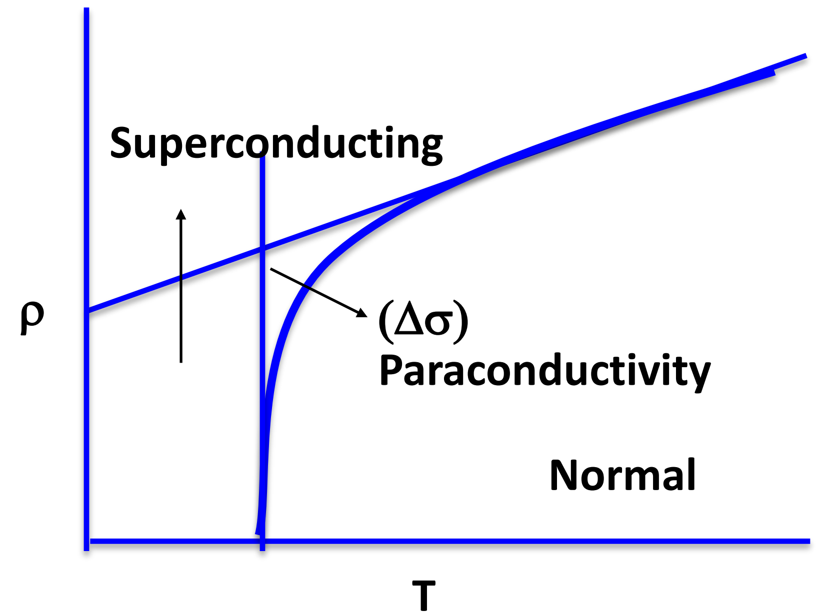



$$\psi = \frac{n_+ - n_-}{n_+ + n_-}$$

$n_+$ No 0f spin up and $n_-$ no of spin down

# Excess conductivity




## 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 $\Delta\sigma$
- ➢ Obtain superconducting coherence length $\xi(0\ K)$
- ➢ Obtain effective dimension of the Fluctuations
- ➢ Address the very mechanism of superconductivity in HTSC's

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

$\rho_M$ IS THE MEASURED RESISTIVTY

AND

$\rho_R$ IS THE REGULAR RESISTIVITY

# 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.**

  **$\lambda$ = 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 $\varepsilon^{-3}$ [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.

# Why silver Composite ?

Does not degrade superconducting 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. 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. Singh, J. Joo, D. Singh, T. Warzynski and R.B. Poeppel Journal of Materials Research (1993), 8: 1226-1231

