A Seminar Talk On

Role of Tungsten Oxide in Enhancing Superconducting and Mechanical Properties of $YBa_2Cu_3O_{7-\delta}$

By

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Plan of Presentation

- Introduction
- BCS Formalism and application of Superconductors
- The cuprates and WO_3 added YBCO system
- Critical current density and elasticity enhancement
- Conclusion

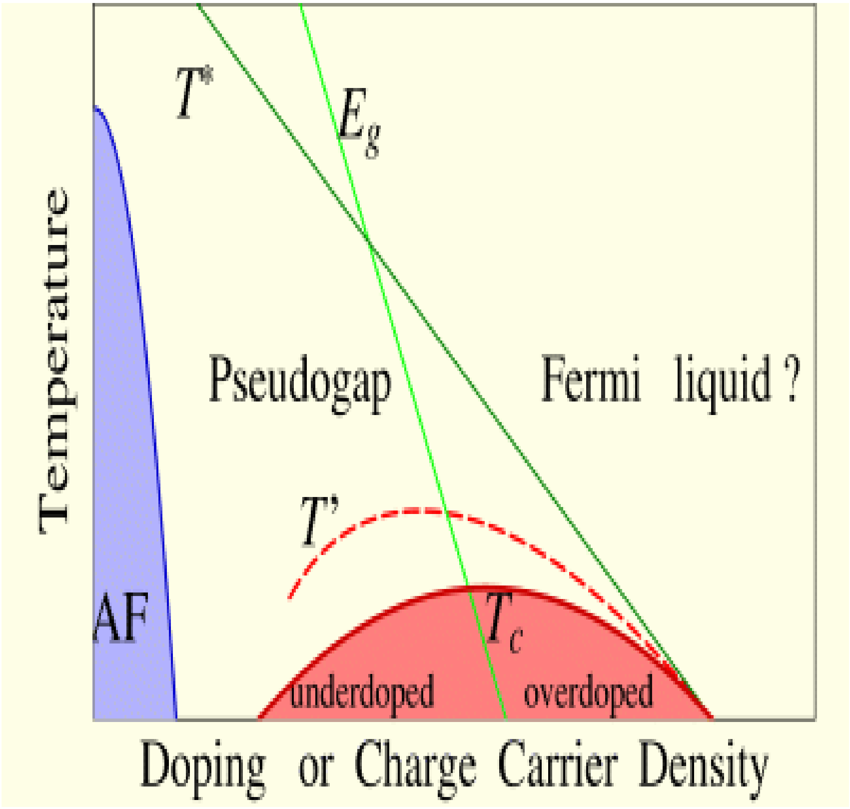
Superconductors from Mutt Insulator

Mott insulators are a class of materials that should conduct electricity under conventional band theories but are in fact insulators when measured (particularly at low temperatures).

This effect is due to electron–electron interactions, which are not considered in conventional band theory.

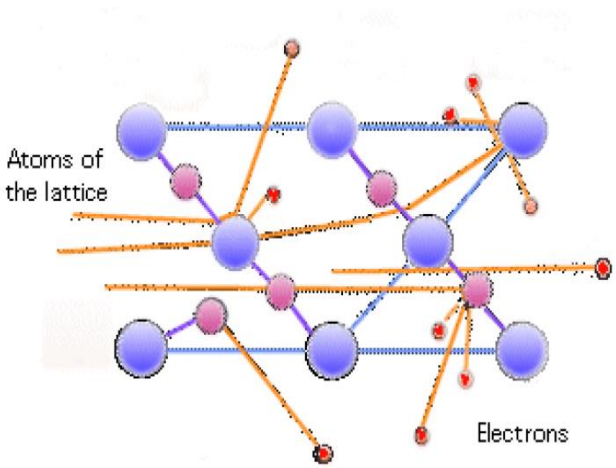
The bandgap in a Mott insulator exists between bands of like character, such as 3d character, whereas the bandgap in charge transfer insulators exists between anion and cation states, such as between O 2p and Ni 3d bands in NiO

Ferromagnetism and conventional singlet **superconductivity** can be regarded as competing ordering phenomena.

