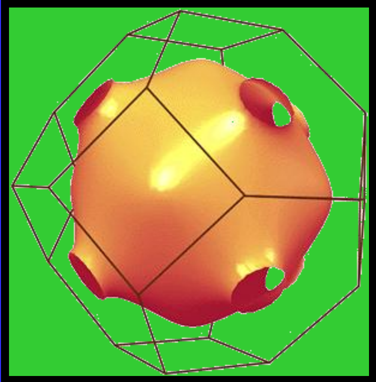


100-lecie nadprzewodnictwa

Hg

Nadprzewodnictwo

Wysokotemperaturowe

MgB2+inne

FeSe,As

CeCu2Si2

Kołodziejczyk Andrzej

Akademia Górniczo- Hutnicza

Wydział Fizyki i Informatyki Stosowanej

Katedra Fizyki Ciała Stałego

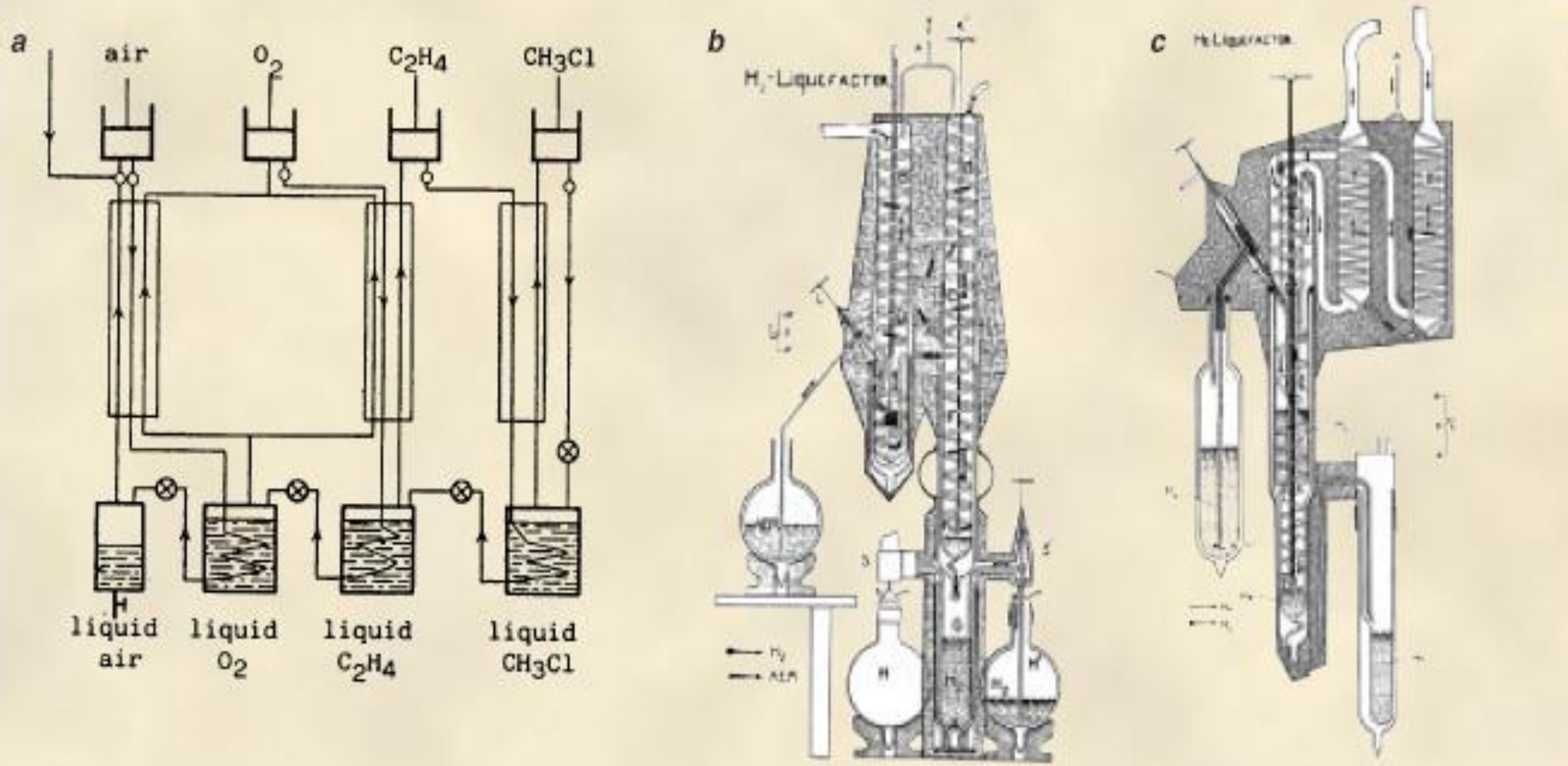
Seminarium wydziału, 8 Kwiecień 2011, w dzień odkrycia nadprzewodnictwa

Karol Olszewski i Zygmunt Wróblewski
1883

1846-1915

1845-1888

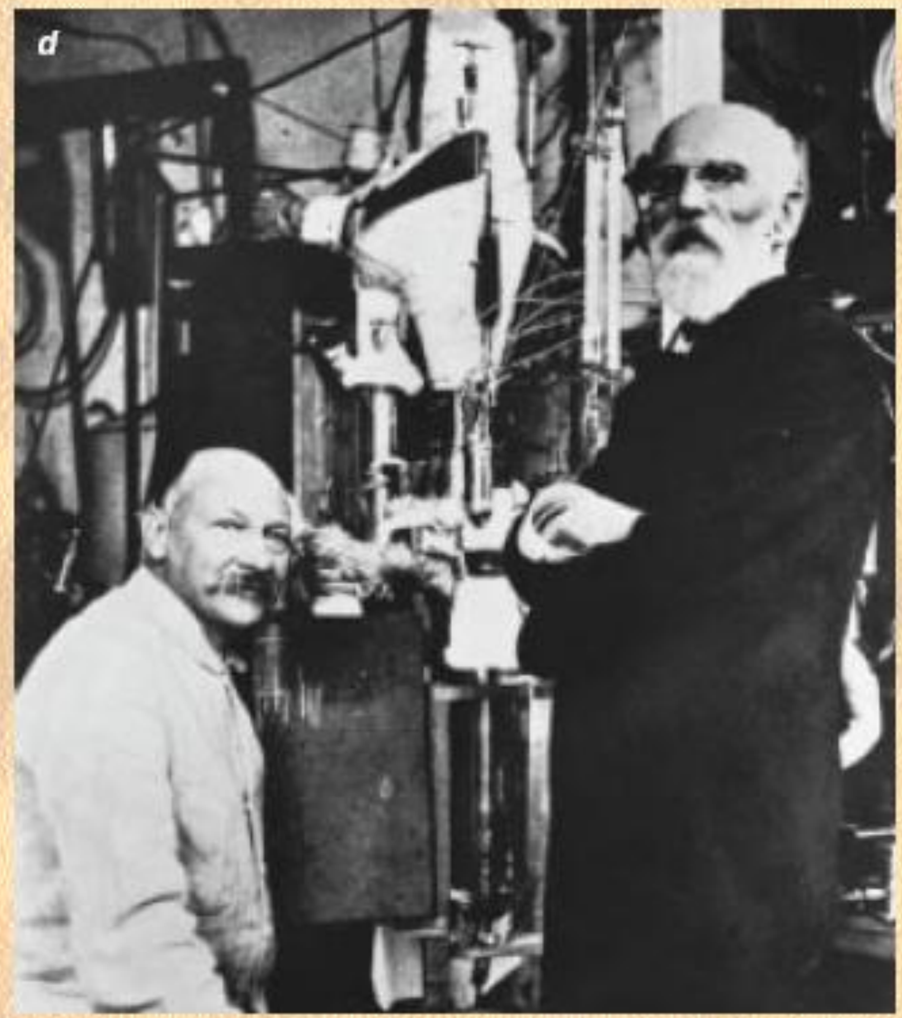
Muzeum UJ



APARATURA DO PROCESU KASKADOWEGO skonstruowana przez Onnesa w 1892 roku *(a)* produkowała 14 l ciekłego powietrza na godzinę. Bez ciekłego powietrza nie mogłaby działać skraplarka wodoru *(b)*, udoskonalona przez Onnesa w 1906 roku. Gazowy wodór przepływał przez układ do naczynia chłodzonego ciekłym azotem, a następnie do zaworu, przez który przechodząc, rozprężał się, wskutek czego ulegał skropleniu. Ciekły wodór był gromadzony, a reszta gazu zawracana do kompresora. W 1908 roku Onnes skonstruował pierwszą skraplarkę helową *(c)*. Na fotografii z 1911 roku *(d)* pozuje na jej tle wraz ze swym mentorem, Johannesem Diderikiem van der Waalsem, a 10 lat później – ze swym głównym asystentem Gerritem Flimem *(e)*.