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

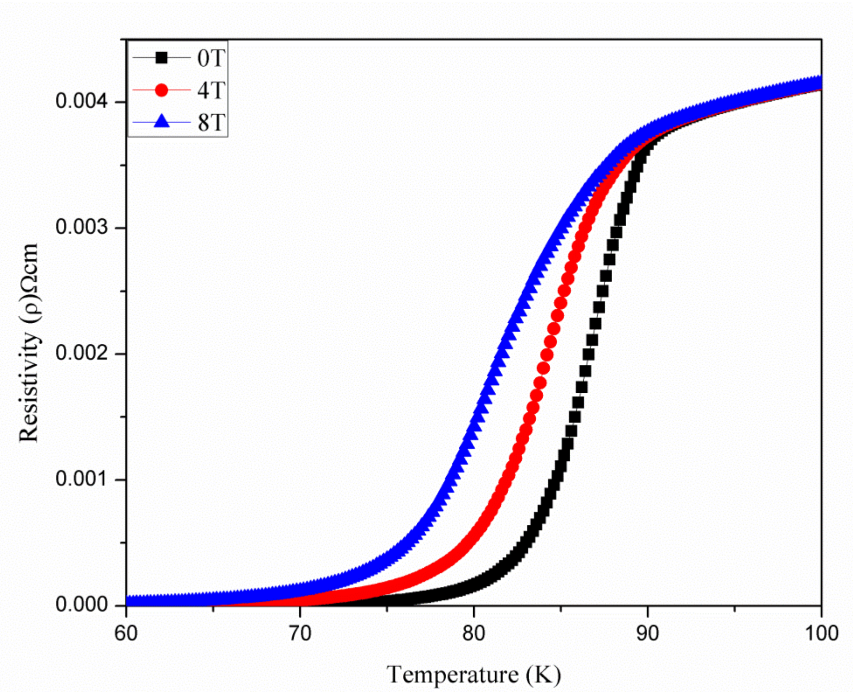
# Thin film preparation

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

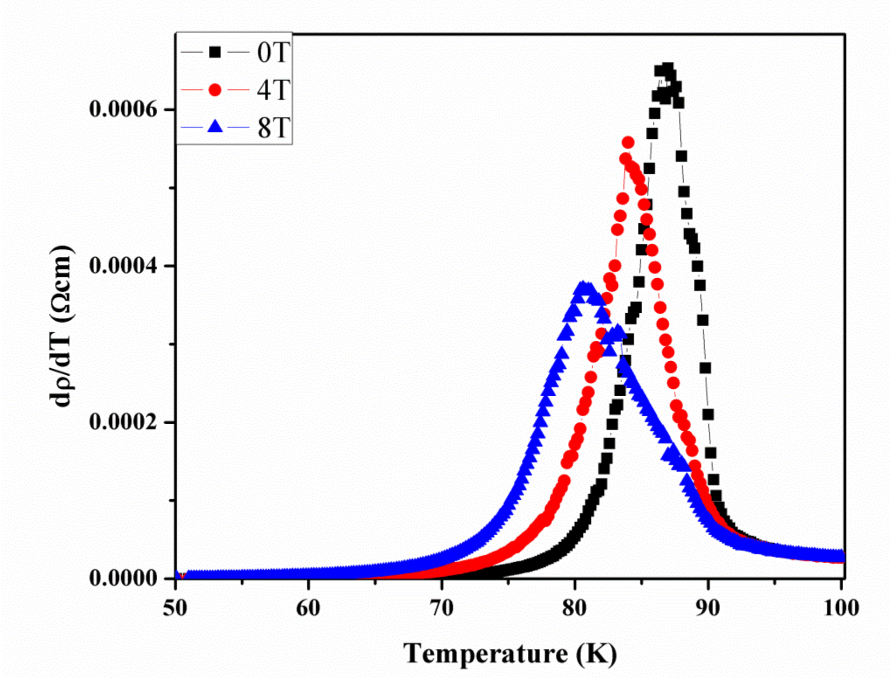
| | |
|---|---|
| Laser | KrF (268nm) |
| Target | YBCO/Ag composite pellet |
| Substrate | LAO |
| Substrate target distance | 5 cm |
| Repetition frequency | 10Hz |
| Thickness | 100nm |
| Energy Density | 220 mJ |
| Oxygen pressure | 400 m Torr |
| Substrate Temperature | 820° C |

