Possible High T_c Superconductivity in the Ba - La- Cu- O System

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Possible High T_c Superconductivity in the Ba–La–Cu–O System

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Metallic, oxygen-deficient compounds in the Ba–La–Cu–O system, with the composition $Ba_xLa_{5-x}Cu_5O_{5(3-y)}$ have been prepared in polycrystalline form. Samples with $x=1$ and 0.75, $y>0$, annealed below 900 °C under reducing conditions, consist of three phases, one of them a perovskite-like mixed-valent copper compound. Upon cooling, the samples show a linear decrease in resistivity, then an approximately logarithmic increase, interpreted as a beginning of localization. Finally an abrupt decrease by up to three orders of magnitude occurs, reminiscent of the onset of percolative superconductivity. The highest onset temperature is observed in the 30 K range. It is markedly reduced by high current densities. Thus, it results partially from the percolative nature, bute possibly also from $2D$ superconducting fluctuations of double perovskite layers of one of the phases present.

Paper Summary

- Published in 1986
- Resulted in Nobel Prize, Awarded in 1987
- Reported Discovery of High Temperature Superconductivity

The Achievement

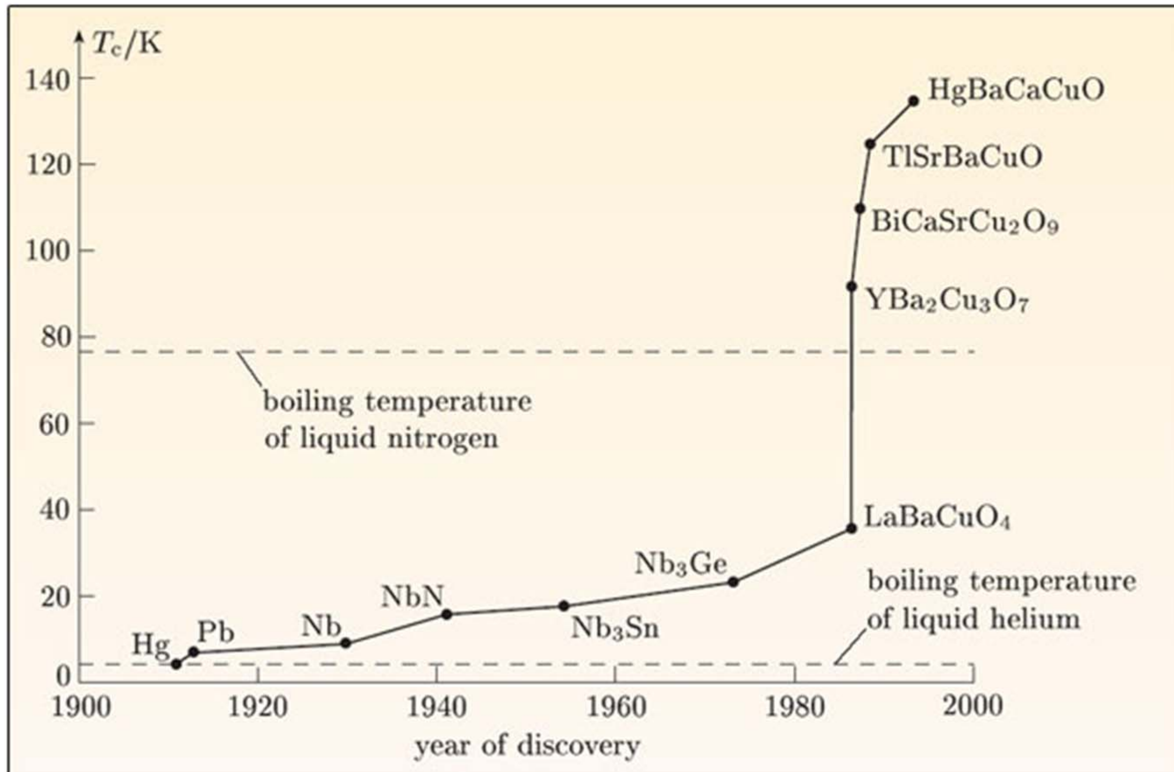
- Growth of BaLaCuO
- Superconducting Critical Temperature in 30 K Range
- Paved Way for Further High Temperature Superconductivity Research

