R. L. Greene APS Talk — March 1987

Electronic Properties of Oxide Superconductors

IBM Research — Yorktown, Almaden

① "Low T_c" superconductors $T_c \approx 30-40K$

$La_{2-x}M_xCuO_4$ $M = Ca, Ba, S$

Mueller — Bednorz

IBM Zurich — 1986

② "High T_c" superconductors $T_c = 90-100K$

$Y_{1.2}Ba_{0.8}CuO_x$, Multiphase samples (Black, green + others)

Chu, Wu et al

Houston, Alabama Universities

PRL — March 3, 1987

③ Very high T_c ?

SUPERCONDUCTIVITY ABOVE 90K IN THE COMPOUND $YBa_2Cu_3O_x$: STRUCTURAL, TRANSPORT AND MAGNETIC PROPERTIES

P. M. Grant, R. B. Beyers, E. M. Engler, G. Lim, S. S. P. Parkin, M. L. Ramirez, V. Y. Lee, A. Nazzal, J. E. Vazquez and R. J. Savoy

IBM Almaden Research Center
San Jose, CA 95120

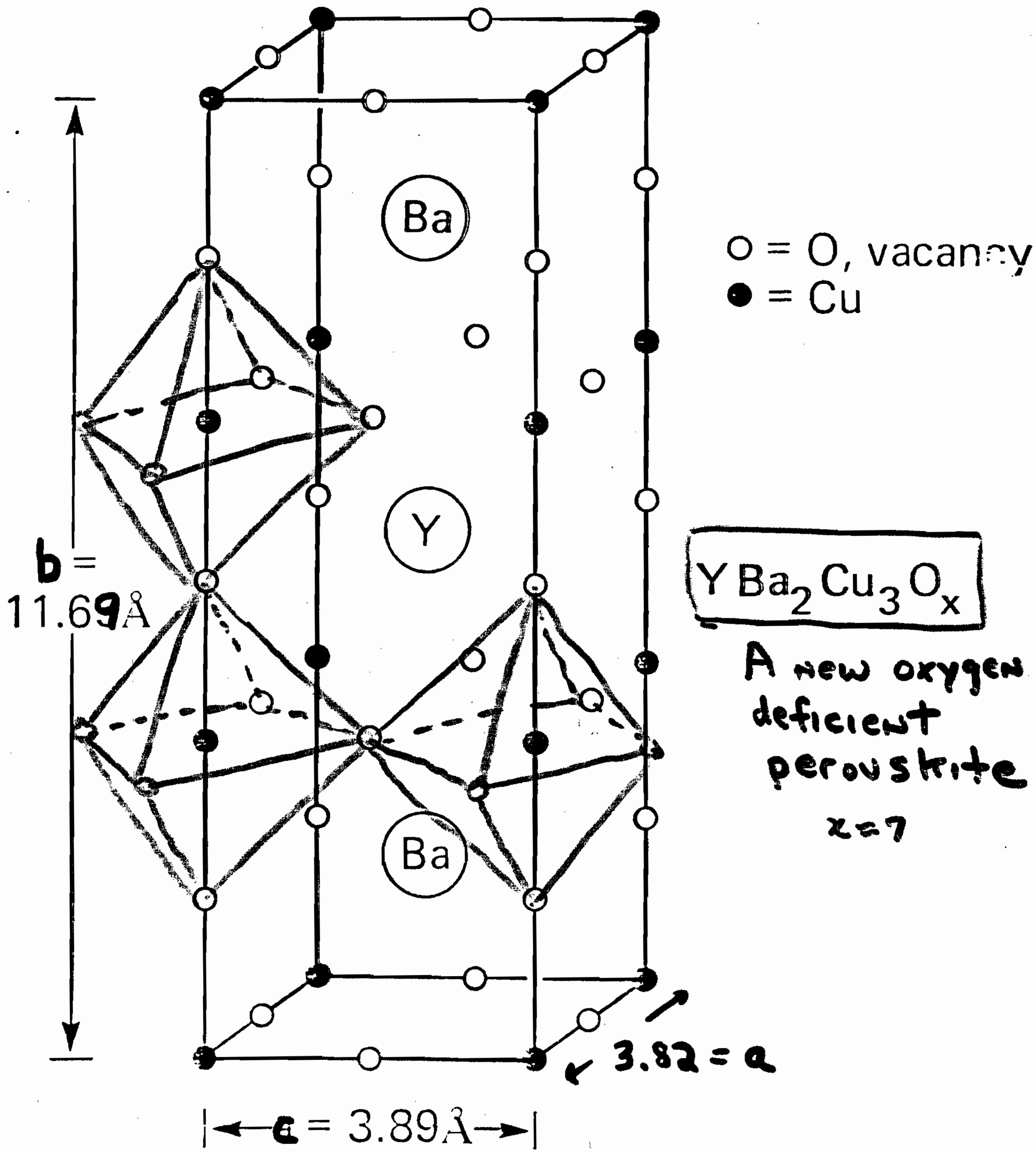
ABSTRACT: We report the structural, transport, and magnetic properties of the principle phase responsible for superconductivity in the recently discovered YBaCuO compounds with transition temperatures greater than 90K.

PACS 74.10.+v

PACS 74.70.Rv

Structure — IBM Yorktown + Almaden

Pmm2



$YBa_2Cu_3O_x$

A new oxygen deficient perovskite

x = 7

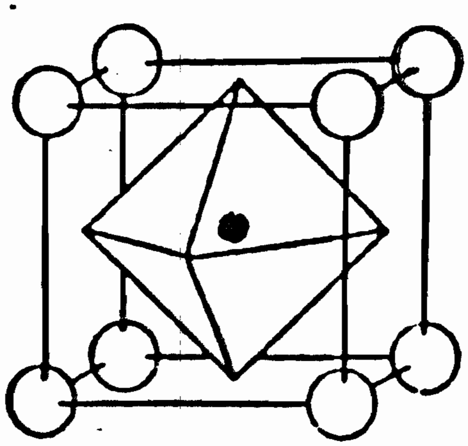
$M_x La_{2-x} Cu O_4$ Structure – tetragonal