# Result and discussion

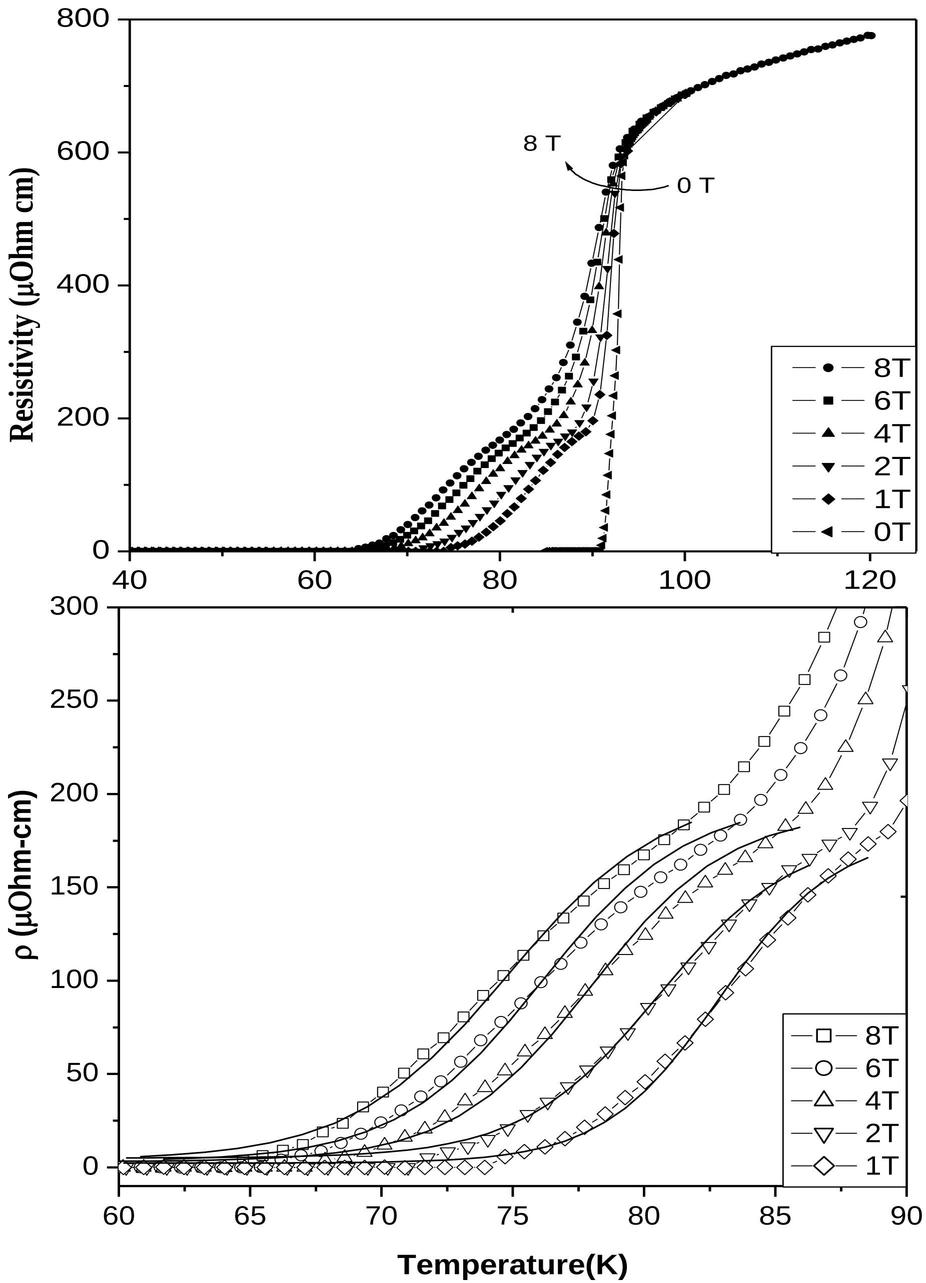
# Electrical Transport property




- Onset of superconducting transition temperature ($T_c$) is ~ 92 K unaffected with application of field.
- Applied field results in broadening of resistive transition.




- Mean field transition temperature ($T_{cmf}$) decreases with field.
- Zero resistance temperature ($T_{co}$) also decreases.