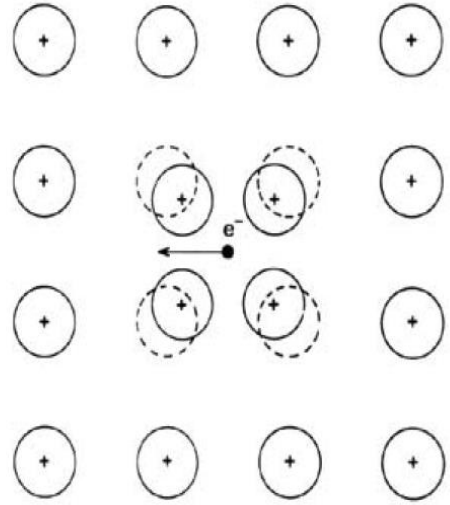


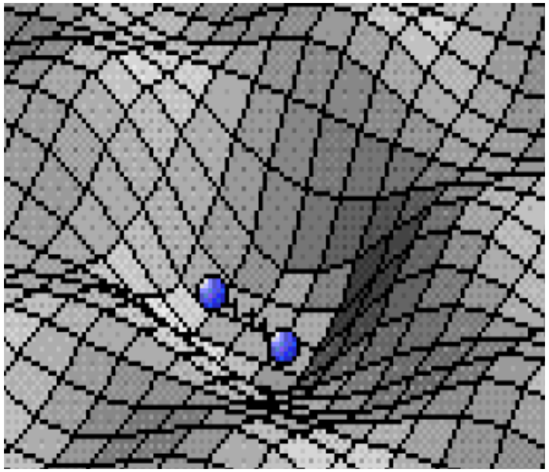
BCS theory

Normal conducting state



Superconducting state



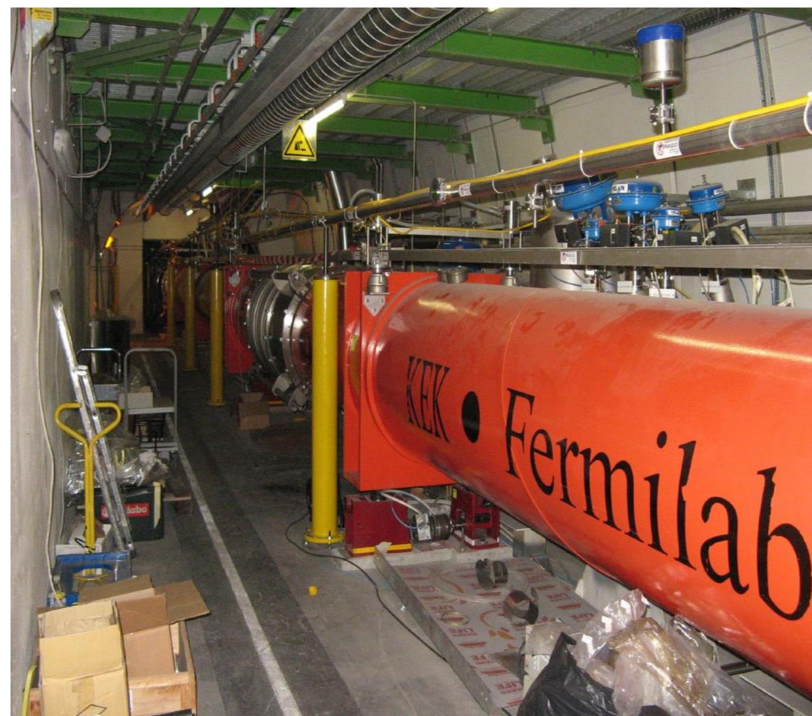


- $T_c \sim 1/\sqrt{M_{isotopic}}$ -> phonons should play a role in superconductivity
- Creation of Cooper pairs (over-screening effect)
  - An e^- attracts the surrounding ion creating a region of increased positive charge
  - The lattice oscillations enhance the attraction of another passing by e^- (Cooper pair)
  - The interaction is strengthened by the surrounding sphere of conduction e^- (Pauli principle)
- In a superconductor the net effect of e^-e^- attraction through phonon interaction and the e^-e^- coulombian repulsion is attractive and the Cooper pair becomes a singlet state with zero momentum and zero spin
- To break a pair the excitation energy is $\Delta E = 2\Delta$


PHILIPS


VARIAN


STOP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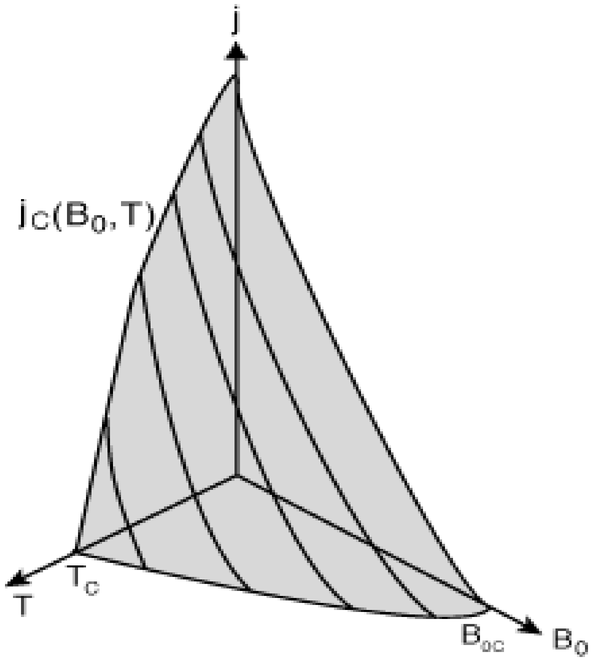
Important Factors to define a Superconducting State:

- **The superconducting state is defined by three very important factors:**
  1. **Critical temperature , ($T < T_c$)**
  2. **Critical field, ($H < H_c$)**
  3. **Critical current density ($J < J_c$)**



- **Each of these parameters is very dependent on the other two properties present.**

Significant features of Cuprate Superconductivity:

1. Strong Correlation

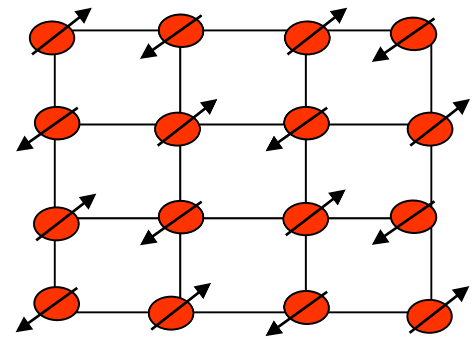
2. Quasi-2D anisotropy

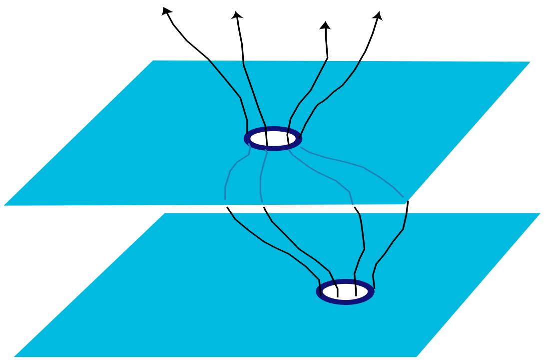
3. Short coherence length‘ξ’