Comparison to previous work : experimental

- *"At the extreme forefront of research in superconductivity is the empirical search for new materials."* – Michael Tinkham

- Attempt to find high superconducting critical temperatures

Alloys / Transition Metals compounds
Hg, Pb, Al, Nb, Os, Nb, NbN, Nb$_3$Sn, Nb$_3$Ge thin films
(23.3 K)
Cannot be explained by BCS theory



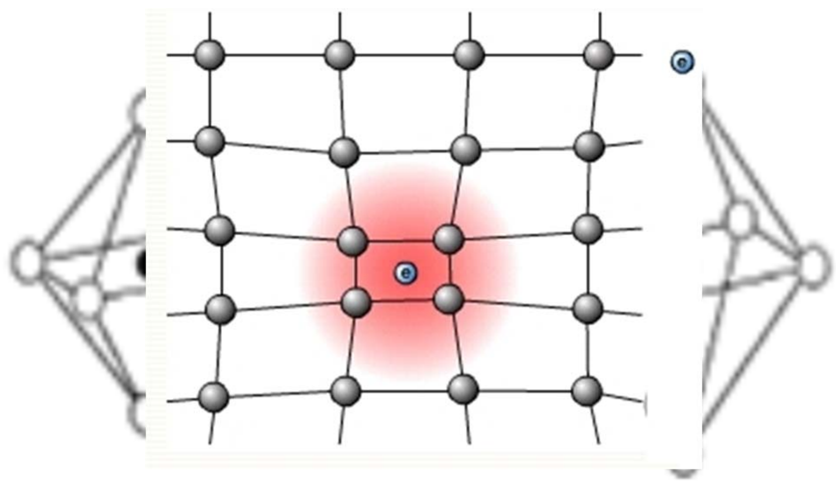
Timeline of critical temperature for superconductors (Courtesy : University of Cambridge)

Comparison to previous work : theoretical

- Strong electron-phonon interaction (For High T_c)

  Attractive interaction in BCS theory

- Mechanism for the interaction
  - Polaron formation
  - Jahn-Teller distortion



A polaron in 2-dimensional square lattice

Jahn-Teller distortion of octahedral site

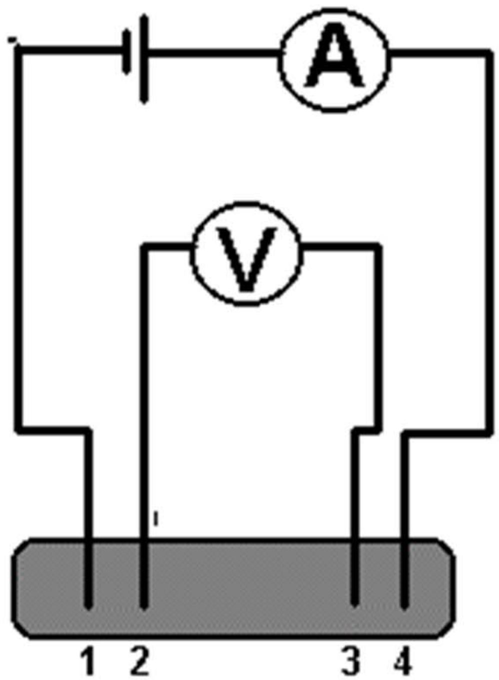
The Experiment

1. Sample Preparation and Characterization
    - Coprecipitation method oxalates
    - Heated at 900°C for 5h, pressed at 4kbar, reheat at 900°C

2. X-Ray Analysis : Three different Phases discovered
    1. Perovskite structure (K_2NiF_4)
    2. Cubic (Ba concentration)
    3. Oxygen-deficient perovskite