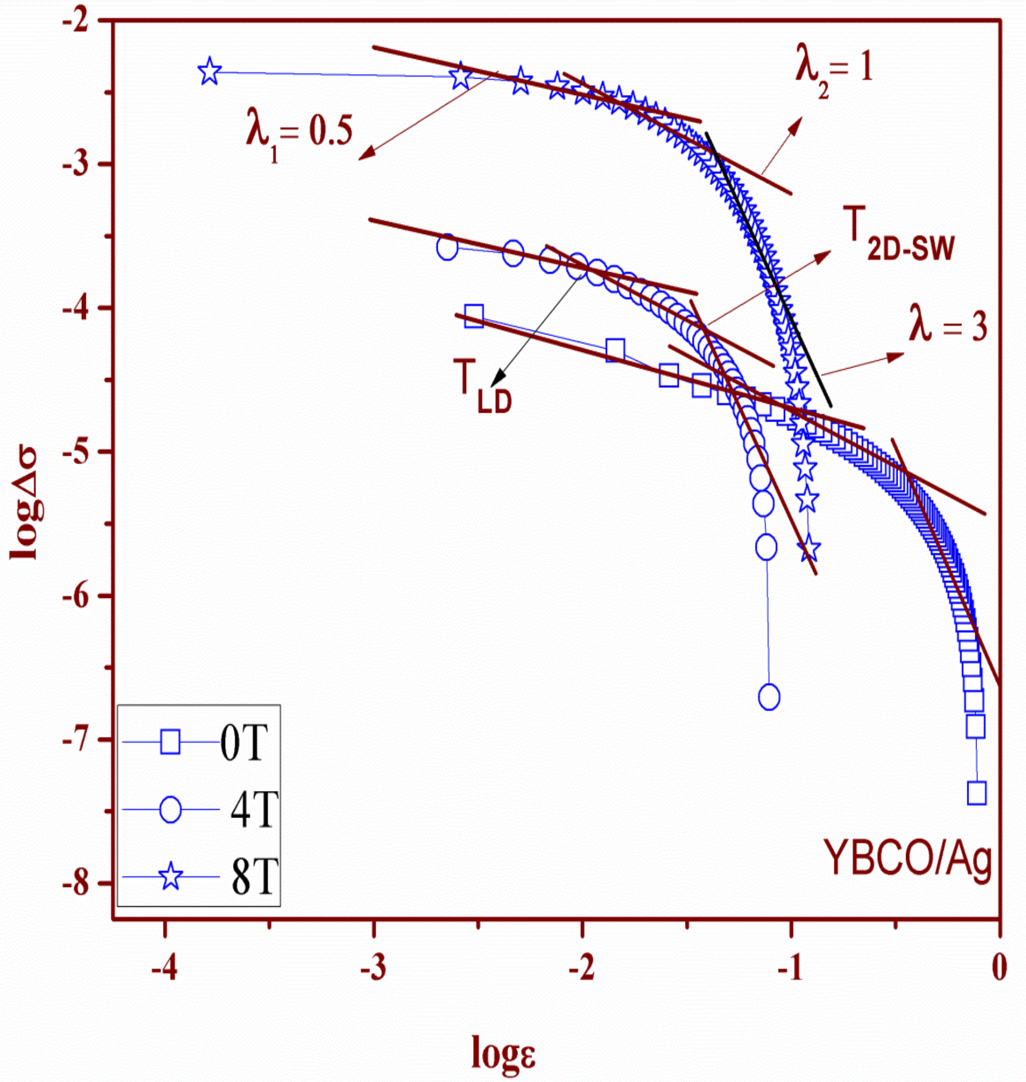

## Ambegaokar and Halperin (AH) Model

$$\rho = \rho_n \{ I_0 (\frac{\gamma_0}{2}) \}^{-2}$$

$$\gamma_0 = \frac{U_0}{K_B T} = A(1-t)^q$$

**Suggests the dissipation phenomena in $YBa_2Cu_3O_{7-\delta}$ superconductor is caused by two mechanisms, viz. the order parameter fluctuations and the vortex-dynamics**

# Excess conductivity




Plot of excess conductivity versus reduced temperature

$$\Delta\sigma = A\varepsilon^{-\lambda}$$

- ❖ Excess conductivity for 4 T and 8 T shows an 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.
- ❖ Field hampers the motion of activated cooper pairs in 3D

## Field dependence of different transition 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 |

- **Dimensional fluctuation occurring from 2D to 3D sets in faster for pristine (109.76 K - 94.87 K)**