$x \gtrsim 0.08$

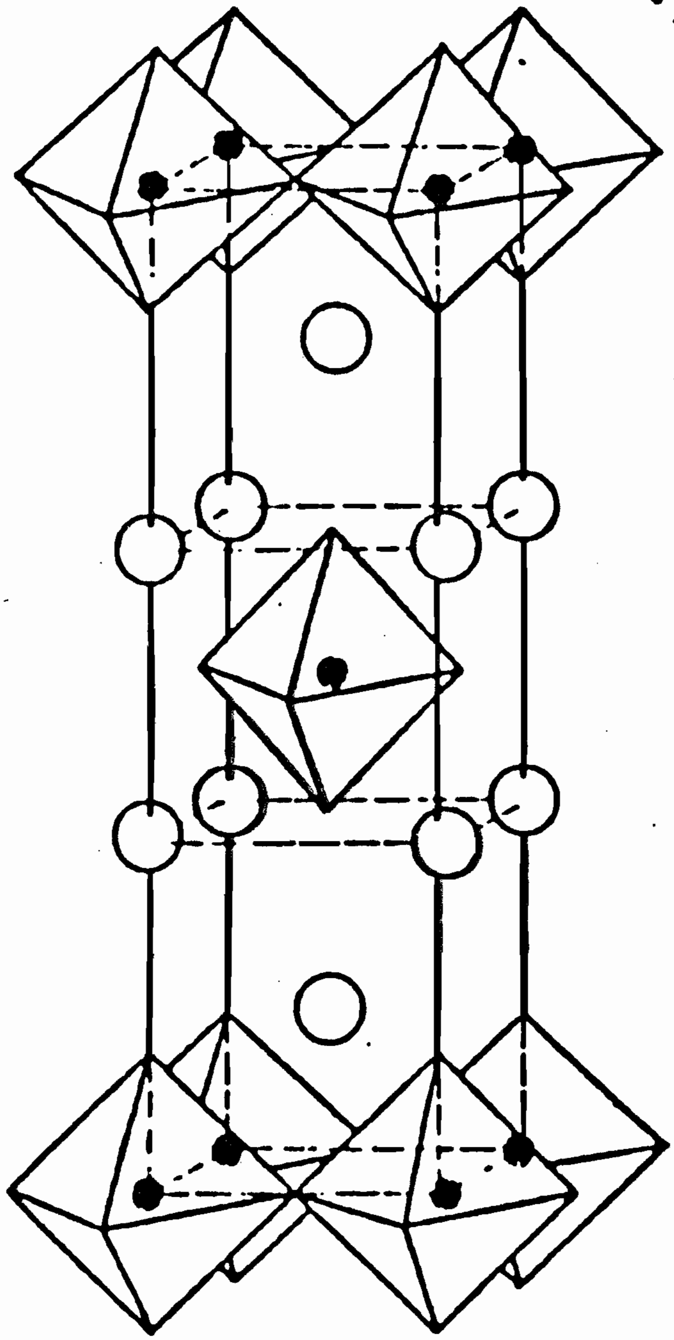
M = Ba, Sr, Ca

○ A, La

● B, Cu



ABX_3



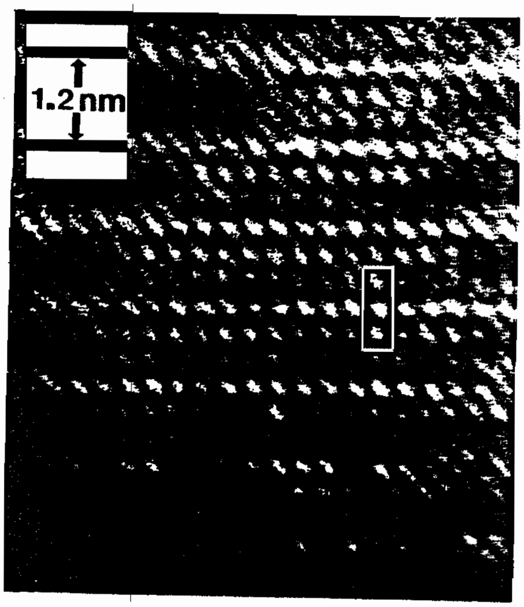
A_2BX_4

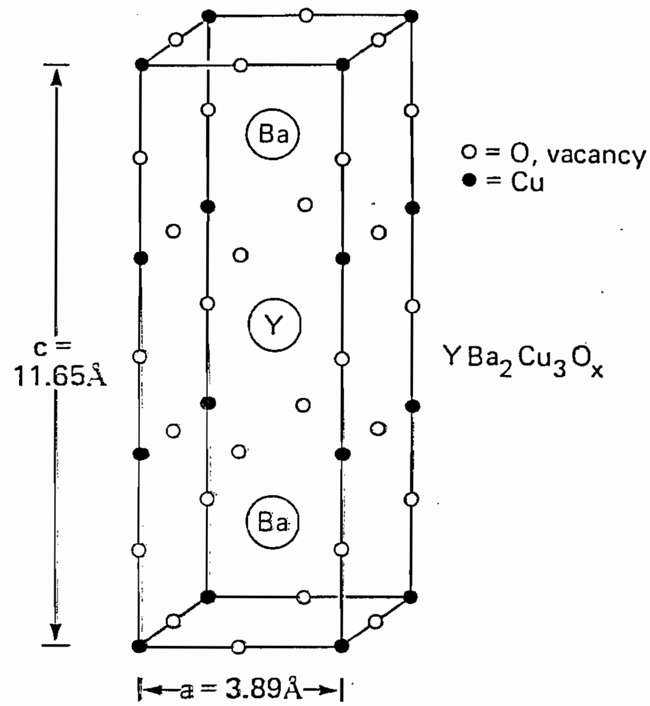
K_2NiF_4 structure type

2D

$YBa_2Cu_3O_x$

[illegible]





TEM ⇒ Ba, Y ordered

Ref: W.J. Gallagher, R.L. Sandstrom, T.R. Dinger, T.M. Shaw, and D.A. Chance, Solid State Comm. (submitted). — IBM Yorktown