1) Rudolf de Bruyn Ouboter, *Heike Kamerlingh Onnes's Discovery of Superconductivity* Scientific American March 1997.
2) PHYSICS TODAY, March 2008, page 36

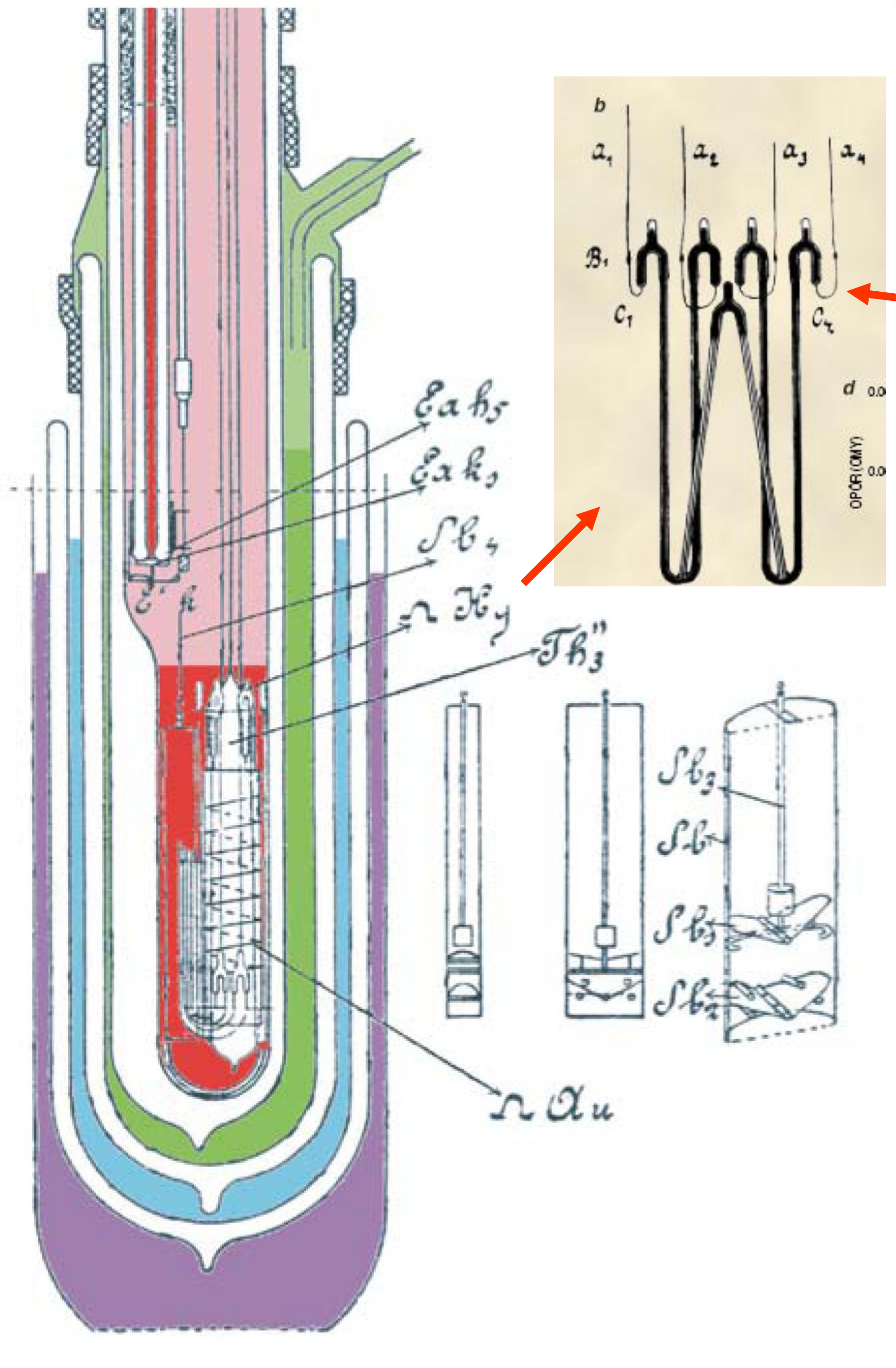
CH3Cl,Chloro-metan 249K, C2H4,Etylen 169.3K, O_2 90.2 K, powietrze ok.,82 K, H 20 K, He 4.22 K



Za zgodą LABORATORIUM ONNESA, Uniwersytet w Lejdzie, Holandia

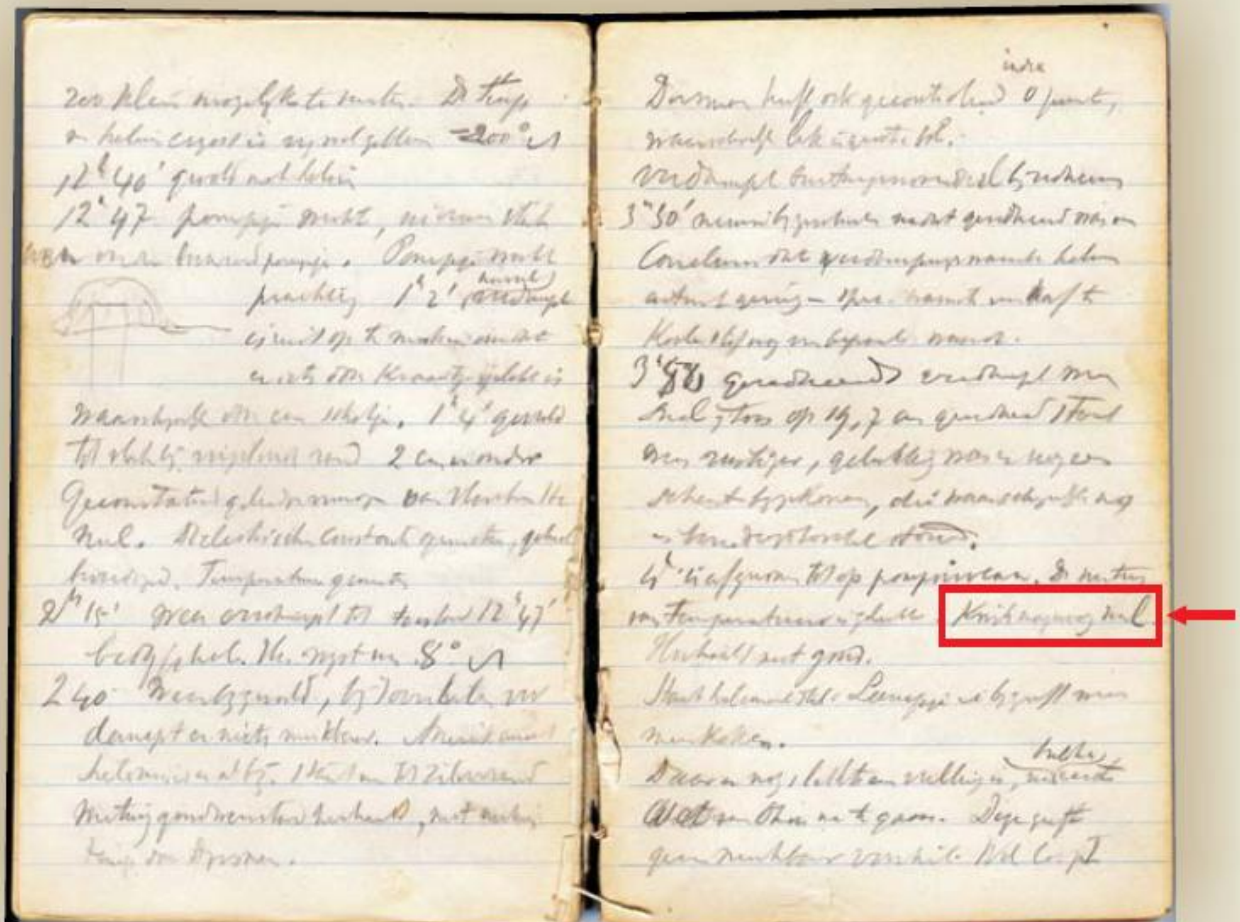
Heike Kamerlingh Onnes, Johannes Diderik van der Waals

3) IEEE/CSC & ESAS EUROPEAN SUPERCONDUCTIVITY NEWS FORUM
No. 15, January 2011,
4) Physics Today 63, No. 9, 38-42 (2010).
Dirk van Delft , Peter Kes, The discovery of superconductivity.
Boerhaave Museum



At the beginning of April 1911, the new cryostat was ready for its first cooldown. It was a masterpiece of technical design, demonstrating amazing levels of glassblowing skill and fine mechanical construction6 (see figure 3).
The mercury resistor was constructed by connecting seven U-shaped glass capillaries in series, each containing a small mercury reservoir to prevent the wire from breaking during cooldown.

Figure 3. Bottom of the cryostat in which Heike Kamerlingh Onnes and coworkers carried out the 8 April 1911 experiment that first revealed superconductivity. The original drawing is from
reference 6, but colors have been added to indicate of various cryogenic fluids within the intricate dewar: alcohol (purple), liquid air (blue), liquid and gaseous hydrogen (dark and light green), and
liquid and gaseous helium (dark and light red). Handwritten by Gerrit Flim are labels for the mercury and gold resistors (Ω Hg and Ω Au), the gas thermometer (Th3), components at the end (a) of the transfer tube from the helium liquefier, and parts of the liquidhelium stirrer



1911

Figure 2. A terse entry for 8 April 1911 in Heike Kamerlingh Onnes's notebook 56 records the first observation of superconductivity. The highlighted Dutch sentence *Kwik nagenoeg nul* means "Mercury['s resistance] practically zero [at 3 K]." The very next sentence, *Herhaald met goud.* means "repeated with gold." (Courtesy of the Boerhaave Museum.)

The experiment was started at 7am and Kamerlingh Onnes arrived when helium circulation began at 11:20am. The resistance of the mercury fell with the falling temperature. ....The team established that the liquid helium did not conduct electricity, and they measured its dielectric constant. Holst made precise measurements of the resistances of mercury and gold at 4.3 K. Then the team started to reduce the vapor pressure of the helium, and it began to evaporate rapidly.
They measured its specific heat and stopped at a vapor pressure of 197 mmHg (0.26 atmospheres), corresponding to ***about 3 K***.
Exactly at 4pm, says the notebook, the resistances of the gold and mercury were determined again. The latter was, **"Mercury practically zero."**
Kamerlingh Onnes was simply thinking how right he had been to choose mercury. Zero resistance was what he expected to find in extremely pure metals at liquid-helium temperatures. 1910 The resistance of a platinum wire became constant below 4.25 K. Furthermore, the Leiden lab had a lot of experience with the purification of mercury by distillation, and the material would not be contaminated by the necessity of drawing a thin wire.(The liquid mercury in a capillary simply freezes at 234 K [–39 °C].