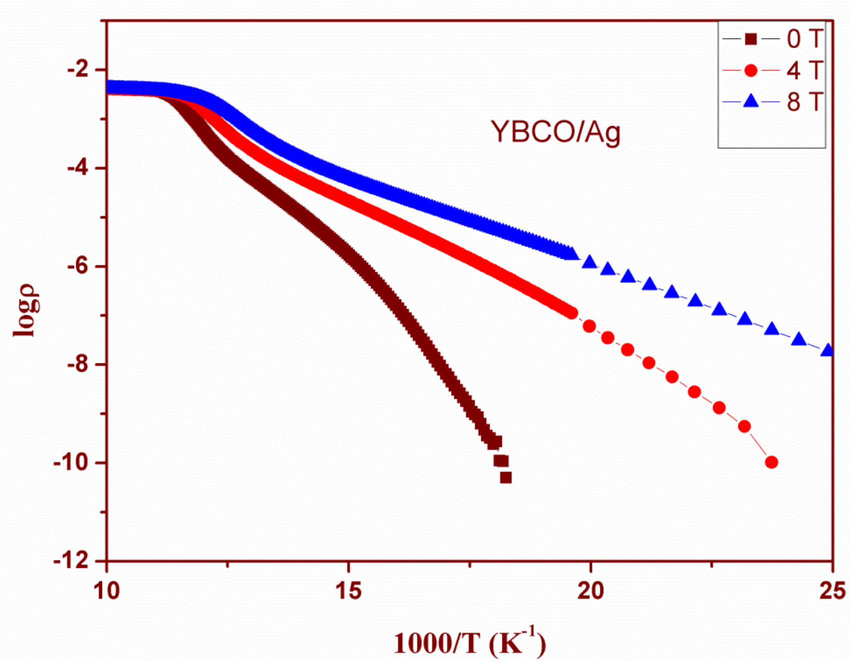
# Activation energy

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

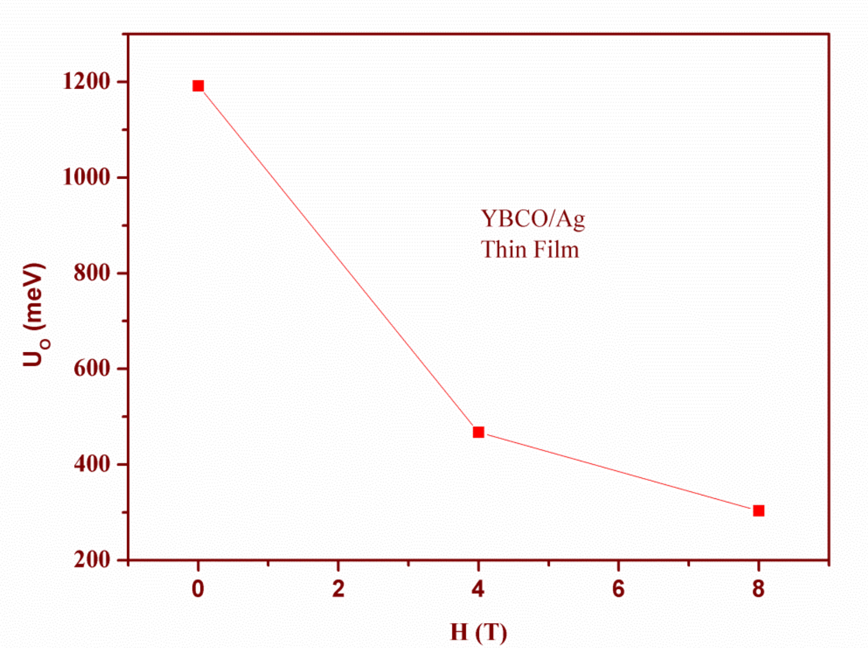
$$\rho(B, T) = \rho_0 \exp[-U(B,T)/KT]$$

$$U(T,H) = U_0(T)(1- B/B_{c2})^2$$

- 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.