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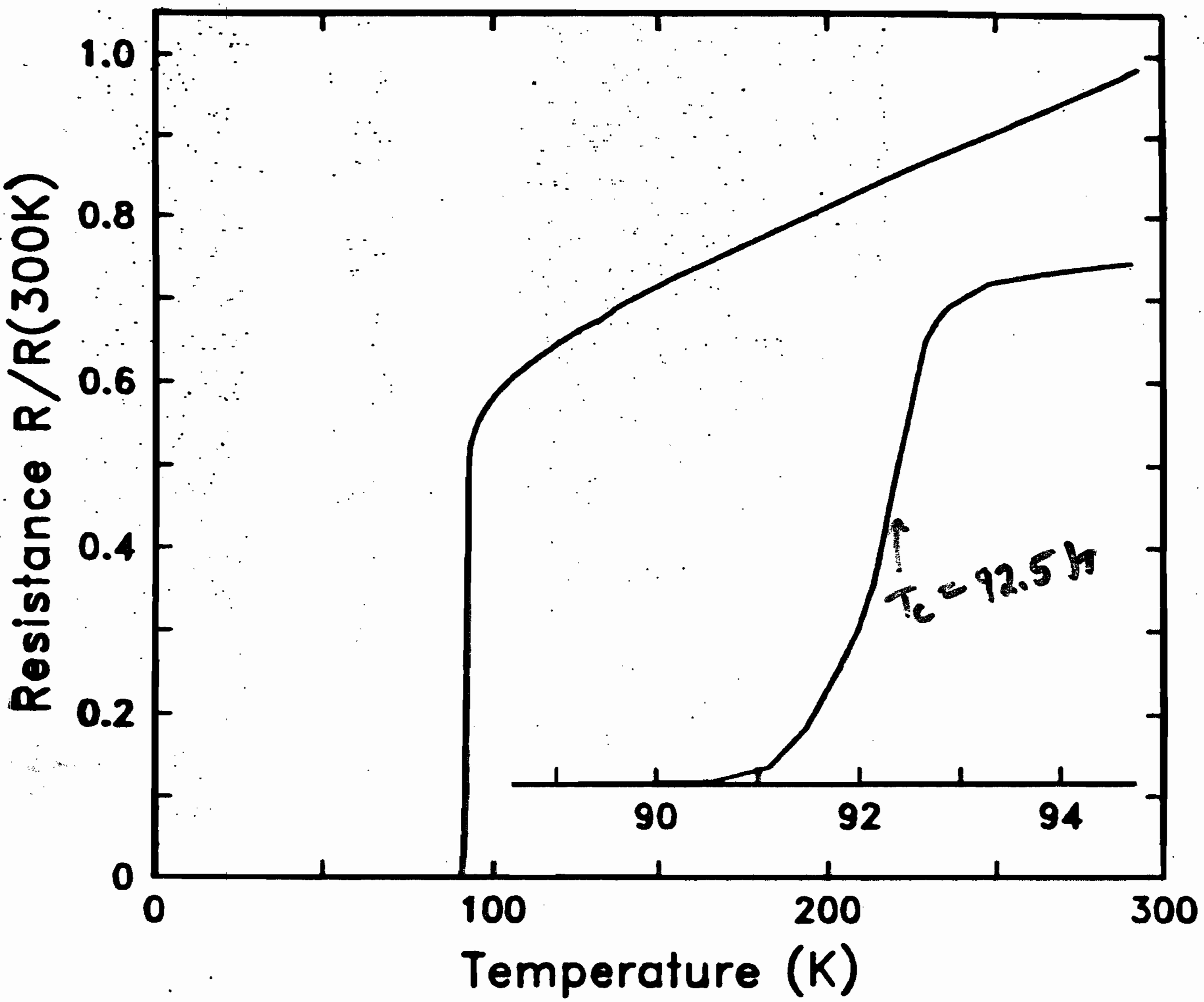
Refined structure done jointly – to be published

Single Phase $(Y_{0.30}Ba_{0.7})CuO_x$