The Experiment

3. Conductivity Measurements



Schematic of the four point resistivity measurement method

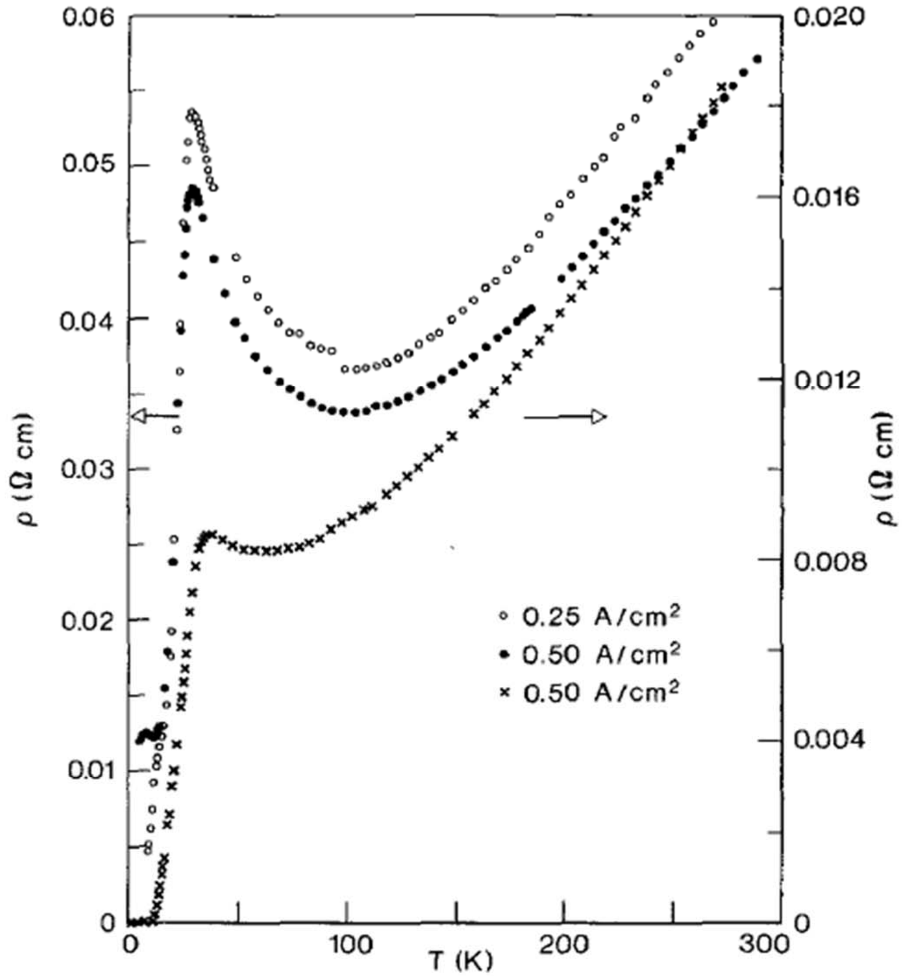


Fig. 1. Temperature dependence of resistivity in $Ba_xLa_{5-x}Cu_5O_{5(3-y)}$ for samples with x(Ba) = 1 (upper curves, left scale) and x(Ba) = 0.75 (lower curve, right scale). The first two cases also show th influence of current density