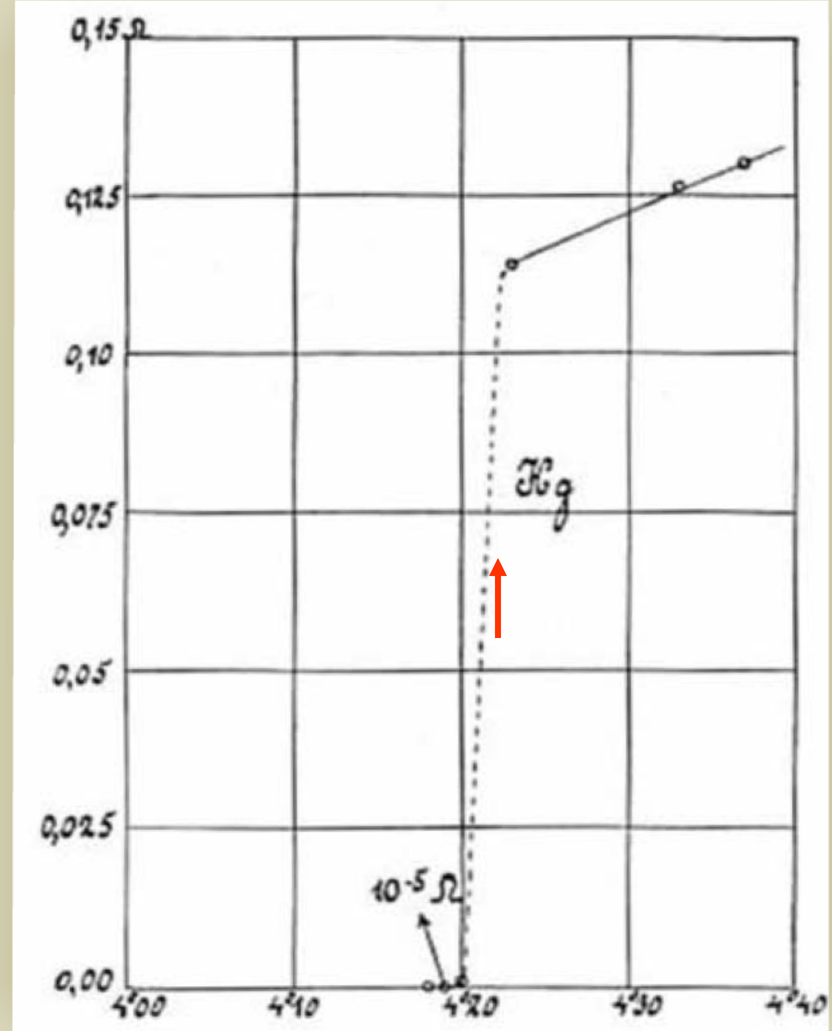


Figure 4. Historic plot of resistance (ohms) versus temperature (kelvin) for mercury from the 26 October 1911 experiment shows the superconducting transition at 4.20 K. Within 0.01 K, the resistance jumps from unmeasurably small (less than 10^{-6} Ω) to 0.1 Ω. (From ref. 9.)

the cryostat—just in case the helium transfer worked.

The mercury resistor was constructed by connecting seven U-shaped glass capillaries in series, each containing a

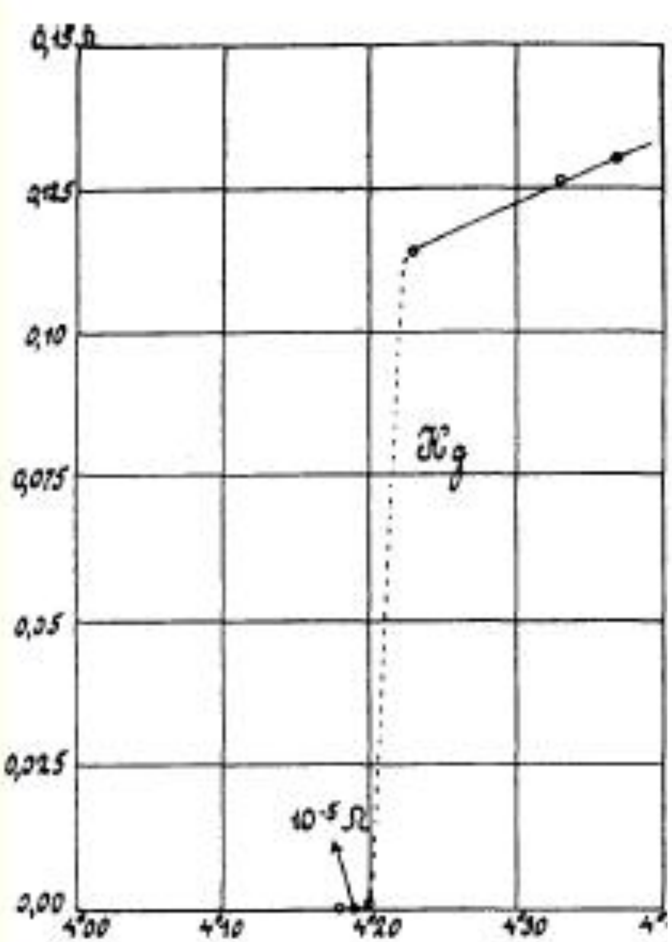
the historic entry, "practically zero." The notebook further records that the helium level stood quite still. That entry contradicts the oft-told anecdote about the key role of a "blue boy"—an apprentice from the instrument-maker's school Kamerlingh Onnes had founded. (The appellation refers to the blue uniforms the boys wore.) As the story goes, the blue boy's sleepy inattention that afternoon had let the helium boil, thus raising the mercury above its 4.2-K transition temperature and signaling the new state—by its reversion to normal conductivity—with a dramatic swing of the galvanometer.

The experiment continued into the late afternoon. At the end of the day, Kamerlingh Onnes finished with an intriguing notebook entry: "Dorsman [who had controlled and measured the temperatures] really had to hurry to make the observations." The temperature had been surprisingly hard to control. "Just before the lowest temperature [about 1.8 K] was reached, the boiling suddenly stopped and was replaced by evaporation in which the liquid visibly shrank. So, a remarkably strong evaporation at the surface." Without realizing it, the Leiden team had also observed the superfluid transition of liquid helium at 2.2 K. Two different quantum transitions had been seen for the first time, in one lab on one and the same day!

Three weeks later, Kamerlingh Onnes reported his results at the April meeting of the KNAW.[7] For the resistance of ultrapure mercury, he told the audience, his model had yielded three predictions: (1) at 4.3 K the resistance should be much smaller than at 14 K, but still measurable with his equipment; (2) it should not yet be independent of temperature; and (3) at very low temperatures it should become zero within the limits of experimental accuracy. Those predictions, Kamerlingh Onnes concluded, had been completely confirmed by the experiment.

For the next experiment, on 23 May, the voltage resolution of the measurement system had been improved to about 30 nV. The ratio $R(T)/R_0$ at 3 K turned out to be less than 10^{-7}. (The theory's normalizing parameter R_0 was the calculated resistance of crystalline mercury extrapolated to 0 °C.) And

Odkrycie nadprzewodnictwa (1911)



Heike Kamerlingh-Onnes (1853 - 1926)

From the sudden jump it was clear that a totally new and unexpected phenomenon had been discovered. Just one week later, Kamerlingh Onnes reported his discovery in Brussels to the elite of the physics world at the very first of the historic Solvay Conferences.[H. Kamerlingh Onnes, *Commun. Phys. Lab. Univ. Leiden. Suppl.* **29,**(Nov. 1911)].

supraconductor

About one year later, the Leiden team had discovered that Pb and Sn were also superconductors, with transition temperatures near 6 K and 4 K, respectively.[H. Kamerlingh Onnes, *Commun. Phys. Lab. Univ. Leiden* **133d** (May 1913), reprinted in *Proc. K. Ned. Akad. Wet.* **16**, 113 (1913)].

Solvay Congress 1911

GOLDSCHMIDT PLANCK RUBENS LINDEMANN HASENOHRL
NERNST BRILLOUIN SOMMERFELD M. DE BROGLIE HOSTELET
SOLVAY KNUDSEN HERZEN JEANS RUTHERFORD
LORENTZ WARBURG WIEN EINSTEIN LANGEVIN
PERRIN Madame CURIE POINCARÉ KAMERLINGH ONNES

An experiment on 17 January 1914 revealed the destructive effect of magnetic fields on superconductivity. For lead, the critical field at 4.25 K was only 600 gauss.[H. Kamerlingh Onnes, *Comm. Phys. Lab. Univ. Leiden* **139f** (Feb. 1914), reprinted in *Proc. K. Ned. Akad. Wet.* **16**, 987 (1914).]

1914

Persistent currents

Kamerlingh Onnes next concentrated on the question of how small the “microresidual” resistance actually was in the superconducting state. He designed an experiment to measure the decay time of a magnetically induced current in a closed superconducting loop—a small multiloop coil of lead wire cooled to 1.8 K. To probe the decay of the current circulating in the closed loop after the induction magnet had been removed, he used a compass needle placed close to the cryostat and precisely to its east. To compensate for the geomagnetic field and calibrate the supercurrent, he positioned an almost identical copper coil on the other side of the compass (see figure 5).

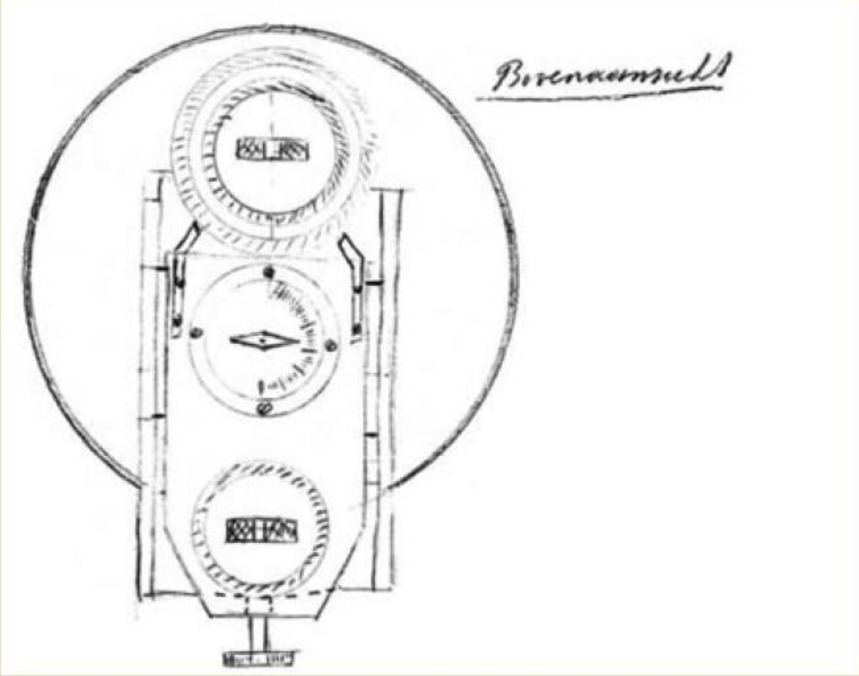


Figure 5. Gerrit Flim’s drawing of the setup for a persistent-current experiment in May 1914. In this top view (*bovenaanzicht*), one sees a compass needle pointing north between a superconducting lead coil (west) immersed in liquid helium in a double-walled dewar and a normally conducting copper coil (east) of equal size immersed in liquid air in a single-walled vessel. The copper coil, whose connection to a current source and galvanometer is not shown, calibrates and monitors the persistent current in the superconducting coil. When both currents are equal, the compass points due north. (Courtesy of the Boerhaave Museum.)