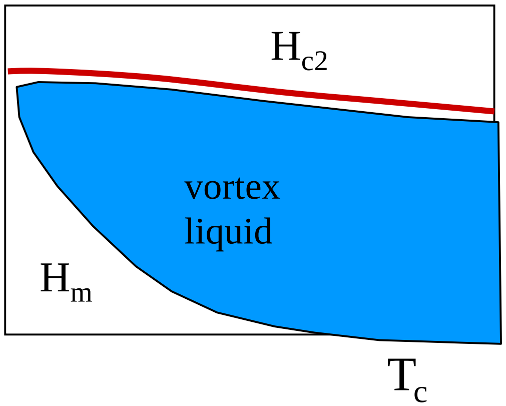
4. Relatively long penetration depth

5. Strong fluctuations, vorticity

6. Loss of phase coherence at T_c

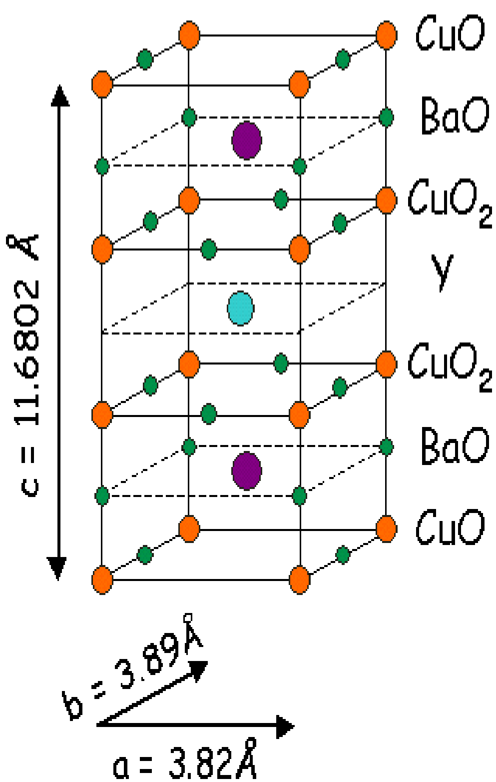




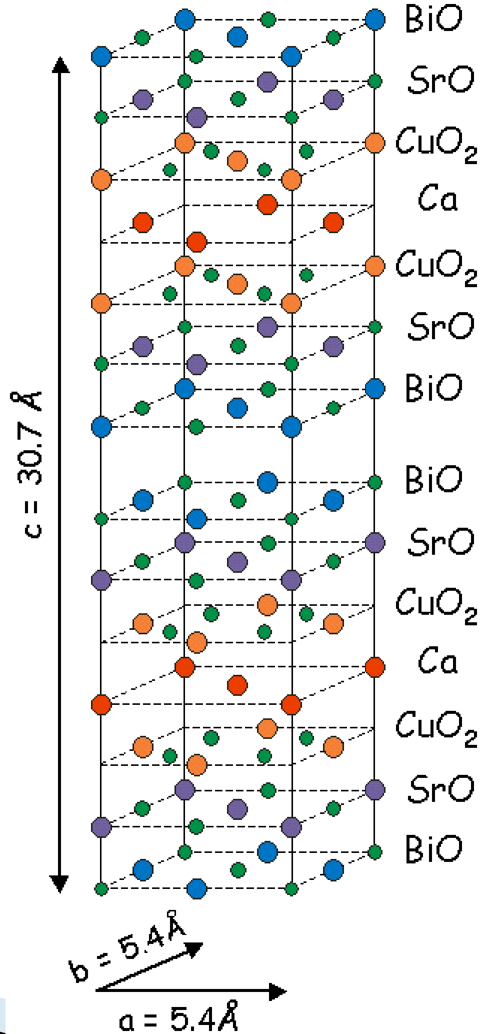


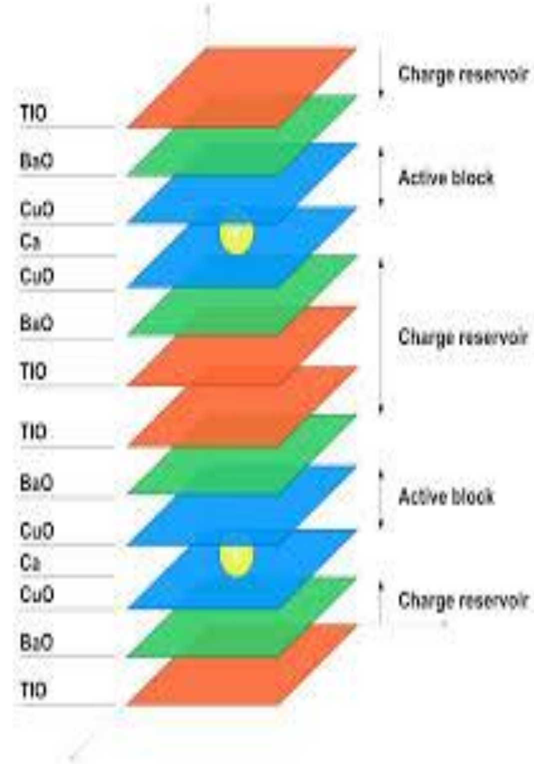
Some Cuprates as HTSC

Muller and Bednorz recorded highest T_c of 35 K in $La_{2-x}Ba_xCu_3O_4$ (LBCO) System.



YBCO T_c =92 K





TBCCO T_c 127 K

BSCCO T_C =110 K

Parent material selected:

YBCO

- **$Y_1Ba_2Cu_3O_{7-\delta}$ (Yttrium Barium Cupper Oxide).**
- **Distorted, oxygen deficient multi-layered perovskite structure.**
- **Presence of two CuO_2 plane responsible for superconductivity.**
- **Cu–O chains plays an important role for superconductivity.**
- **Stable compound with a T_c above 77 K (92 K)**
- **Easy to make single-phase of YBCO.**
- **High J_c at Higher magnetic Field.**
- **Relatively Long Penetration Depth**
- **short coherence length**

Synthesis of Composite Sample:

Stoichiometry amounts of Y_2O_3, $BaCO_3$, CuO are taken as precursors, grinded for 2to 3 hrs.

↓

Heated for 3 times at 920℃ with intermediate grinding

↓

Pelletized followed by sintering at 930 ℃ for 12 hrs.

↓

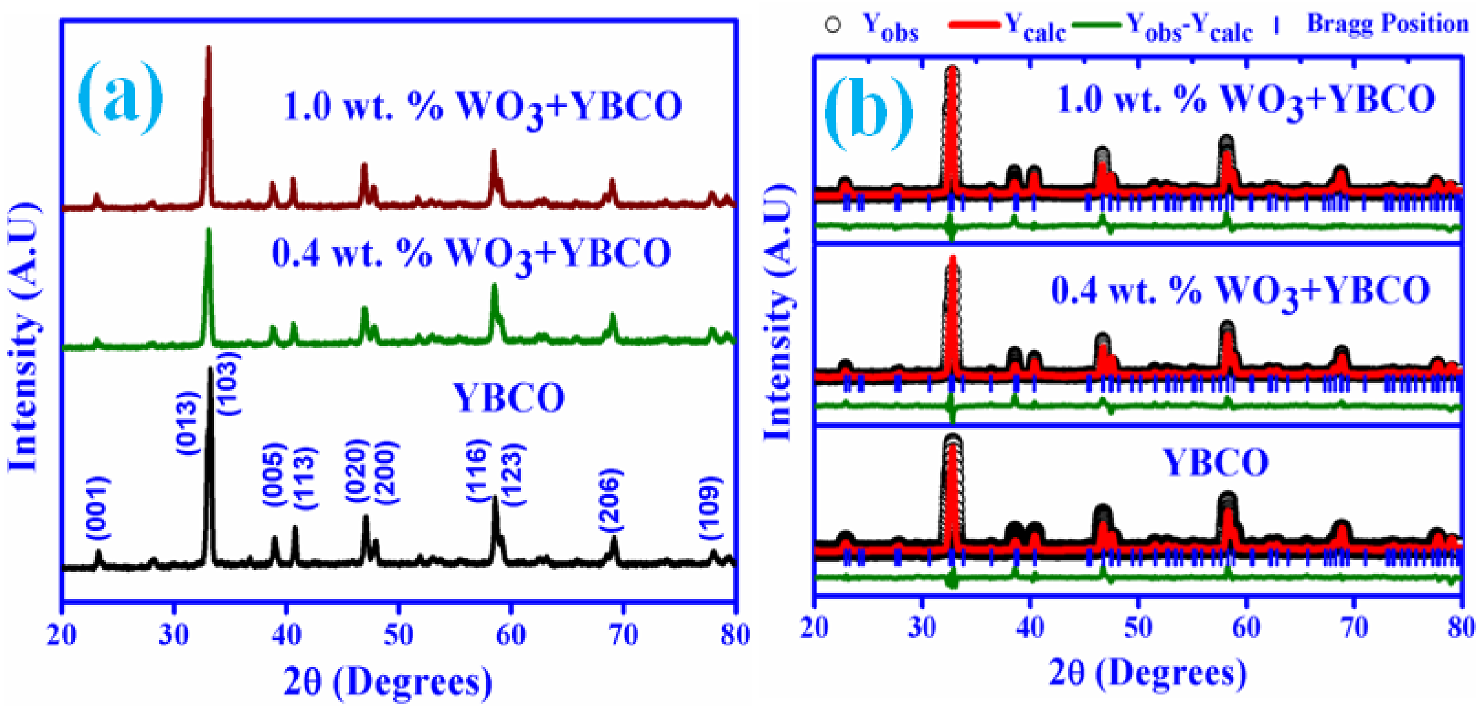
Annealed at 500 ℃ in presence of oxygen for another 12 hrs. and cooled to room temperature