Low temperature conductivity measurements

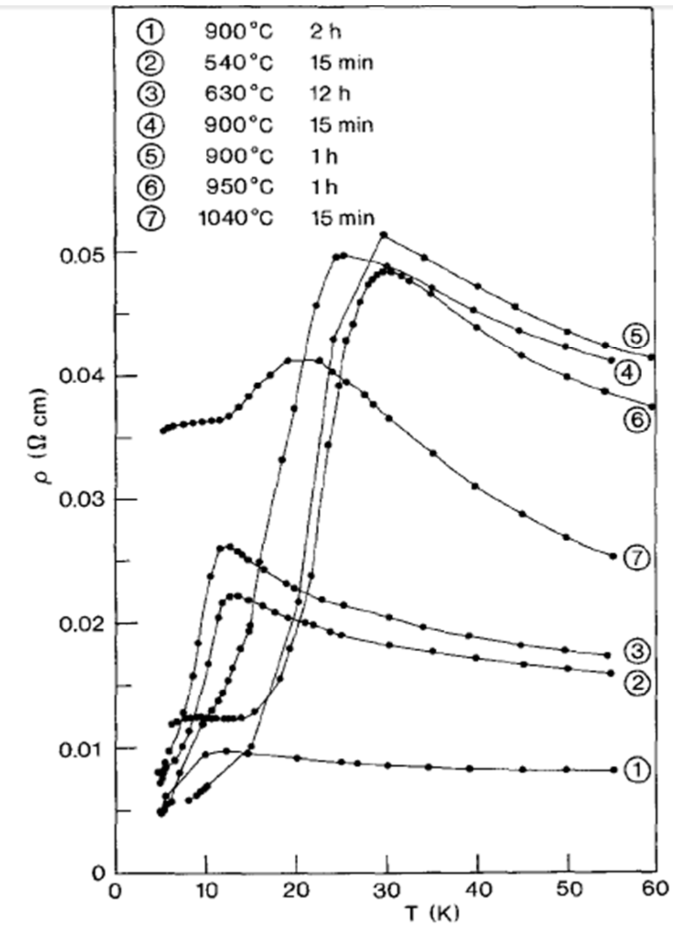


Fig. 2. Low-temperature resistivity of samples with $x(\mathrm{Ba}) = 1.0$, annealed at O_2 partial pressure of 0.2 bar (curve ①) and 0.2×10^{-4} bar (curves ② to ⑦)

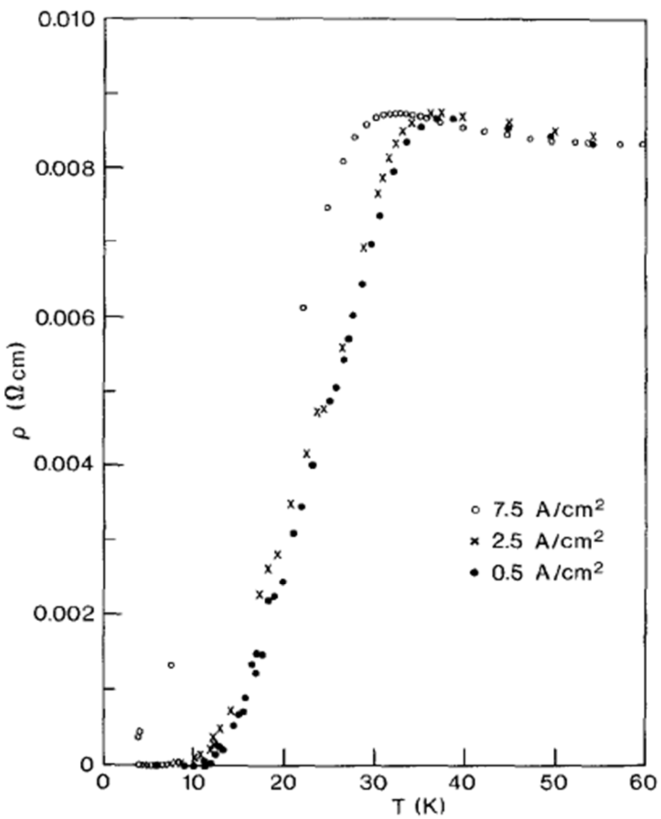


Fig. 3. Low-temperature resistivity of a sample with $x(\mathrm{Ba}) = 0.75$, recorded for different current densities