In 1932, six years after Kamerlingh Onnes’s death Flim flew to London with a portable dewar containing a lead ring immersed in liquid helium and carrying a persistent current of 200 A. He made the trip to demonstrate the most sensational effect of superconductivity at a traditional Friday evening lecture of the Royal Institution. That was the same august venue at which James Dewar had demonstrated the liquefaction of hydrogen in 1899.

1933 Walther Meissner i Robert Ochsenfeld dokonali odkrycia zjawiska usuwania z wnętrza nadprzewodnika pola magnetycznego (idealny diamagnetyzm).

en

ns

Supraleiter (.

gnetisch) fast ungehindert durch sie hindurch. Nach den bisherigen Anschauungen war zu erwarten, daß die Kraftlinienverteilung unverändert bleibt, wenn man die Temperatur, ohne an dem äußeren Magnetfeld etwas zu ändern, bis unter den Sprungpunkt erniedrigt. Unsere Versuche an Zinn und Blei haben im Gegensatz hierzu folgendes ergeben:

1. Beim Unterschreiten des Sprungpunktes ändert sich die Kraftlinienverteilung in der äußeren Umgebung der Supraleiter und wird nahezu so, wie es bei der Permeabilität 0, also der diamagnetischen Suszeptibilität $-\frac{1}{4\pi}$, des Supraleiters zu erwarten wäre.

2. Im Inneren eines langen Bleiröhrchens bleibt — trotz der dem 1. Effekt entsprechenden Änderung des Magnetfeldes in der äußeren Umgebung — beim Unterschreiten des Sprung

netfeld im

Es wur
Bei der ers
von etwa 1
verwendet.
10 mm Län
und mit ei
so daß der
Es ergab si
der Würzb
Verhältnis
Sprungpun
zylinder n
der Wert 1
Nach der M
ter ergibt
nungen vo
Wert 0 de
Die Abwei
räumlichen
auch wege
Einkristall
Bei der
sches Blei
und 2 mm
ballistische
parallel zu
Inneren u
Im Innere
Unterschre
Feldstärke
5 Gauß. (
nicht festg

$B_w = B_z + M$

ale $B_w=0$ (stan Meissnera)

czyli

$\chi = M/B_z = -1/4\pi$

oraz $M = -B_z$

jest ujemne !!!–

nadprzewodnik

jest diamagnetykiem

setki razy mocniejszym

od miedzi!

¹ Berl. Ber. 16, 544 (1933).

war der Feldverlauf nach Unterschreiten des Sprungpunktes wieder etwa so, wie er bei der Permeabilität 0 des Supraleiters zu erwarten ist.

Beim Ausschalten des äußeren Feldes im supraleitenden Zustand des Bleis blieb das Feld im Inneren des Bleiröhrchens unverändert bestehen. Die Feldstärke in der äußeren Umgebung wurde nicht völlig Null. Zum Beispiel blieb an der Stelle der Bleioberfläche, wo im nichtsupraleitenden Zustand das Feld normal zu ihr stand, bei verschiedenen Meßreihen eine Feldstärke von 5—15% derjenigen des äußeren Feldes bestehen.

Wurde das äußere Feld nach Eintritt der Supraleitfähigkeit eingeschaltet, so blieb die Feldstärke im Inneren des Bleiröhrchens, wie schon nach den bisherigen Anschauungen zu erwarten war, Null. Der Kraftlinienverlauf in der äußeren Umgebung entsprach wieder etwa dem bei der Permeabilität 0 des Supraleiters zu Erwartenden.

Die Darstellung des Befundes durch Angabe der Änderung der makroskopisch definierten Permeabilität stößt vielleicht für die Vorgänge im Inneren des Bleiröhrchens auf Schwierigkeiten, da möglicherweise kein eindeutiger Zusammenhang zwischen Induktion und Feldstärke mehr besteht. Statt dessen kann man offenbar, tiefer gehend, die Ergebnisse darzustellen suchen durch Angabe von mikroskopischen oder makroskopischen Strömen in den Supraleitern unter Annahme der Permeabilität 1 an den stromfreien Stellen. Diese Ströme ändern sich offenbar spontan oder treten spontan neu auf beim Eintritt der Supraleitfähigkeit entsprechend dem neuen Effekt.

Mit dem neuen Effekt hängen folgende weitere experimentelle Befunde zusammen, die hier nur kurz erwähnt werden können:

Sind die parallelen Supraleiter durch eine an einem Ende angebrachte Verbindung hintereinandergeschaltet und wird durch sie von außen ein oberhalb der Sprungtemperatur eingeschalteter Strom hindurchgeschickt, so wird der Magnetfeldfluß zwischen den Supraleitern beim Unterschreiten des Sprungpunktes ohne Änderung des äußeren Stromes größer. Wird die Sprungkurve an Zinneinkristallen bei niemals unterbrochenem äußeren Strom aufgenommen, so treten auch ohne äußeres Magnetfeld Hysteresiserscheinungen auf, indem die Sprungpunkte beim Steigen und Sinken der Temperatur nicht zusammenfallen.

Schließlich sei noch auf die Analogie zum Ferromagnetismus hingewiesen, den schon früher Gerlach¹ in Parallele zur Supraleitfähigkeit gestellt hatte.

Berlin, Physikalisch-Technische Reichsanstalt, den 16. Oktober 1933. W. Meissner. R. Ochsenfeld.

¹ Metallwirtschaft 9, 1006 (1930).

Fritz Walther Meissner

Robert Ochsenfeld

Def.

R=0

B_w=0

Teoria

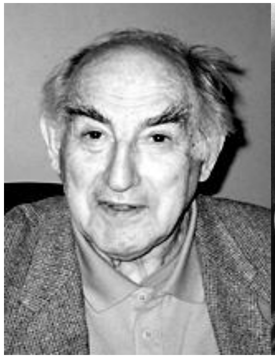
1933 Walther Meissner i Robert Ochsenfeld dokonali odkrycia zjawiska usuwania z wnętrza nadprzewodnika pola magnetycznego (idealny diamagnetyzm).

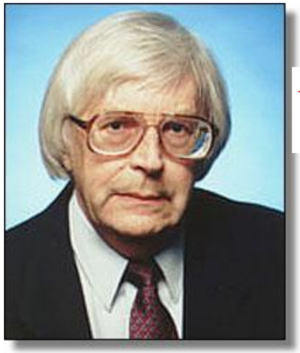
1935 bracia Fritz i Heinz Londonowie teoretyczny opis tych zjawisk w oparciu o **elektrodynamikę Maxwella**

$$\vec{B} = \vec{B}(0)\, e^{-x/\lambda_L}$$

1950 Witalij Ginzburg i Lew Landau opublikowali teorię nadprzewodnictwa na podstawiefenomenologicznej teorii przejść fazowych Landaua

1955-7 potem rozwiniętą przez Aleksija Abrikosova i Gorkova (**GLAG**)



$$\Psi(\underline{r}) = |\Psi(\underline{r})| e^{i\varphi(\underline{r})} = |\Psi(\underline{r})| e^{i(\underline{p}.\underline{r})/\hbar}$$

$$\lambda_{GL} = 9.37\times10^{7}\gamma^{1/2}(nS)^{-1}(1-t)^{-1/2}$$

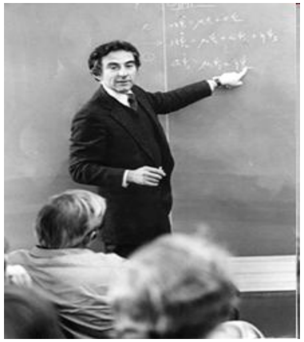
$$\xi_{GL} = 5.87\times10^{-17}(nS)(T_s\gamma)^{-1}(1-t)^{-1/2}$$

$$\kappa = 1.6\times10^{24}T_s\gamma^{3/2}(nS)^{-2} = \lambda_{GL}/\xi_{GL}$$

1957 pojawia się zadowalający mikroskopowy opis nadprzewodnictwa, J. Bardeena, L. Coopera i J. R. Schrieffera , teoria **BCS**