IBM Yorktown



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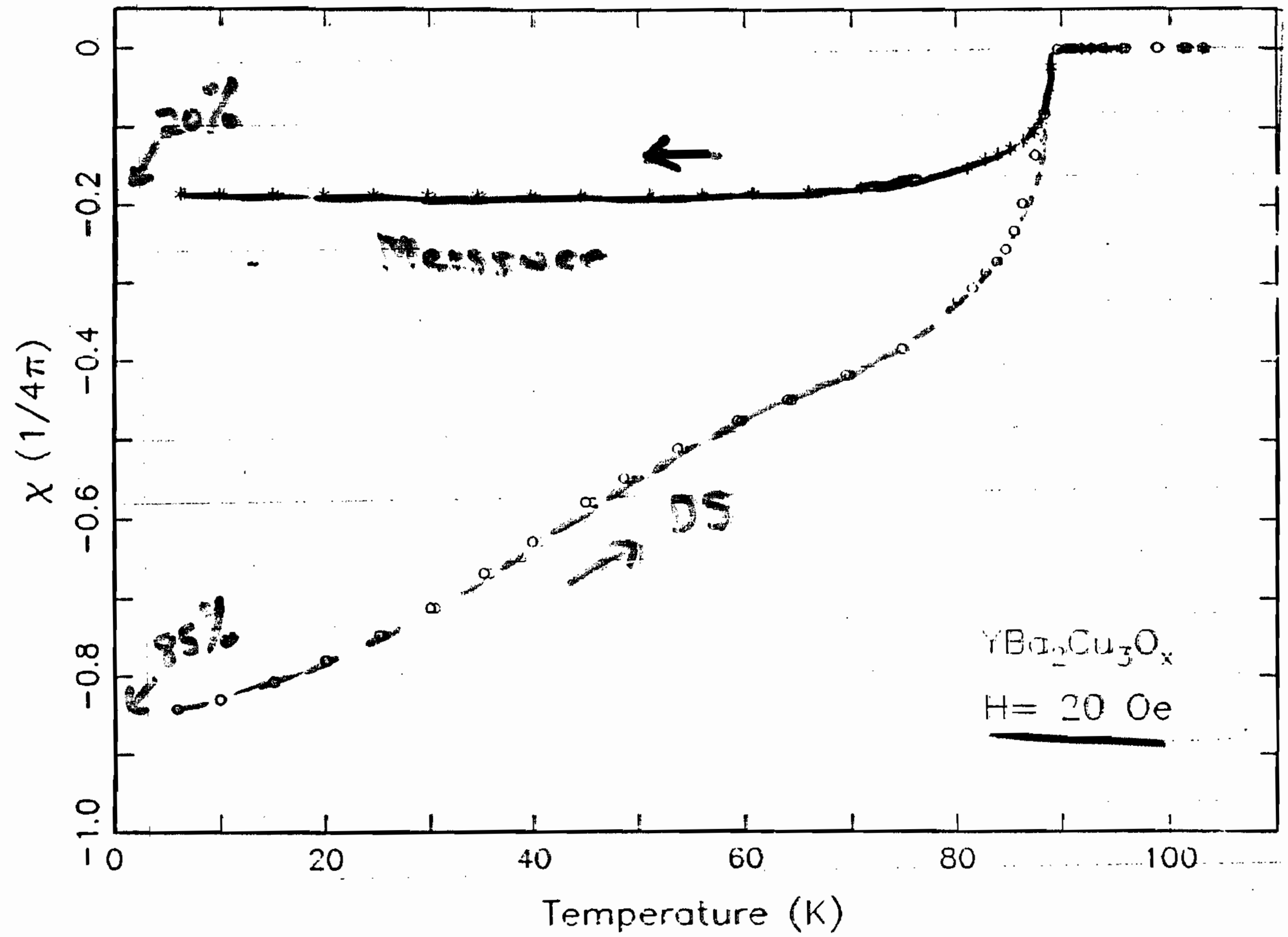
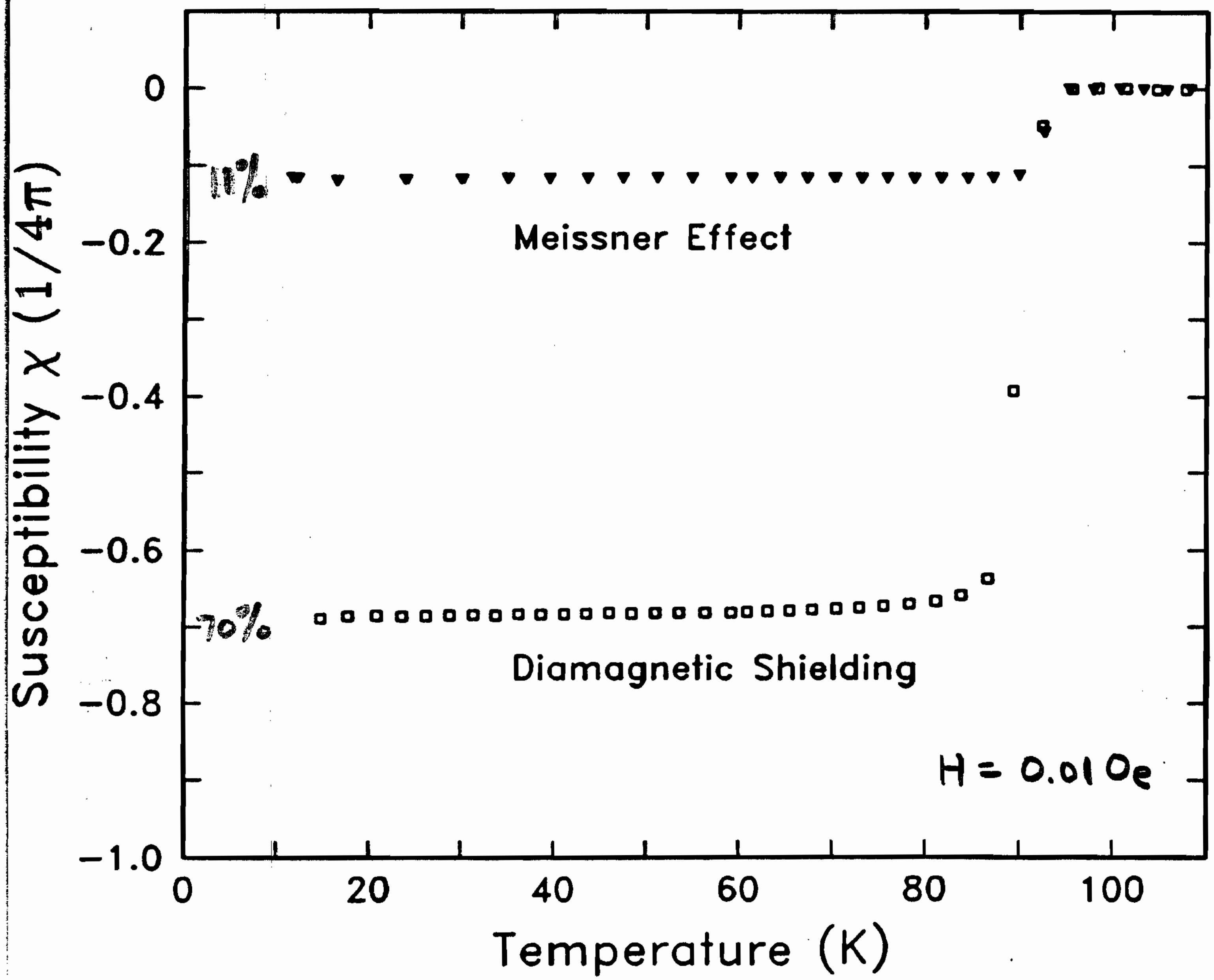