↓

YBCO

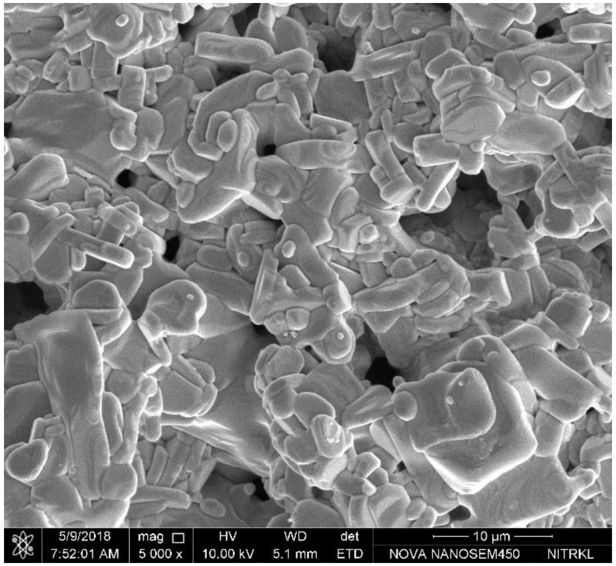
The adequate wt.% of WO_3 (x = 0.0, 0.4 and 1.0) was mixed with the total mass of the sample under the same condition.

X-ray powder diffraction patterns of YBCO samples added with different wt.% of WO_3 nanoparticles:

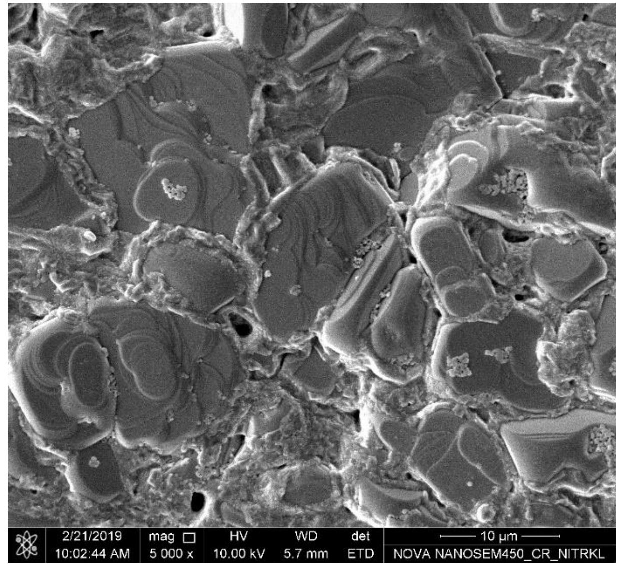


Sample	YBCO	0.4 wt. % WO_3+YBCO	1.0 wt. % WO_3+YBCO
a (Å)	3.831	3.833	3.833
b(Å)	3.858	3.855	3.864
c(Å)	11.683	11.683	11.684
Oxygen content	6.68	6.74	6.79
χ^2	2.06	2.19	2.34

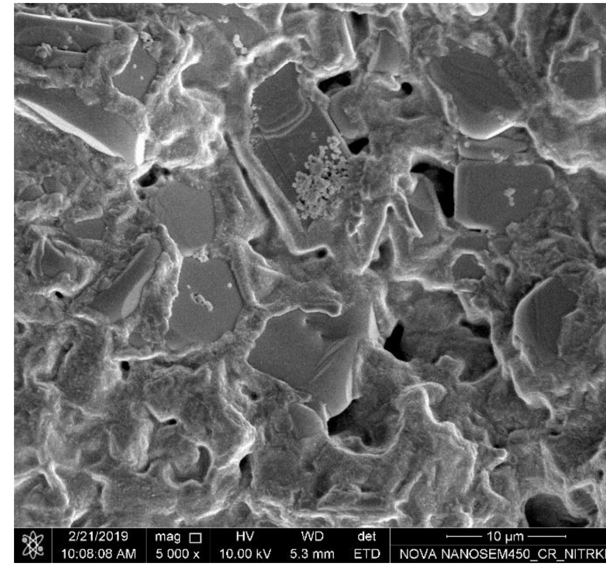
Field Emission Scanning Electron Microscopy Analysis:



YBCO



0.4 wt. % WO_3 +YBCO

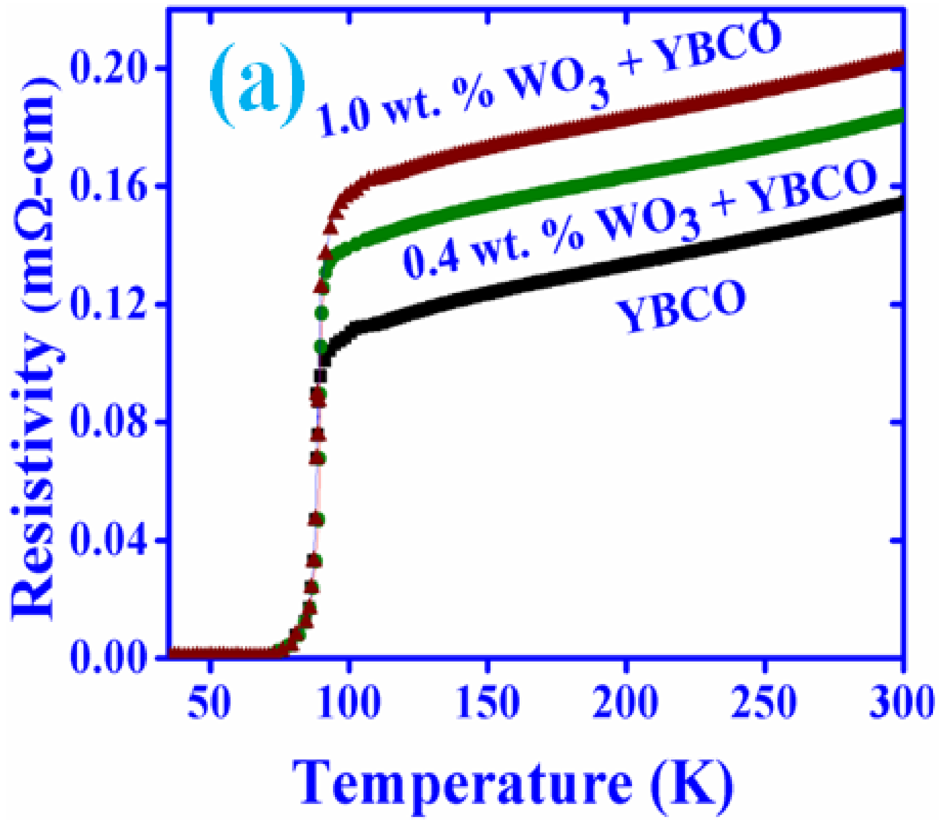


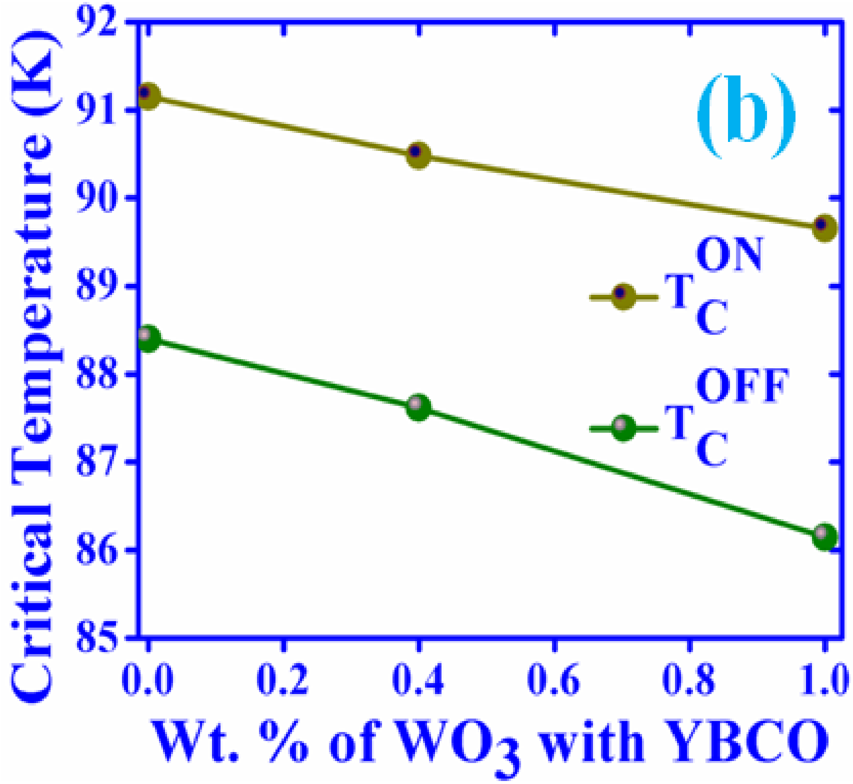
1.0 wt. % WO_3 +YBCO

- **For Pristine YBCO sample, rectangular rod like shaped structure are observed with distinguished numbers of pores and voids.**

- **Inclusion of WO_3 nanoparticles, increases the grain connectivity by residing near the grain boundary and grain growth takes place.**

Temperature dependent resistivity study:





❑ Enhancement of ρ_{300K} may ascribed to the scattering cross-section of the charge carriers, as WO_3 resides near the grain boundary.

❑The value of gradually increases with increasing wt. % of WO_3 confirms a large number of defects, disorders, and inhomoginity arises near the grain boundary of YBCO.

calculated superconducting parameters for YBCO samples sintered with various amounts of Tungsten Oxide from transport measurement.