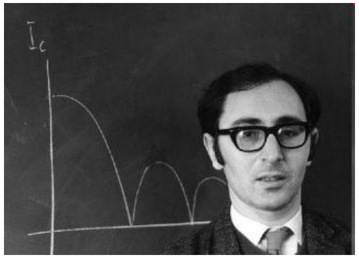
$$\Delta \approx 2\hbar\omega_D e^{-1/V_0 N(E_F^0)}$$

$$kT_C = 1.14\hbar\omega_B e^{-1/V_0 N(E_F^0)}$$

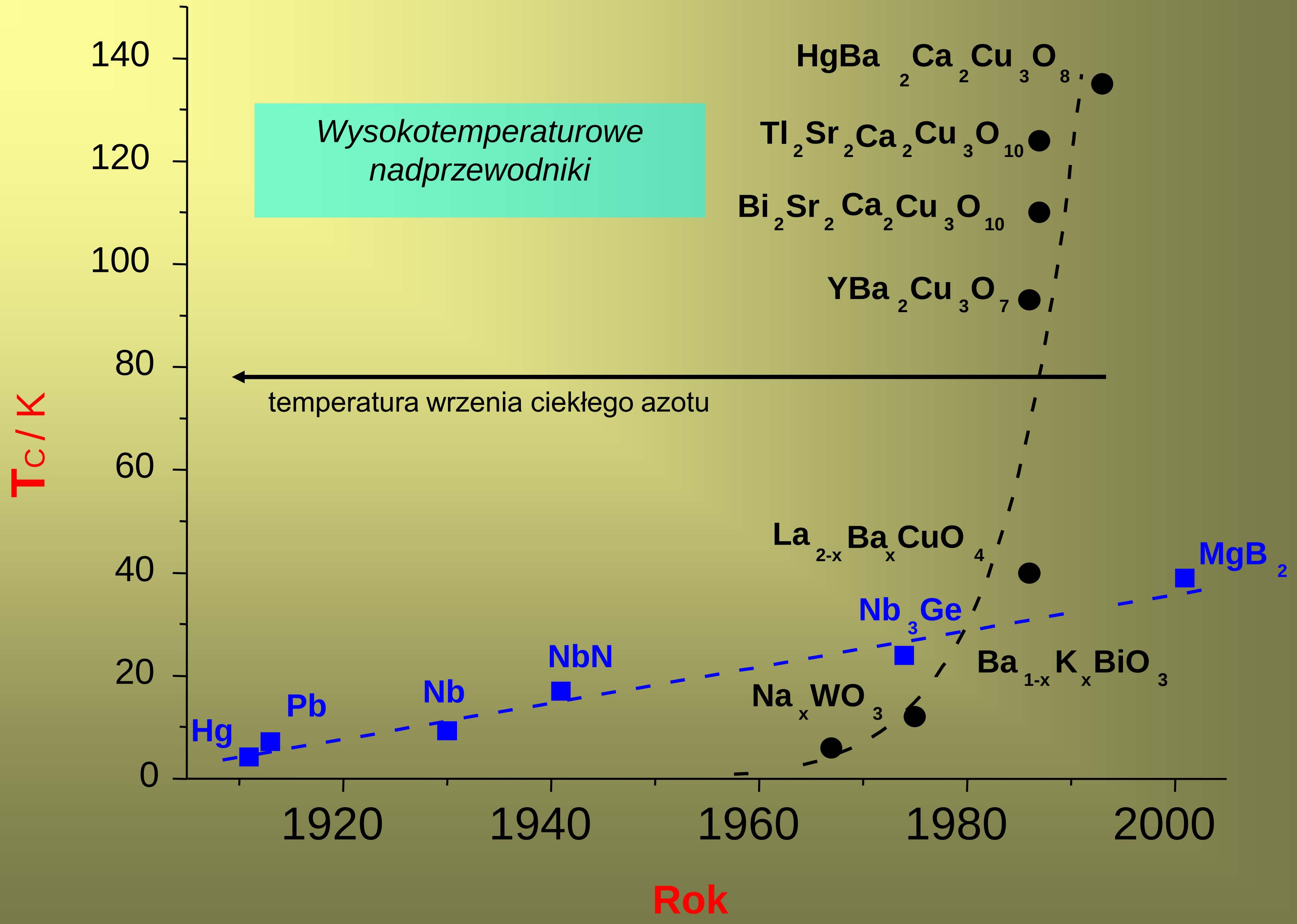




1962 Teoria tunelowania par przez złącze **S-I-S** – zjawisko B. Josephsona, Nobel 1973

$$I = I_c \sin\phi$$



SQUID



HgBa$_2$Ca$_2$Cu$_3$O$_8$
Tl$_2$Sr$_2$Ca$_2$Cu$_3$O$_{10}$
Bi$_2$Sr$_2$Ca$_2$Cu$_3$O$_{10}$
YBa$_2$Cu$_3$O$_7$
Wysokotemperaturowe nadprzewodniki
temperatura wrzenia ciekłego azotu
La$_{2-x}$Ba$_x$CuO$_4$
MgB$_2$
Nb$_3$Ge
Ba$_{1-x}$K$_x$BiO$_3$
NbN
Na$_x$WO$_3$
Nb
Pb
Hg
0
20
40
60
80
100
120
140
1920
1940
1960
1980
2000
Tc / K
Rok

ROK	T_c (K)	MATERIAŁ UWAGI
1911	4.154	Hg (odkrycie nadprzewodnictwa), Heike Kamerlingh-Onnes, Georg Holst, Universiteit Leiden, H. Kamerlingh Onnes, Leiden Comm. 120b 122b, 124c,(1911).
1913	7.196	Pb Heike Kamerlingh Onnes, Universiteit Leiden

ROK	T_c (K)	MATERIAŁ UWAGI
1932?	9.25	Nb (najwyższa temperatura dla czystego pierwiastka)
1932	11.5	NbC, ? Niobium carbide
1941	16.1	NbN, E. Justi, Berlin
1953	17.1	V_3Si, G.F. Hardy and J.K. Hulm, University of Chicago *Physical Review*. Vol. 89, No. 4 (February 1953):
1954	18.1	Nb_3Sn, B.T. Matthias, T.H. Geballe, S. Geller, E. Corenzwit Bell Telephone Lab., *Phys. Rev.* 95, (1954): 1435. **Nb_3Al**
1962	9	**$Nb_{1-x}Ti_x$** pierwszy materiał na drut nadprzewodzący, Westinghouse, I. Pfeiffer,H. Hillmann, Acta Met.16, 1429 (1968). Niemcy
1971	15	$PbMo_6S_8$ Fazy Chevrela ogólnie:$M_xMo_6X_8$ gdzie M jest metalem 4f a X jest S, Se,Te
1973	23.2	Nb_3Ge (konwencjonalny o najwyższejtemperaturze ⇐BCS)J.R. Gavaler, et al.,Applied Physics Letters. 23 (1973): 480

1961 Odkrycie kwantowania strumienia w nadprzewodniku

1962 Zjawisko Josephsona

Lata dwudzieste ?

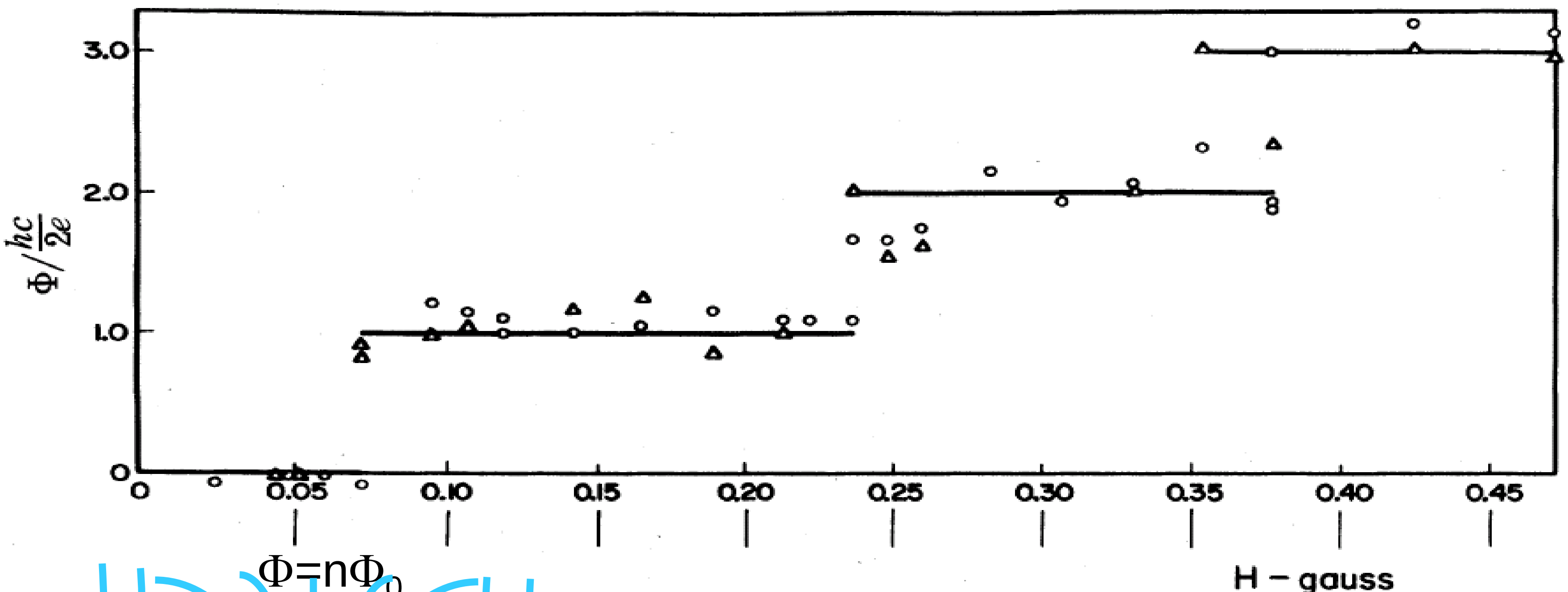
VOLUME 7, NUMBER 2 PHYSICAL REVIEW LETTERS JULY 15, 1961

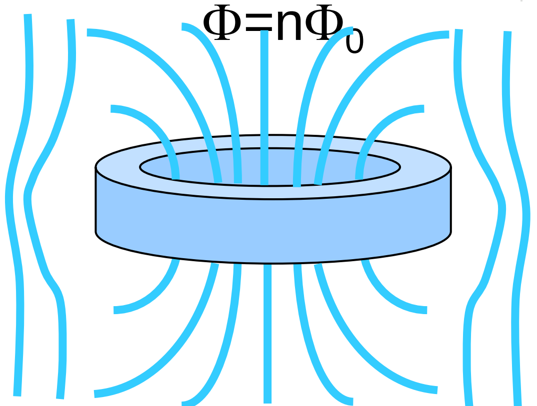
EXPERIMENTAL EVIDENCE FOR QUANTIZED FLUX IN SUPERCONDUCTING CYLINDERS*

Bascom S. Deaver, Jr., and William M. Fairbank
Department of Physics, Stanford University, Stanford, California