20%
Meissner
85%
DS
YBa$_2$Cu$_3$O$_x$
H= 20 Oe
0
-0.2
-0.4
-0.6
-0.8
-1.0
χ (1/4π)
0
20
40
60
80
100
Temperature (K)

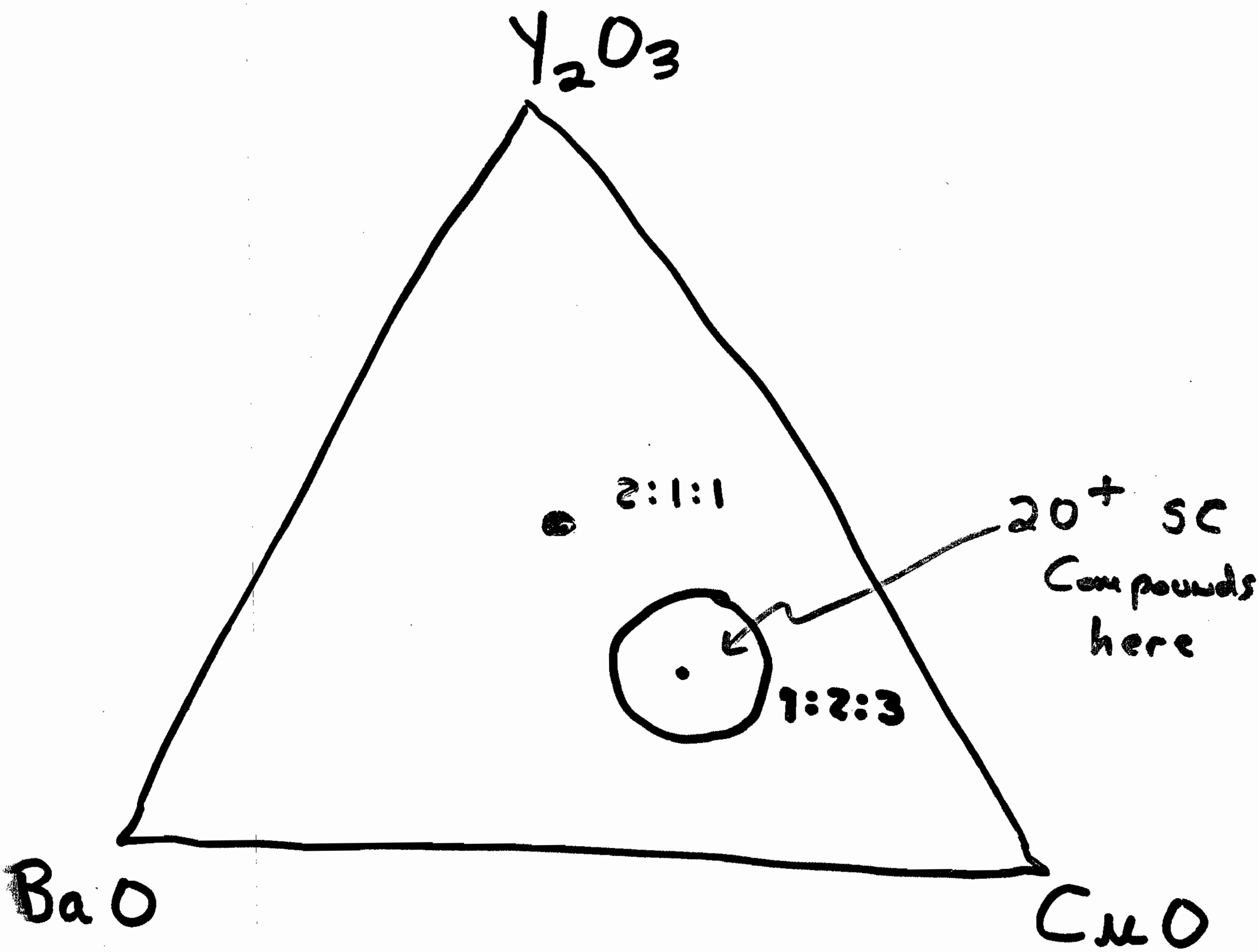
Single Phase $(Y_{0.30}Ba_{0.7})CuO_x$

IBM Yorktown



Ref.: W.J. Gallagher, R.L. Sandstrom, T. Dinger, T. Shaw, and D. Chance, Solid State Comm. (submitted).

D.C. Cronemeyer and A.P. Malozemoff (unpublished)



Y2O3
2:1:1
20+ SC Compounds here
1:2:3
BaO
CuO

IBM Almaden

following the heating step, the compositions be cooled slowly. It is believed that this slow cooling is required because when the material is cooled slowly, it retains slightly more oxygen than when it is cooled rapidly.

The following materials have all demonstrated bulk superconductivity at a temperature above 77°K. They are all single phase perovskite-like crystalline structures within the general formula

$$A_{1\pm x}M_{2\pm x}Cu_3O_y$$

The materials are:

Y Lu — $(Y_{0.8}Lu_{0.2})_{1.0}Ba_{2.0}Cu_3O_y$

$(Y_{0.5}Lu_{0.5})_{1.0}Ba_{2.0}Cu_3O_y$

Y La — $(Y_{0.5}La_{0.5})_{1.0}Ba_{2.0}Cu_3O_y$

Y Sc — $(Y_{0.5}Sc_{0.5})_{1.0}Ba_{2.0}Cu_3O_y$

La Sc — $(La_{0.5}Sc_{0.5})_{1.0}Ba_{2.0}Cu_3O_y$

$Y_{1.0}(Ba_{0.5}Ca_{0.5})_{2.0}Cu_3O_y$

$Y_{1.0}(Sr_{0.5}Ca_{0.5})_{2.0}Cu_3O_y$

$Y_{0.8}Ba_{2.0}Cu_3O_y$

$Y_{1.2}Ba_{2.0}Cu_3O_y$

$Y_{1.0}Ba_{1.8}Cu_3O_y$

$Y_{1.0}Ba_{1.5}Cu_3O_y$

$Y_{1.2}Ba_{1.8}Cu_3O_y$

Many more single phase materials with $T_c > 77$ K + + +

Y Sr Ca Cu_3O_x
Yb $Ba_2Cu_3O_x$
Lu $Ba_2Cu_3O_x$

All the above samples were confirmed to be superconductive by the AC magnetic susceptibility test method and by electrical resistivity measurements also.

To date, the following materials have not been found to be bulk single phase superconductors above 77°K when formulated and tested by the procedures described above:

$Lu_{1.0}Ba_{2.0}Cu_3O_y$

$Lu_{1.0}Ca_{2.0}Cu_3O_y$

Measured

$H_{c1} = 400$ Oe at 4 K

$$\left.\frac{dH_{c2}}{dT}\right|_{T_c} = -1.6\ T/K$$

Derived

$H_{c2}(0) \approx 100\ T$

$H_c(0) \approx 9600$ Oe

$\kappa \approx 70$

* $\gamma^{1/2} \propto H_c(0)/T_c \Rightarrow \gamma$ same as in La_2CuO_4 material.

So High T_c not caused by higher $N(0)$ or λ

Oxygen defects control Cu^{2+}/Cu^{3+} mixed valence

Mechanism for high T_c ? probably not el-ph

$La_{2-x}Sr_xCuO_4$ SC's

2 important new facts from experiment

— Far IR gap and Tunneling gap very different

$$\frac{2\Delta}{kT_c} \sim 2 \qquad\qquad \frac{2\Delta}{kT_c} \sim 4.5$$

Exp. discussed by Z. Schlesinger — Weds. nite

— Pauli $\chi = \mu_B^2 N^b(0)$ significantly enhanced over value determined from one electron band structure calcs., $N^b(0) \simeq 1-2 \frac{\text{states}}{\text{eV-cell}}$