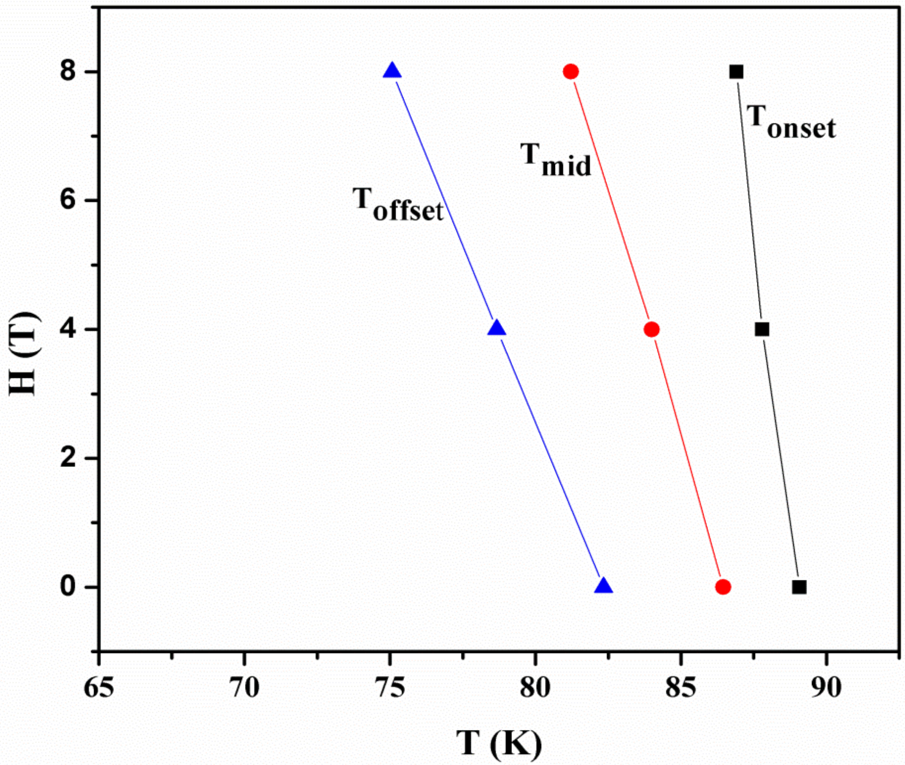

Arrhenius plot of YBCO/Ag thin film




Magnetic field dependence of the activation energy($U_0$) for YBCO/Ag film.

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

# $H_{c2}$ calculation




Werthamer – Helfand - Hohenberg (WHH) formula

$H_{c2}(0) = -0.693(dH_{c2}/dT)\ T_c$

$\xi\ (0) = [\Phi_o/2\ \pi\mu_o H_{c2}]^{1/2}$

| YBCO/Ag(1 wt.%) | Onset (90% of $\rho_n$) | Mid(50% of $\rho_n$ ) | Offset(10% of $\rho_n$ ) |
|---|---|---|---|
| $H_{C2}$ | 217.73 T | 95.23 T | 62.29 T |
| ξ(0) | 12.2 Ǻ | 18.5 Ǻ | 22.9 Ǻ |

# Magnetic transport properties

# Under the action of Lorentz force the thermally activated flux flow (TAFF) occurs and the dependence of activation energy on temperature and field is determined by two major mechanisms.

(a) Thermally activated excitation of dislocations

(b) Thermally activated creep of preexisting quenched dislocations

# The flux creep and flux flow model hold well if the magnetic flux enters into the material in the vortex state by bending due to the grain boundary or by crystallographic anisotropy.

# Magnetic transport properties

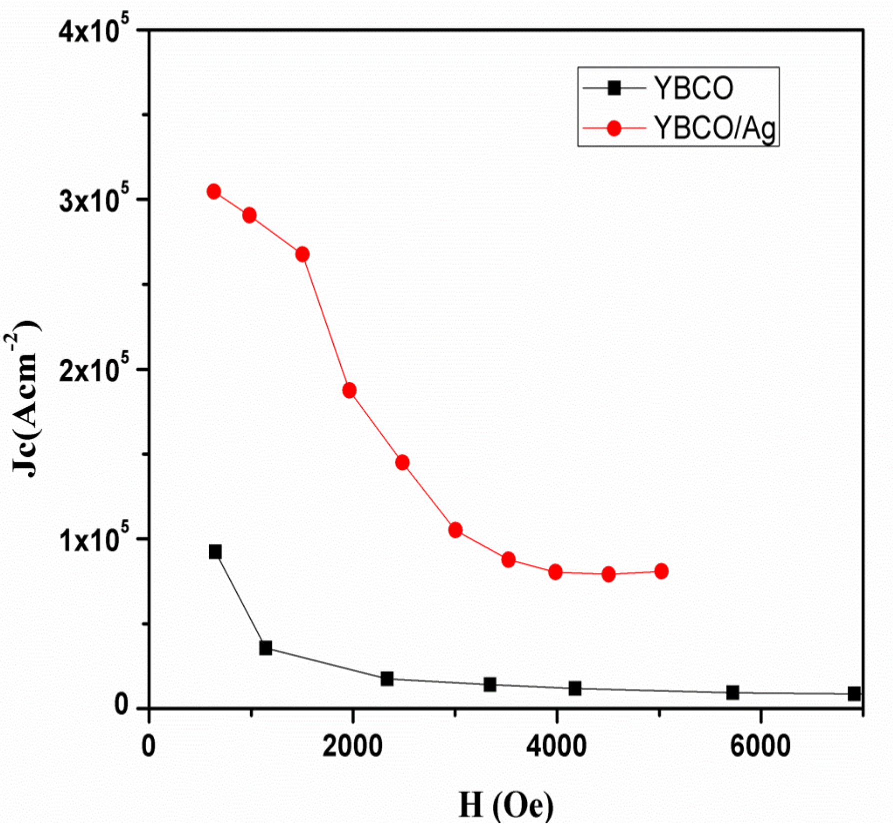
**Critical current density is calculated with Bean's critical state Model**