(Received June 16, 1961)

1961





Pole B jest wyrzucone z nadprzewodzącego pierścienia; „złapany" strumień jest skwantowany

$\Phi_0 = h/2e = 2 \cdot 10^{-15}$ Wb

$S = 1\,mm^2 \Rightarrow B = 2 \cdot 10^{-9}$ T

ROK	T_c (K)	MATERIAŁ	UWAGI
1972	8	PdH_x T. Skośkiewicz, Superconductivity in PdH and PdNiH system Phys.St.Solidi (a) 11 (1972) K123	
1974	300	Al-C-Al , K. Antonowicz, **Possible superconductivity at room temperature**, *Nature* **247**, 358-360 (8 February 1974) doi:10.1038/247358a0, Nicolas Copernicus University, Torun,	
1979	0.6	$CeCu_2Si_2$, początek ery nadprzewodników ciężko- fermionowych, F.Steglich et al. Phys.Rev.Lett., 43 (1979) 1892	
1980	2-3	Y_4Co_3, Y_9Co_7, **współistnienie VWIF + S po raz pierwszy !** Kołodziejczyk A., Sarkissian B.V.B., Coles B.R.,Magnetism and superconductivity in a transition metal compound Y_4 Co_3 ", J.Phys.F: Metal Phys. 10 (1980) L333	
1980	1.4 10,4	$(TTMTSF)_2$-X = ReO_4, PF_6 K. Bechgaard i D.Jerome, Dania b-$(BEDT\text{-}TTF)_2X$= $Cu(NCS)_2$ (T=0,9 K, p=12 kbar).W.Little „Organic superconductors" 1990	
1985		**Odkrycie fullerenów,** H W Kroto, J R Heath, S C O'Brien, R F Curl and R E Smalley, 'C60: Buckminsterfullerene',Nature, 318 (1985) 162	
1991	10-50	**Fuleryty nadprzewodzące,** Hebard, A.F.; et al. (1991). "Superconductivity at 18 K in potassium-doped C60". Nature 350, 600 Nobel 1996	

PdHx

1972

phys. stat. sol. (a) 11, K123 (1972)

Subject classification: 14.2; 21

Kamerlingh Onnes Laboratorium, Leiden

Superconductivity in the Palladium-Hydrogen and Palladium-Nickel-Hydrogen Systems

By

T. SKOSKIEWICZ[1)]

There is only one example of the enhancement of superconductivity due to hydrogen reported in the literature (1). It was found that the thorium hydride of the composition approximating Th_4H_{15} is superconducting with the transition temperature ranging from 8.05 to 8.35 K. Thorium itself is known to be superconducting with the critical temperature 1.37 K.

In this paper I would like to present the superconductivity discovered by electrical resistance measurements in palladium-hydrogen and palladium-nickel-hydrogen systems.

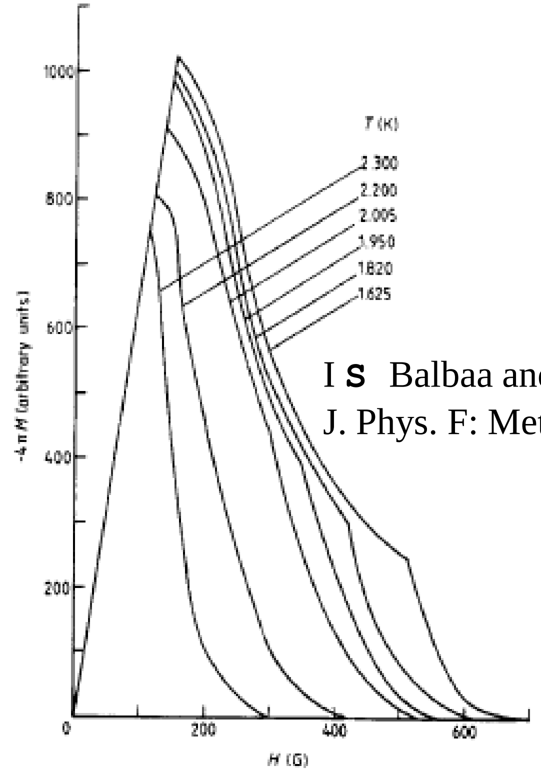
Samples of dimensions 70x2x0.1 mm^3 were used in the measurements. Platinum wires were used as the potential and current leads. The leads were spot welded to the samples.

Measurements of the electrical resistance of the samples before the hydrogen was introduced revealed no anomalous behaviour.

The samples were loaded with hydrogen by electrolysis of 0.1 n H_2SO_4 using a current density ranging from 50 to 150 mA/cm^2. The different hydrogen concentrations were obtained by controlled desorption of hydrogen from the samples. The amount of the hydrogen desorbed was determined with a mass spectrometer. Th precision of the H/Pd determinations was about 2%.

In Fig. 1 the electrical resistance of the palladium hydride sample is shown as a function of temperature. On the right-hand side of the figure the resistivity scale is given. Before the introduction of hydrogen the resistance of the sample was measured at liquid nitrogen temperature, and the geometrical factor was determined by comparison with White and Wood's data (2). The resistance of th sample with the atomic ratio H/Pd = 0.87 exhibits a broad superconducting tran-

1) Permanent address: Institute of Physical Chemistry, Polish Academy of Scier Warsaw.



I S Balbaa and F D Manchester
J. Phys. F: Met. Phys. **13 (1983) 395**

Figure 1. Magnetisation against applied magnetic field for a sample with H/Pd = 0.863, showing the kink in the magnetisation between H_{c_1} and H'_{c_1}. The magnetisation shown is for increasing applied magnetic field only. For this hydrogen concentration the kink is not apparent for temperatures above 2.005 K.

x = H/Pd	$H_{c_1}(0)$ (G)	$H_c(0)$ (G)	$H_{c_2}(0)$ (G)	$H'_{c_1}(0)$ (G)	T_c (K)
0.821	110	200	395	—	1.488
0.826	110	220	400	—	1.600
0.843	260	400	680	650	2.061
0.852	225	360	720	650	2.365
0.862	255	470	965	840	2.672
0.863	230	420	1000	880	2.695
0.875	250	480	1110	1000	3.090
0.881	230	455	1200	1000	3.305
0.887	250	480	1250	1075	3.590
0.905	290	515	1290	1250	4.158

1974

Letters to Nature

Nature **247**, 358-360 (8 February 1974) | doi:10.1038/247358a0

Al-C-Al

Possible superconductivity at room temperature

K. ANTONOWICZ
Physical Institute, Nicolas Copernicus University, Torun, Poland

Top of page

Abstract

IN this paper some observations are presented on an anomalous current in aluminum-carbon-aluminium (Al-C-Al) sandwiches, at room temperature, which in several respects behaves in the same way as the Josephson current might be expected to do. At first the switching effect was studied in Al-C-Al sandwiches discovered by Ovshinsky[1] and Pearson[2] in chalcogenide glasses and amorphous oxides. In carbon sandwiches subjected to proper electrical pulsing, changes in resistance of a factor of 1,000 were found, the changes being reversible and with a memory time of the order of a few days[3].

RTSC czy USO ?

Nadprzewodnictwo aktynowców

Table 1 *Actinide superconductors, with their transition temperature T_c and nearest f-f spacing d.*

Material	T_c(K)	*d* (nm)	*Material*	T_c(K)	*d* (nm)
α-U	<0.1[10,a]	0.31	U_2PtC_2	1.47[20]	0.35
β-U	0.75-0.85[11,b]	0.31	UAl_2Si_2	1.34[16]	0.41
γ-U	1.85-2.07[12,c]	0.29	UAl_2Ge_2	1.60[16]	0.42
UCo	1.22[13]	0.27/0.36[c]	UGa_2Ge_2	0.87[16]	0.42
U_6Fe	3.78[13]	0.32	URu_2Si_2	1.5[21,f]	0.41
U_6Mn	2.31[13]	0.32	UGe_2	0.4[22,g]	0.38
U_6Co	2.33[13]	0.32	UIr	0.14[23,h]	0.33-0.38[g]
U_6Ni	0.33[14]	0.32	UPd_2Al_3	1.9[24,i]	0.40
UPt_3	0.54[15,d]	0.41	UNi_2Al_3	1.0[25,j]	0.40
URu_3	0.145[16]	0.40	URhGe	0.25[26,k,j]	0.35
UBe_{13}	0.9[17]	0.51	$PuCoGa_5$	18.5[27]	0.42
U_3Ir	1.3[18]	0.40	$PuRhGa_5$	8.7[28]	0.43
U_5Ge_3	0.99[19,e]	0.29/0.36[c]	Am	0.79[29,l]	0.30

1969

1984

[a]T_c exceeds 2 K under pressure; [b]T_c depends on element
structure; [c]Two inequivalent U sites; [d]Superconductivity c
(T_N=5 K); [e]Superconductivity controversial; [f]Supercond
magnetism (T_N=17.5K); [g]Superconductivity pressure inc
coexists with weak itinerant ferromagnetism; [h]Four
superconductivity pressure induced at $P_c \approx$ 2.6 GPa, near t
ferromagnetism; [i]Superconductivity coexists with strong a
[j]Superconductivity coexists with weak magnetism (T_N
coexists with weak itinerant ferromagnetism (T_C=9.5 K); [l]T
as discussed in the text.