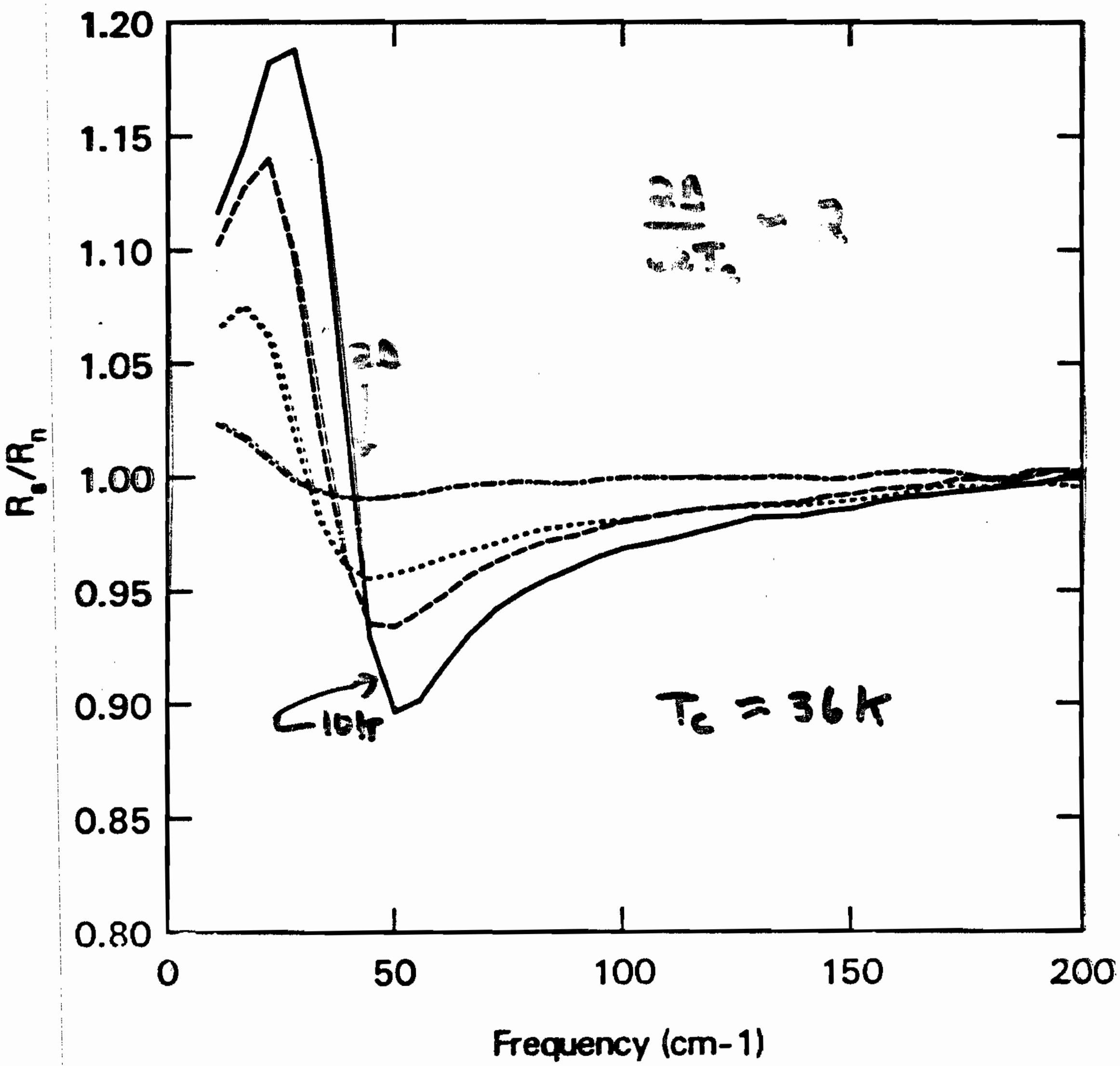
$\Rightarrow$ electron-electron correlations or 2 band model must be considered