Sample	T_c^{on} (K)	T_c^{off} (K)	ρ_0 (μΩ-cm)	ρ_{300K} (μΩ-cm)	α (μΩ-cmK^{-1})	ΔTc (K)
YBCO	91.1	88.4	1056.2	1517.8	1.98	2.7
0.4 wt. % WO_3 +YBCO	90.4	87.6	1302.8	1839.5	2.02	2.8
1.0 wt. % WO_3 +YBCO	89.6	86.1	1456.3	2028.1	2.05	3.5

- **The Transition manifests significant amount of strongly coupled grains and the zero resistance state is achieved when the Josephson tunneling between the grains forms a connected superconducting path across the entire sample is lowered.**

- **T_c^{off} value of the cuprate superconductor depends on the confined charge carrier concentration of the CuO_2 planes. As the concentration of charge carriers decreases with increasing WO_3, hence T_c^{off} is decreased.**

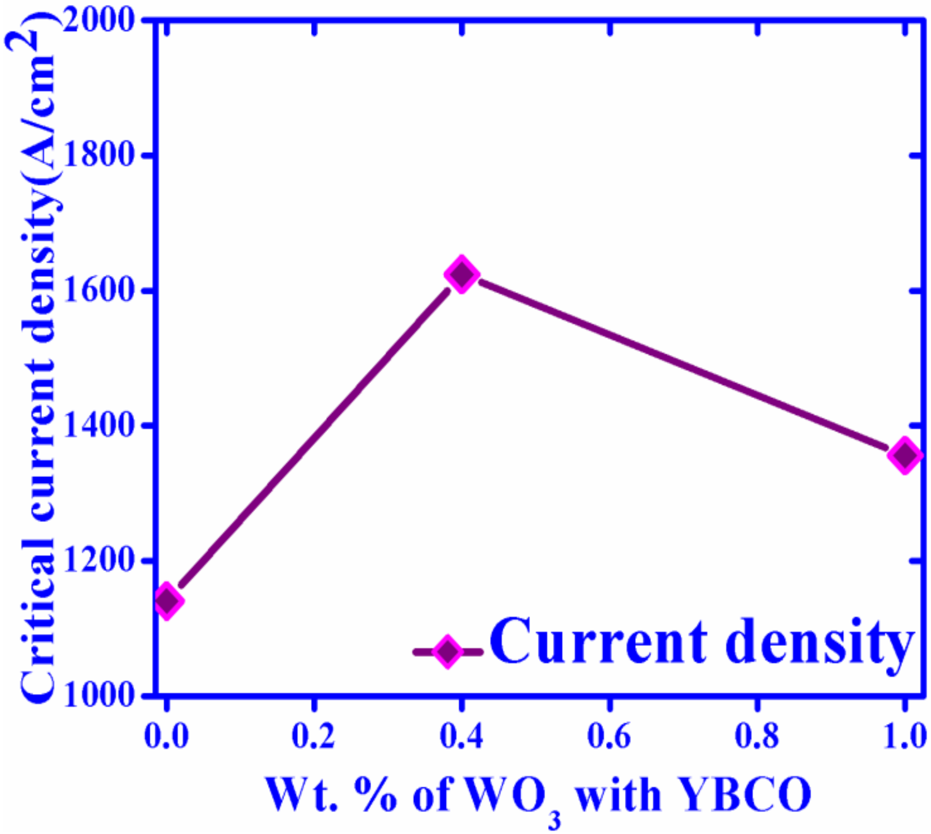
Using Bean's critical state model,
J_c is calculated

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

where

- a thickness of the bar shaped sample
- b width of the bar shaped sample
- $\Delta M = M_+ - M_-$ extracted from the magnetization loop.

Calculation of critical current density:

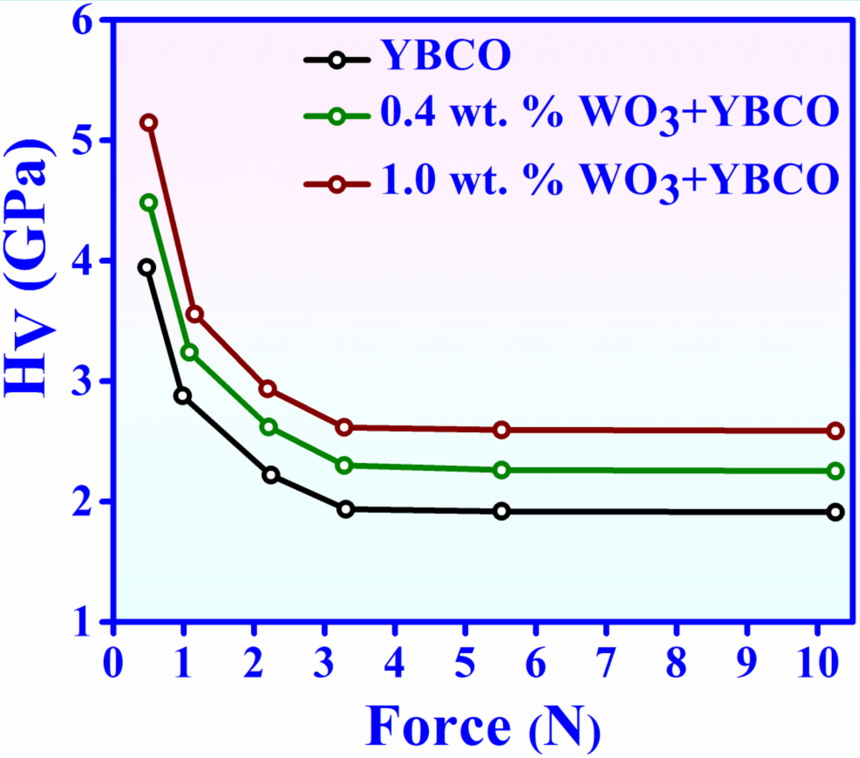


Enhancement of Critical Current Density

Strong weak-link among the Superconducting Grains due to inclusion of WO_3 nanoparticles.