$CeCu_2Si_2$ (1979)

10 J. C. Ho, N. E. Phillips and T. F. Smith, *Phys. Rev. Lett.*, 1966, **17**, 694.
11 B. T. Matthias et al., *Science*, 1966, **151**, 985.
12 B. B. Goodman et al., in Proc. VII Int. Conf. on Low Temp. Phys., eds., G. M. Graham and A. C. Hollis Hallet, Univ. Toronto Press, Toronto, 1961, p. 350.
13 B. S. Chandraesekar and J. K. Hulm, Jr., *J. Phys. Chem. Solids*, 1958, **7**, 259.
14 H. H. Hill and B. T. Matthias, *Phys. Rev.*, 1968, **168**, 464.
15 G. R. Stewart, Z. Fisk, J. O. Willis and J. L. Smith, *Phys. Rev. Lett.*, 1984, **52**, 679.
16 H. R. Ott, F. Hulliger, H. Rudiger and Z. Fisk, *Phys. Rev. B*, 1985, **31**, 1329.
17 H. R. Ott, H. Rudiger, Z. Fisk and J. L. Smith, *Phys. Rev. Lett.*, 1983, **50**, 1595.
18 M. B. Maple, M. S. Torikachvili, C. Rossel, J. W. Chen, *Physica*, 1985, **135B**, 430.
19 Y. Onuki et al., *J. Phys. Soc. Jpn.*, 1989, **58**, 795; P. Boulet et al., *J. Alloys Compnds.*, 1997, **262-263**, 229.
20 B. T. Matthias, C. W. Chu, E. Corenzwit and D. Wohlleben, *Proc. Nat. Acad. Sci.*, 1969, **64**, 459.
21 W. Schlabitz et al., *Z. Phys. B*, 1986, **62**, 177.
22 S. S. Saxena et al., *Nature*, 2000, 406, 587.
23 T. Akazawa et al., *J. Phys. Condens. Mat.*, 2004, 16, L29.
24 C. Geibel et al., *Z. Phys. B*, 1991, **84**, 1.
25 C. Geibel et al., *Z. Phys. B*, 1991, **83**, 305.
26 D. Aoki et al., *Nature* 2001, 413, 613.
27 J. L. Sarrao et al., *Nature*, 2002, 420, 297.
28 F. Wastin et al., *J. Phys. Condens. Mat.*, 2003,15, S2279.
29 J. L. Smith and R. G. Haire, *Science*, 1978, **200**, 535.

J. Phys. F: Metal Phys., 10(1980)L333–7. Printed in Great Britain

Pierwsza praca 30 lat temu

1980, Y_4Co_3

Magnetism and superconductivity in a transition metal compound: Y_4Co_3

(potem Y_9Co_7)

A Kolodziejczyk†, B V B Sarkissian and B R Coles
Blackett Laboratory, Imperial College, London SW7, England, UK

Received 22 September 1980

Abstract. Measurements of AC susceptibility and electrical resistivity show the onset of magnetic order at about 5 K and the onset of superconductivity at about 1·5 K in samples of Y_4Co_3 which are believed to be single phase. Interpretations are considered which take into account the characteristic structure of the compound and different possible types of magnetic ordering.

J. Phys. F: Met. Phys. **14** (1984) 1277–1289. Printed in Great Britain

Magnetyczne fluktuacje spinowe

Spin fluctuations in a very weak itinerant ferromagnet: Y_4Co_3

A Kołodziejczyk and J Spałek

Department of Solid State Physics, Academy of Mining and Metallurgy (AGH), Al. Mickiewicza 30, 30-059 Kraków, Poland

Received 7 July 1983, in final form 23 September 1983

Abstract. We present a detailed comparison of the data on magnetic susceptibility and resistivity as a function of temperature with the predictions of the theory of weak itinerant ferromagnetism which takes spin fluctuations into account. The agreement is good provided we decompose the paramagnetic susceptibility into the Curie–Weiss and the temperature-independent parts. We also compare the results obtained for Y_4Co_3 with those for other weak ferromagnets. The Stoner enhancement factor and the molecular field at $T=0$ are determined. We also draw some conclusions about the electronic structure of Y_4Co_3 (or Y_9Co_7) above the superconducting transition temperature.

Współistnieniu obu zjawisk, **które w zasadzie powinny konkurować, a które zostało udowodnione w naszych późniejszych pracach podsumowanych w habilitacji w 1986 roku.**

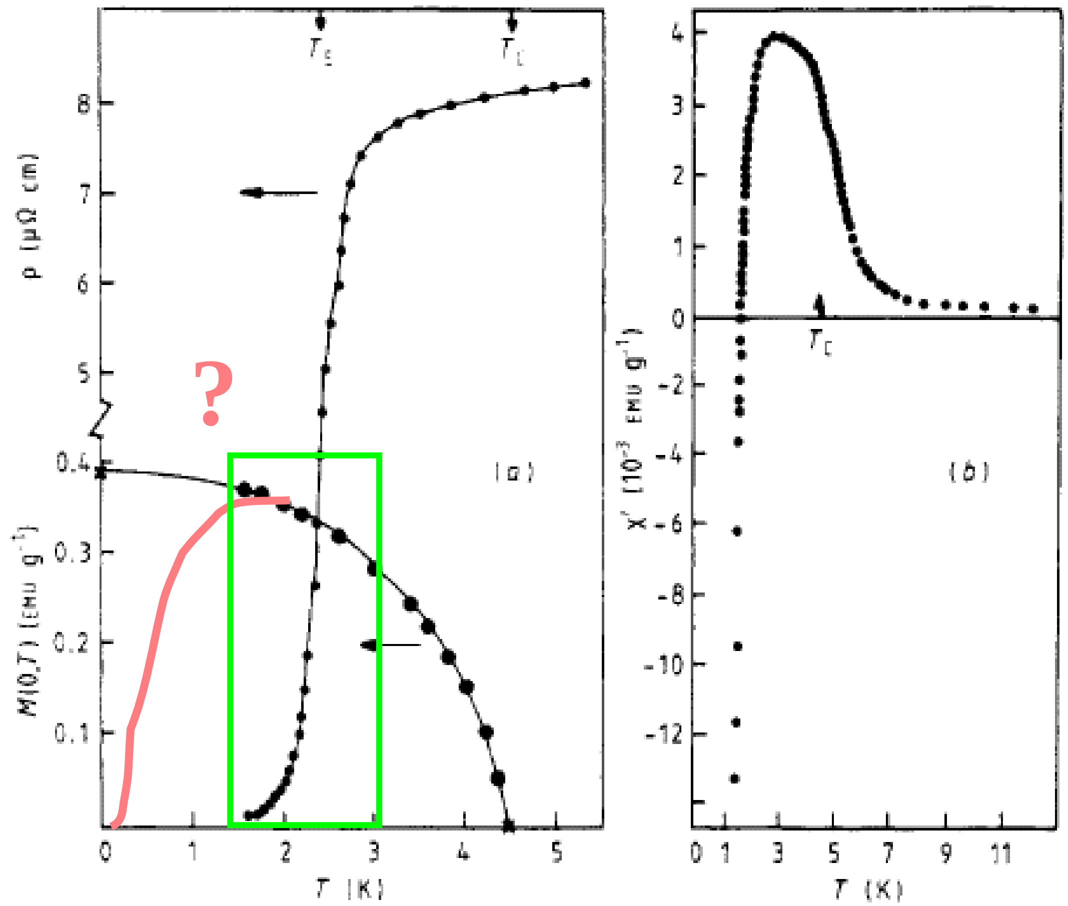


Figure 1. The temperature dependences of (*a*) resistivity, ρ, and spontaneous magnetisation, $M(0, T)$ and (*b*) ac susceptibility, χ', for Y_9Co_7.

1985

Kołodziejczyk A.,
"Magnetism and Superconductivity in Weak Ferromagnets",
Physica 130B (1985) 189

A.Kołodziejczyk - habilitacja
„Magnetism and superconductivity of Y_9Co_7 ,
Zesz.Nauk. AGH 1986

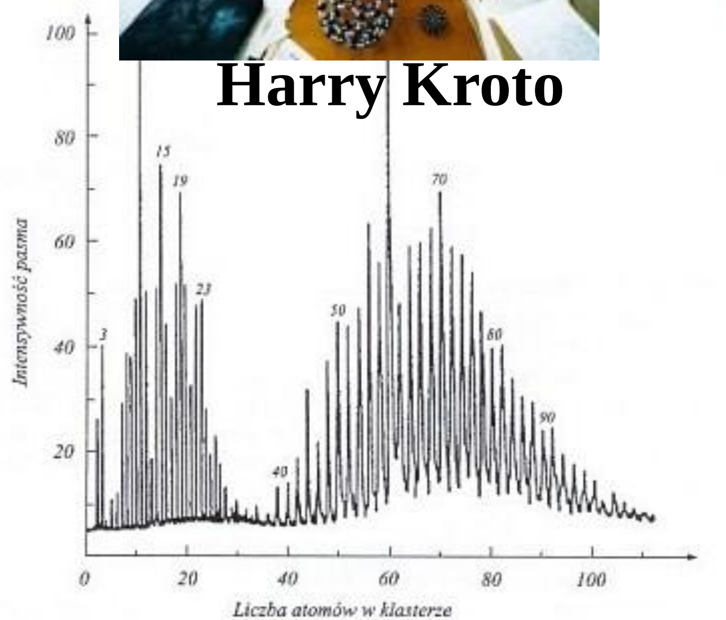
Pierwszy ferromagnetyczny nadprzewodnik pasmowy!!!