Theory Talk by D.H. Lee Weds. nite

FAR-IR Reflectivity

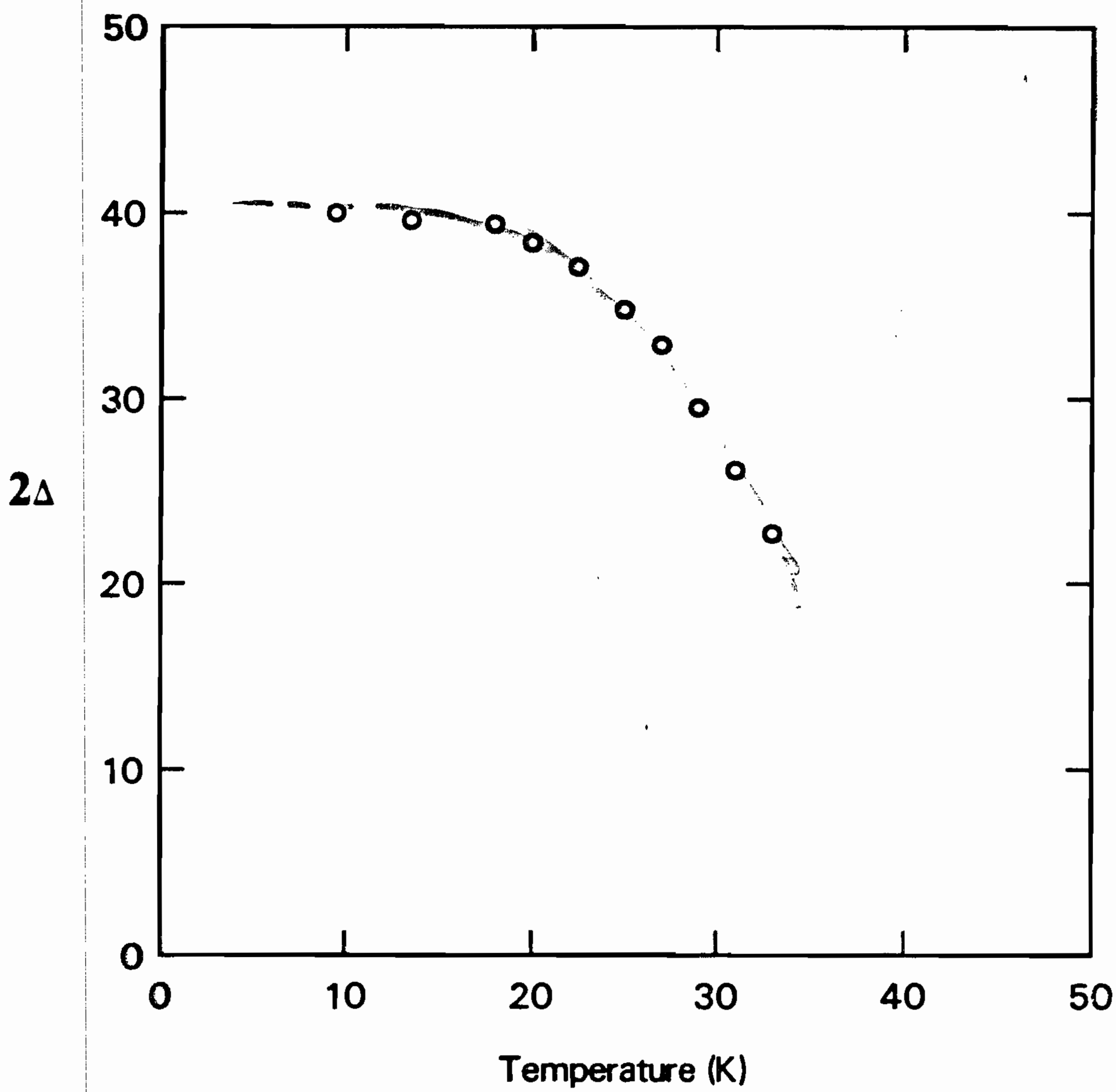
Schlesinger, Shafer – IBM YHT

$La_{1.8}Sr_{0.2}CuO_4$

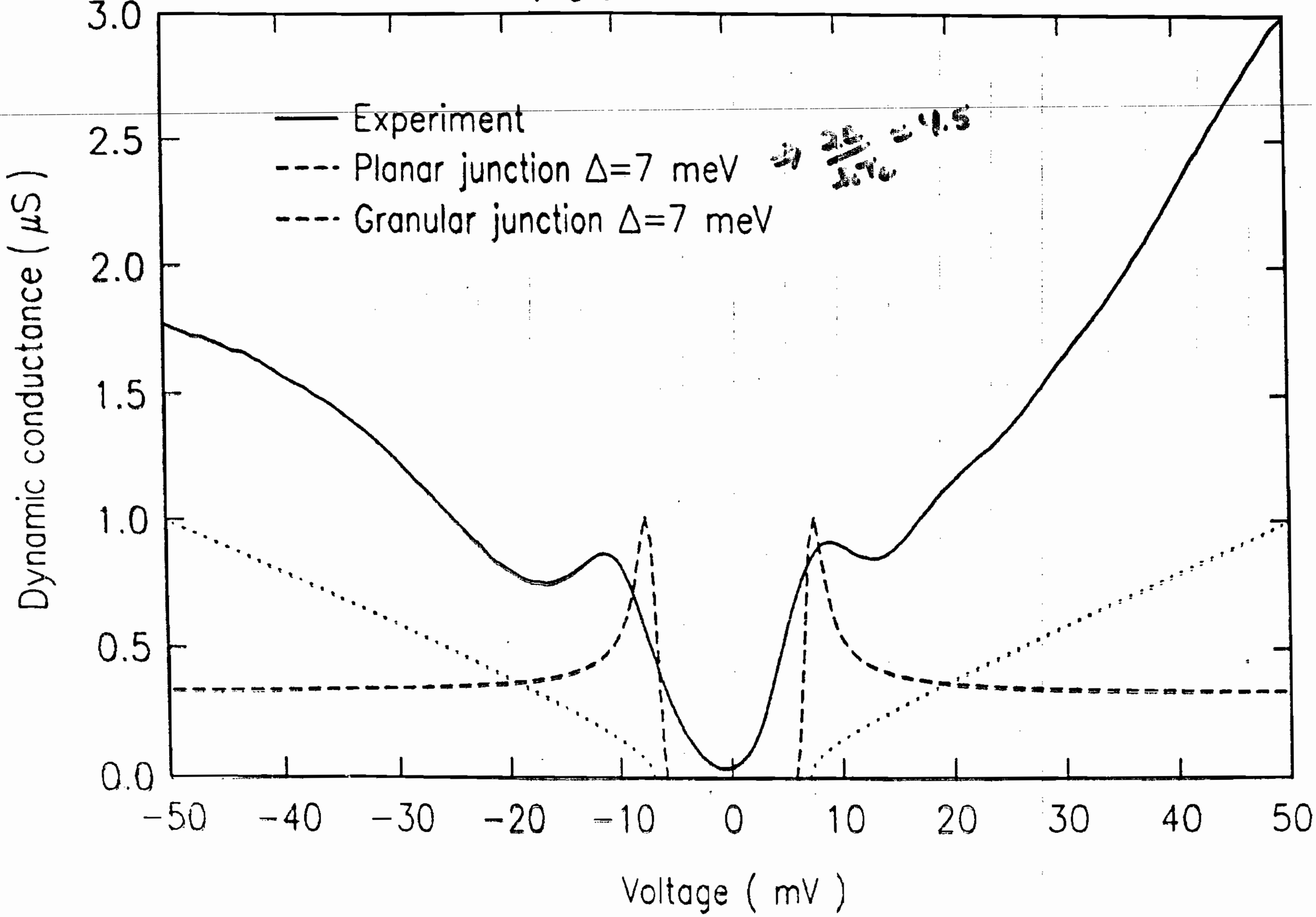


Schlesinger, Shafer – IBM YHT

BCS like T dep.