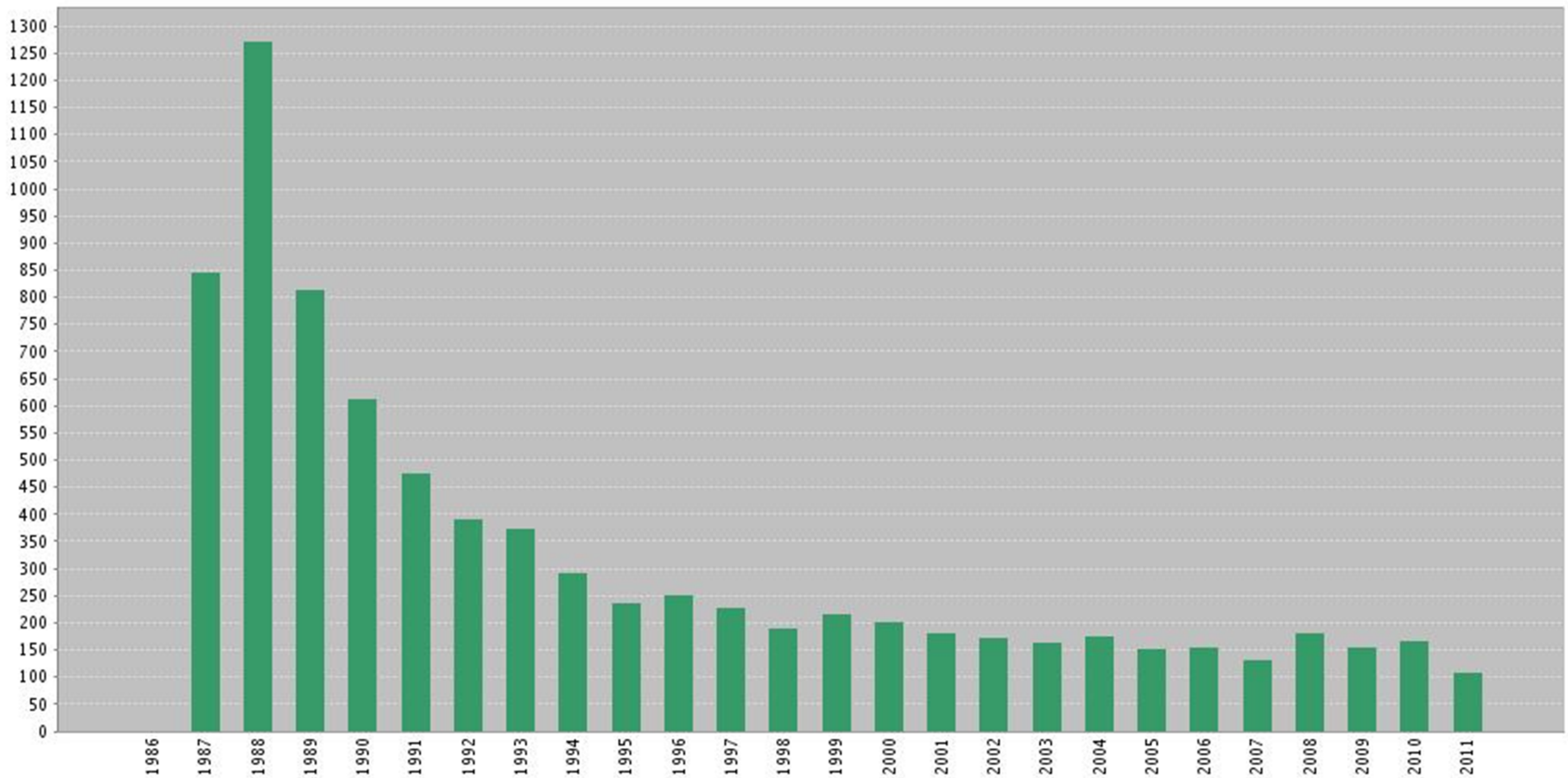
Conclusions

1. Speculation: metal-to metal structural phase transition

2. The size of the superconducting grains is 100Å

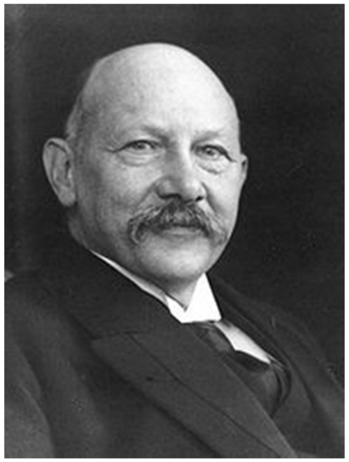
3. The way the samples have been prepared seems to be of crucial importance to superconductivity

Citation Analysis



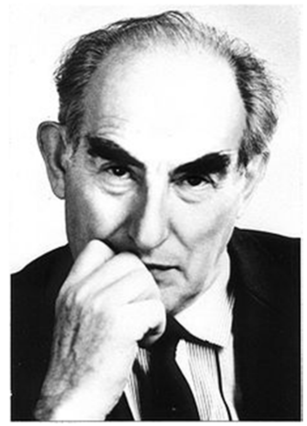
- 848 in 1987 (Nobel Prize Year)
- 1272 in 1988
- Avg. 314 Citations per year