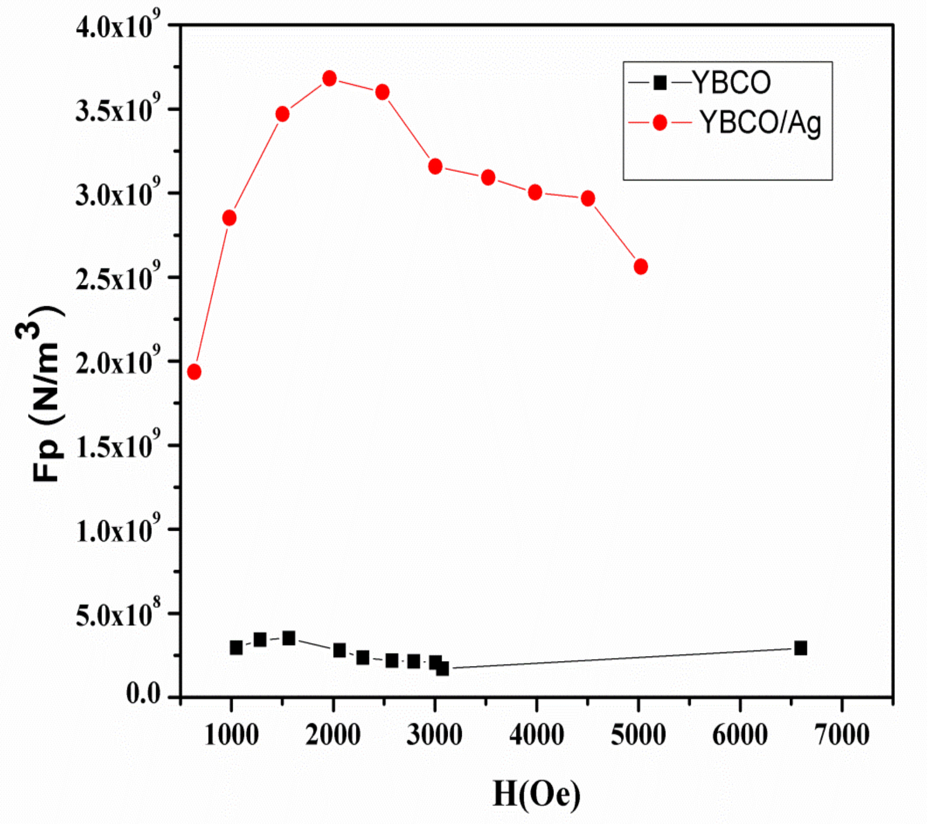
$$J_c = \frac{20\Delta M}{a(1-\frac{a}{3b})}$$

**Where as a < b and $\Delta$ M= $|M_+|$ - $|M_-|$ which is extracted from M (H) loop and a is the thickness and b is the width of the bar shaped sample.**


6. Y. Y. Luo, Y. C. Wu, X. M. Xiong, Q. Y. Li,1 W. Gawalek, and Z. H. He, *Journal of Superconductivity: Incorporating Novel Magnetism*, **13**, 575 (2000)

7. J.L. MacManus-Driscoll, S.R. Foltyn, Q.X. Jia, H. Wang, A. Serquis, L. Civale, B. Maiorov, M.E. Hawley, M.P. Maley and D.E. Peterson, *Nature Materials* **3**, 439 (2004).




| | Jc ($A/cm^2$) | Fp ($N/m^3$) |
|---|---|---|
| YBCO | $9.3x10^4$ | $3.3x10^8$ |
| YBCO/Ag | $3.2x10^5$ | $3.7x10^9$ |

# Conclusions

- **We observe resistive broadening in silver doped YBCO thin film with different fluctuations regimes**

**(a) Mean Field Region : Exhibiting 2 slopes**

**(i) $\lambda$= 0.5 (3D fluctuations)**

**(ii) $\lambda$ = 1 (2D fluctuations)**

**(b) Short wave fluctuations $\lambda$ = 3**

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

# Conclusions continues

** Activation energy decreases with increasing applied magnetic field

** $H_{c2}$ values decreases with increase of magnetic field

** Enhancement of critical current density $J_c$ and pinning force $F_p$ is recorded in the composite film


THANK YOU