- **The value of J_c is estimated by the criterion of 1μV/cm from the electric field (E) versus current density (J).**
- **The maximum value of J_c is found to be 1619.22 A/cm^2 for 0.4 wt. % added sample at 77K.**

Microhardness Measurement:



Relation between the Applied Load and Vicker's microhardness Number:

$$H_V = 1854.4\ (F/d^2)\ GPa$$

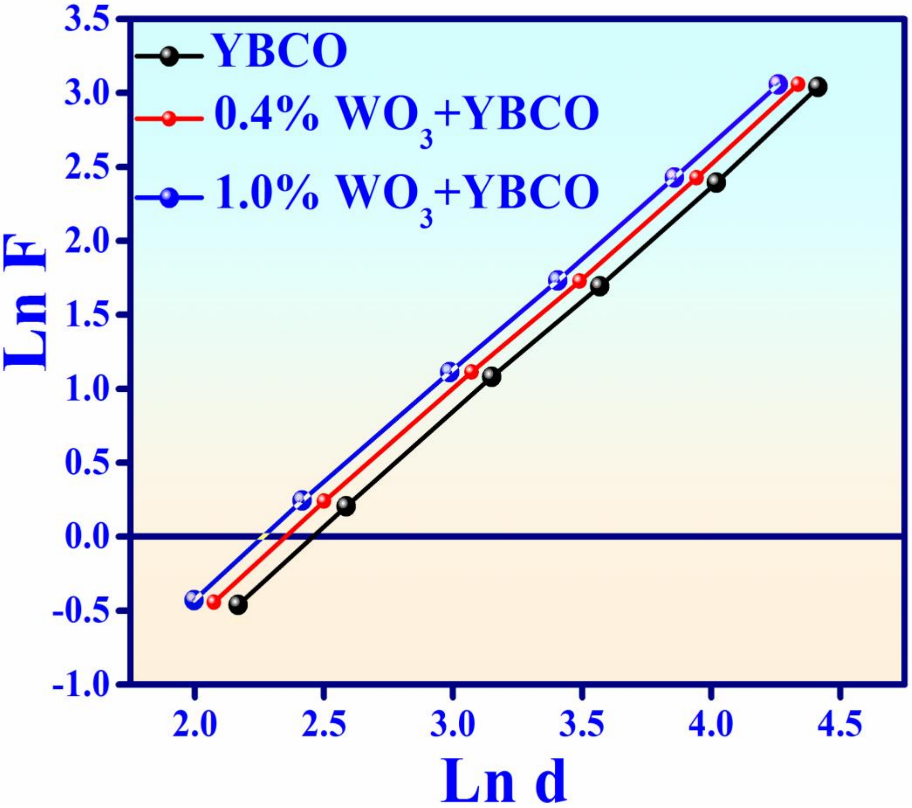
Here H_V = Vicker's Microhardness Number,

F = Applied Load

d = The pyramidal diagonal length of the indenter

- ❖ **The degradation of H_V is more effective for a small amount of applied load i.e. from 0 to 3 N.**
- ❖ **After that 3N load, there is no significant decrease in microhardness with the applied load, such behaviour is termed as the indentation size effect (ISE).**
- ❖ **The initial decrease in microhardness values is attributed to the surface layer effect.**

Microhardness Measurement (Mayer's law Approach)



Mayer's law is given by

$$F = A\, d^{\,n}$$

'F' stands for Applied load

'A' gives information about the applied load required to set up the indentation.

'n' represents Mayer's Index

Sample	Mayer's Law		
	H_V (GPa)	n	$A*10^{-3}$ (GPa)
YBCO	**2.54**	**1.51**	**5.48**
0.4 wt. % WO_3+YBCO	**2.68**	**1.53**	**5.32**
1.0 wt. % WO_3+YBCO	**2.96**	**1.52**	**5.08**

For n > 2, Reverse indentation size effect (RISE)

For n < 2, Normal indentation size effect (ISE)

Elastic Parameters Obtained from Microhardness Analysis:

Sample	H_V (GPa)	E (GPa)	Y (GPa)
YBCO	1.98	162.28	0.66
0.4 wt. % WO_3+YBCO	2.24	183.59	0.74
1.0 wt. % WO_3+YBCO	2.68	219.66	0.89

Elastic modulus (E) = (81.9635) x Vickers microhardness (H_V)

Yield strength (Y) = 1/3 {Vickers microhardness (H_V) }

- **No dislocation motion is possible as WO_3 nanoparticles resides near the grain boundary.**
- **The lattice strain is decreased, hence Elastic parameters are increased.**

Conclusions:

- **Addition of WO_3, leads to increase the grain connectivity.**
- **The superconducting transition temperature is decreased by increasing wt. % of WO_3.**
- **The tungsten oxide increases the critical current density up to an optimum limit of addition.**
- **The room temperature resistivity and residual resistivity are increased with increasing wt. % of WO_3.**
- **The elastic modules also increase with increasing wt. % of WO_3.**


THANK YOU!