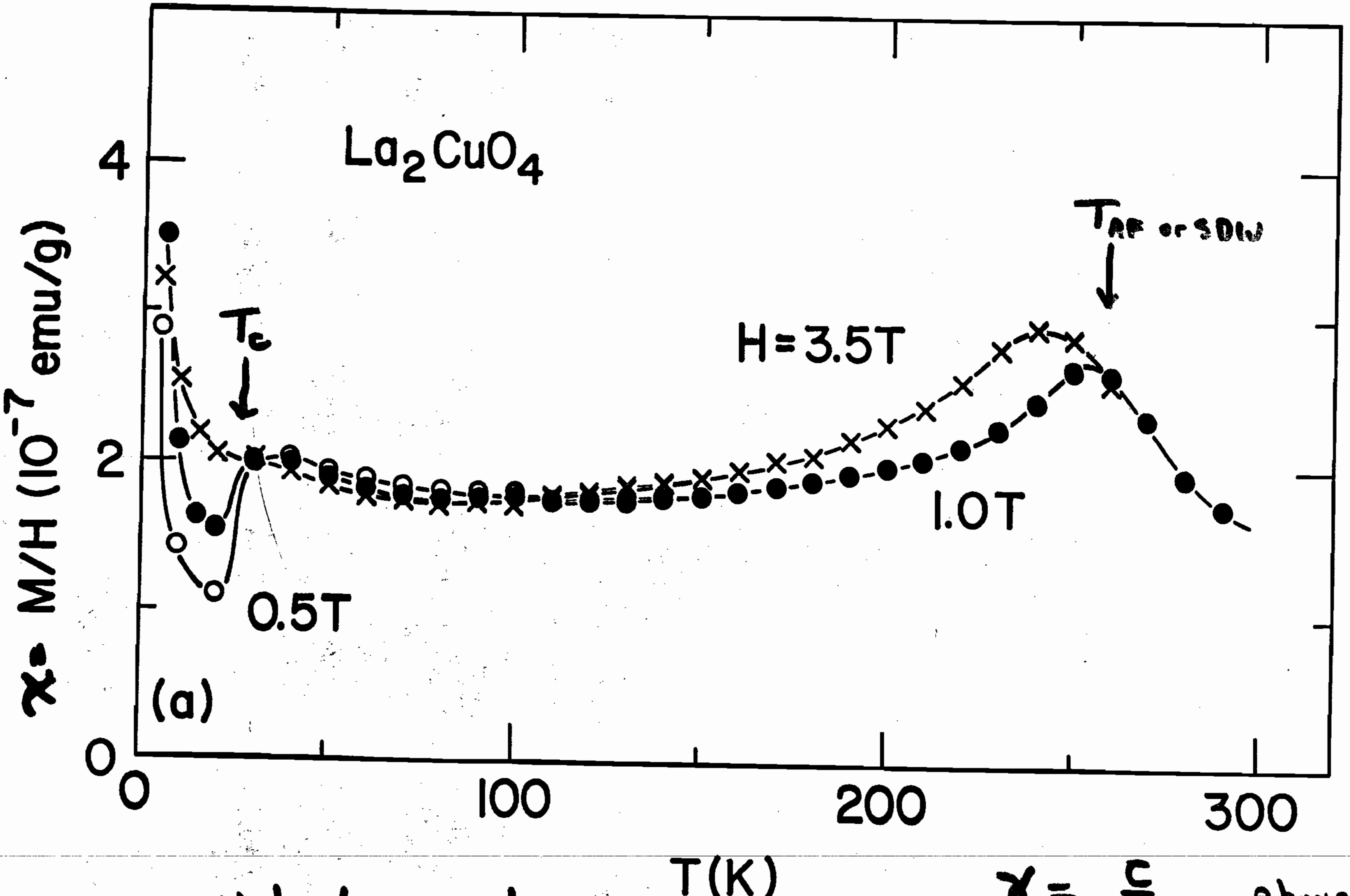
$3.5 < 2\Delta/k_B T_c < 6.3$



$La_{1.85}Sr_{0.15}CuO_{4-Y}$ T_c=36K PtIr Tip T=5K

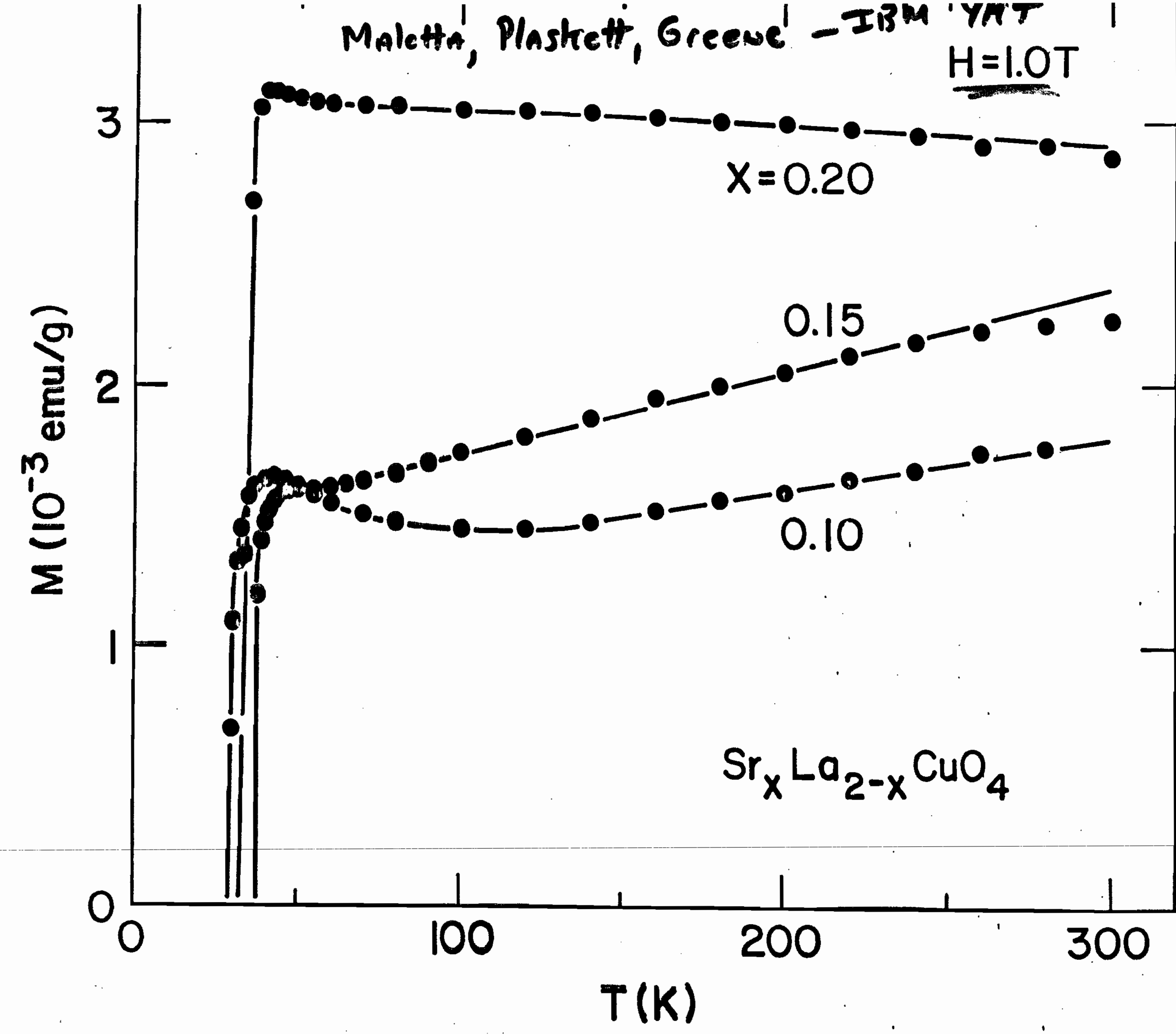
J.R. Kirtley, C.C Tsuei, C.C Chi, S.T Park, J. Rozen and M.W Shafer

Greene, Maletta, Plaskett, Muller, Bednorz – IBM



Not sharp peak ⇒ mag. flucs or lousy samples

$\chi = \frac{C}{T+\Theta}$ above 250K (to 400K) gave $\mu = 0.5\mu_B$ per Cu, $\Theta = -250K$



Maletta, Plaskett, Greene – IBM 'YHT
H=1.0T
M (10-3 emu/g)
3
2
1
0
X=0.20
0.15
0.10
SrxLa2-xCuO4
0
100
200
300
T(K)

$$\chi = \chi_{pauli} + \chi_{Landau} + \chi_{core}$$

$$\chi_{core} = -99 \times 10^{-6} \text{ emu/mole}$$

Take $\chi_L = -\frac{1}{3}\chi_p$

For $x = 0.15$ Compound at $T = 0$ find

$$\chi_p = 234 \times 10^{-6} \text{ emu/mole}$$

$$= \mu_B^2 N(0) \Rightarrow$$

$N(0) = 14.4$ states/eV-cell — χ_p

$N^b(0) \approx 1-2$ states/eV-cell — single particle BS

$N^b(0)[1+\lambda] \approx 10.5$ states/eV-cell

Junod et al — Specific Heat jump at T_c

So What's λ?

strong or weak coupling depending on what $N^b(0)$ really is.

The Green Phase

$Y_2 Ba_1 Cu O_x$

has

$T_c \geq 300K$!

But it's Ferroelectric

Happy St. Patrick's Day

+

April Fool's Day

Next year (or soon) this may not be a joke

R.L. Greene APS Talk – March 1987

Grant,
A few interesting things in this talk (in hindsight)

a) Mechanism of high T_c? Not el-ph (see bottom of foil 11)

b) Evidence for SC in La_2CuO_4 from our $\chi(T)$ measurements at Yorktown – where we were focused on the AF transition (see foil 16)

Greene

Ele[...] P[...] of [...]rs

IB[...] [...]maden

① "Lo[...] $T_c \simeq 30-40K$

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