The major players : Before 1986



Kammerlingh Onnes
1911

Walther Meissner
1933



Vitaly Ginzburg

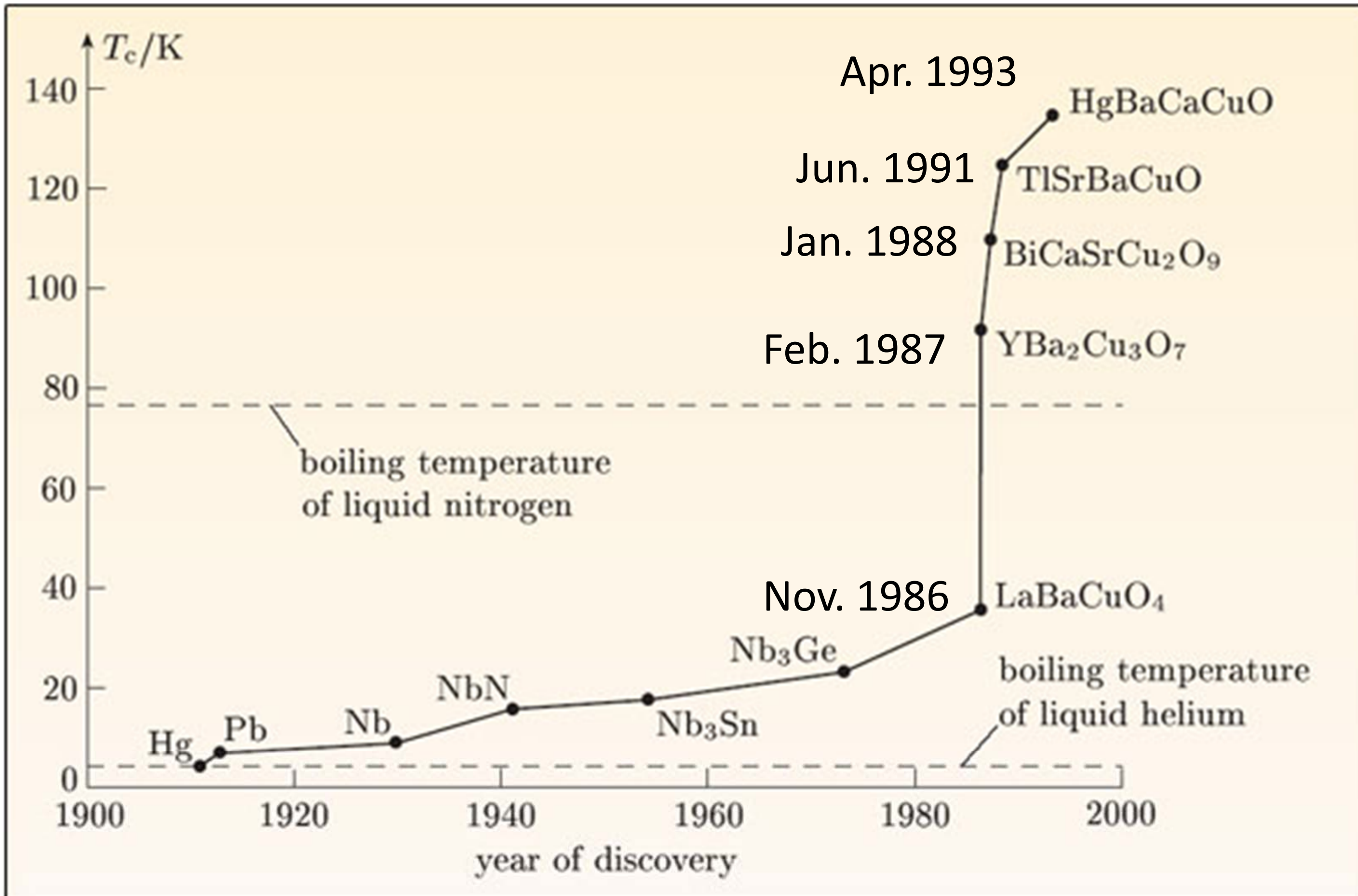
Lev Landau
1950

John Bardeen

Leon Cooper
1957

Robert Schrieffer

The rise of superconductivity



The impact

Cover Page, Time Magazine (May 11, 1987)

The major players : After 1986

Alexei Abrikosov
(small q phonons)

Bob Laughlin
(competing phases)

Phil Anderson
(RVB; interlayer tunneling)

Karl Mueller
(bipolarons)

Bob Schrieffer
(spin bags)

Tony Leggett
(interlayer Coulomb)

(Courtesy : Michael Norman)

Current status of the theory of high temperature superconductivity

- Classic BCS theory not enough
- 2 e^- pairs in real space – Analogous to Cooper pairs in the BCS theory
- The pairs are d-wave (L=2, S=0)
- Quasiparticles exist below T_C
- Still an open-ended problem

Thank you!

QUESTIONS?