Odkrywcy fullerenów (Nobel 1996)

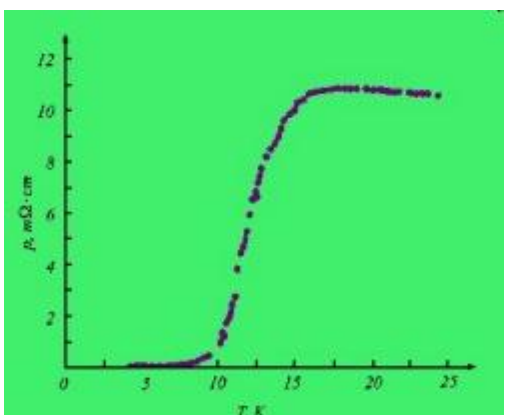
H W Kroto, J R Heath, S C O'Brien, R F Curl and R E Smalley, 'C60: Buckminsterfullerene', Nature, 318 (1985) 162

Harry Kroto

Richard Smalley



Bob Curl



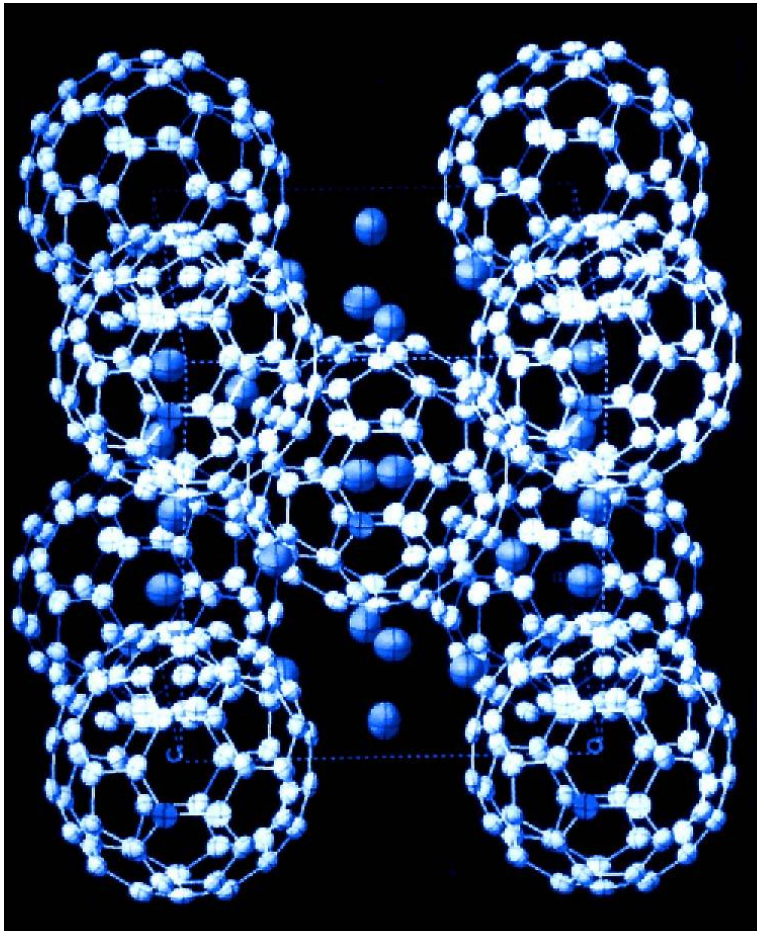
W 1965 r. Hannay i inni odkryli, że domieszkowany grafitem potas KC_8, w któym atomy potasu zajmują położenia między dwiema płaszczyznami przechodzi w stan nadprzewodzący w temperaturze T_c = 0,55 K. W 1991 r. zespół Haddona odkrył nadprzewodnictwo w K_xC_{60}. Hebard, A.F.; *et al.* (1991). "Superconductivity at 18 K in potassium-doped C60". *Nature* **350**: 600.

Fulereny (the Bucky balls)

Buckminsterfulleren zawiera 60 atomów węgla w wierzchołkach triacontaduohedronu o średnicy 7.1Å .

C_{60} samo nie jest nadprzewodnikiem, lecz może być domieszkowany metalami alkalicznymi, (które tworzą fcc sieć ze stałą 10Å) dając w wyniku nadprzewodnik A_3C_{60}

Compound	T_c
K_3C_{60}	19K
K_2RbC_{60}	22K
Rb_2KC_{60}	25K
Rb_3C_{60}	29K
Cs_3C_{60}	47K



Chociaż tutaj efekt izotopowy jest typu BCS-owskiego w C_{60} istnieją dane,że nadprzewodnictwo nie musi być konwencjonalne.

ROK	T_c (K)	MATERIAŁ	UWAGI

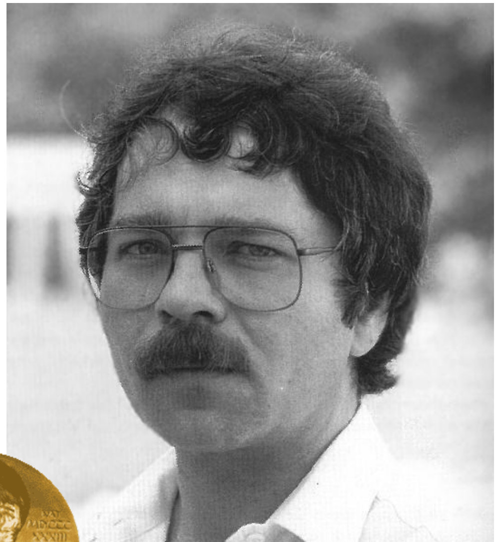
NADPRZEWODNIKI WYSOKOTEMPERATUROWE (WTN)

1986	30	$La_{1.85}Ba_{0.15}CuO_4$, J. Georg Bednorz, K.Alex Müller,IBM Zurich Research Lab.,*Zeitschrift für Physik B*. Vol. 64 (Sept. 1986): 189.
1987	93	$YBa_2Cu_3O_7$ (*Tc* powyżej ciekłego azotu) Wu, Ashburn, Torng, Hor, Meng, Gao, Huang, Wang, Chu,Univ. of Alabama and Univ. of Houston,PRL 58, No. 9 (March 1987): 908.
1988	80-120	$Bi_2Sr_2CaCu_2O_8$, H. Maeda, Y. Tanaka, M. Fukutomi, T. Asano Tsukuba Magnet Lab.,*Japan. Jour.Appl. Phys.* 27 (Jan. 1988) 209. **$Bi_{2.1}(Ca, Sr)_{n+l}Cu_nO_{2n+4+\delta}$** (n=1,2.3), J. L. Tallon in. (N.Zelandia)
1988	60-120	$Tl_2Ba_2Ca_2Cu_3O_{10}$, Z.Z. Sheng, A.M. Hermann,University of Arkansas,*Nature*. Vol. 332 (March 1988): 138.
1993	133	$HgBa_2Ca_2Cu_3O_8$, A. Schilling, M. Cantoni, J.D. Guo, H.R. Ott Lab. für Festkörperphysik, *Nature*. 363 (May 1993) 56. E.Antipov
1995	138	$Hg_{0.8}Tl_{0.2}Ba_2Ca_2Cu_3O_{8.33}$ (highest critical temperature) P. Dai, B.C. Chakoumakos, G.F. Sun, K.W. Wong, Y. Xin, D.F. Lu, Univ. Kansas, Lawrence, *Physica C*. 243, No. 3&4 (Feb. 1995)201.
1994	164	$HgBa_2Ca_2Cu_3O_8$ (pod ciśnieniem 30 GPa), Gao, Xue, Chen, Xiong, Meng, Ramirez, Chu, Eggert, Mao, University of Houston, Physical Review B. Vol. 50, No. 6 (August 1994) 4260.

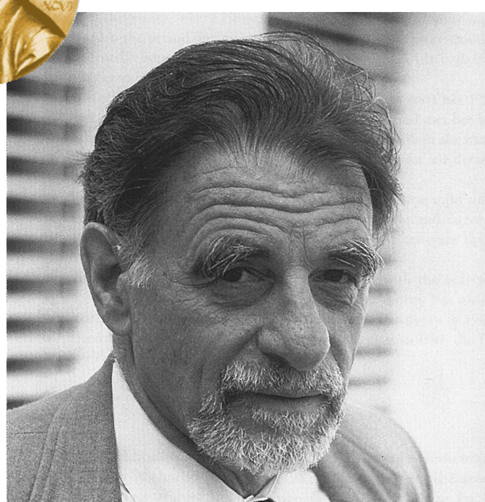
WTN DO DZISIAJ ....

WTN

1986




George Bednorz



Alex Muller

Z. Phys. B – Condensed Matter 64, 189–193 (1986)

Condensed Matter
Zeitschrift für Physik B

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

J.G. Bednorz and K.A. Müller
IBM Zürich Research Laboratory, Rüschlikon, Switzerland

Received April 17, 1986

25 lat

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 2*D* superconducting fluctuations of double perovskite layers of one of the phases present.

I. Introduction

"At the extreme forefront of research in superconductivity is the empirical search for new materials" [1]. Transition-metal alloy compounds of *A* 15 (Nb_3Sn) and *B* 1 (NbN) structure have so far shown the highest superconducting transition temperatures. Among many *A* 15 compounds, careful optimization of Nb – Ge thin films near the stoichiometric composition of Nb_3Ge by Gavalev et al. and Testardi et al. a decade ago allowed them to reach the highest $T_c=$ 23.3 K reported until now [2, 3]. The heavy Fermion systems with low Fermi energy, newly discovered, are not expected to reach very high T_c's [4].

Only a small number of oxides is known to exhibit superconductivity. High-temperature superconductivity in the Li – Ti – O system with onsets as high as 13.7 K was reported by Johnston et al. [5]. Their x-ray analysis revealed the presence of three different crystallographic phases, one of them, with a spinel structure, showing the high T_c [5]. Other oxides like perovskites exhibit superconductivity despite their small carrier concentrations, *n*. In Nb-doped $SrTiO_3$, with $n=2\times10^{20}$ cm^{-3}, the plasma edge is below the highest optical phonon, which is therefore unshielded [6]. This large electron-phonon coupling allows a T_c of 0.7 K [7] with Cooper pairing. The occurrence of high electron-phonon coupling in another metallic oxide, also a perovskite, became evident with the discovery of superconductivity in the mixed-valent compound $BaPb_{1-x}Bi_xO_3$ by Sleight et al., also a decade ago [8]. The highest T_c in homogeneous oxygen-deficient mixed crystals is 13 K with a comparatively low concentration of carries $n=2\text{-}4\times10^{21}$ cm^{-3} [9]. Flat electronic bands and a strong breathing mode with a phonon feature near 100 cm^{-1}, whose intensity is proportional to T_c, exist [10]. This last example indicates that within the BCS mechanism, one may find still higher T_c's in perovskite-type or related metallic oxides, if the electron-phonon interactions and the carrier densities at the Fermi level can be enhanced further.

Strong electron-phonon interactions in oxides can occur owing to polaron formation as well as in mixed-valent systems. A superconductivity (metallic) to bipolaronic (insulator) transition phase diagram was proposed theoretically by Chakraverty [11]. A mechanism for polaron formation is the Jahn-Teller effect, as studied by Höck et al. [12]. Isolated Fe^{4+}, Ni^{3+} and Cu^{2+} in octahedral oxygen environment

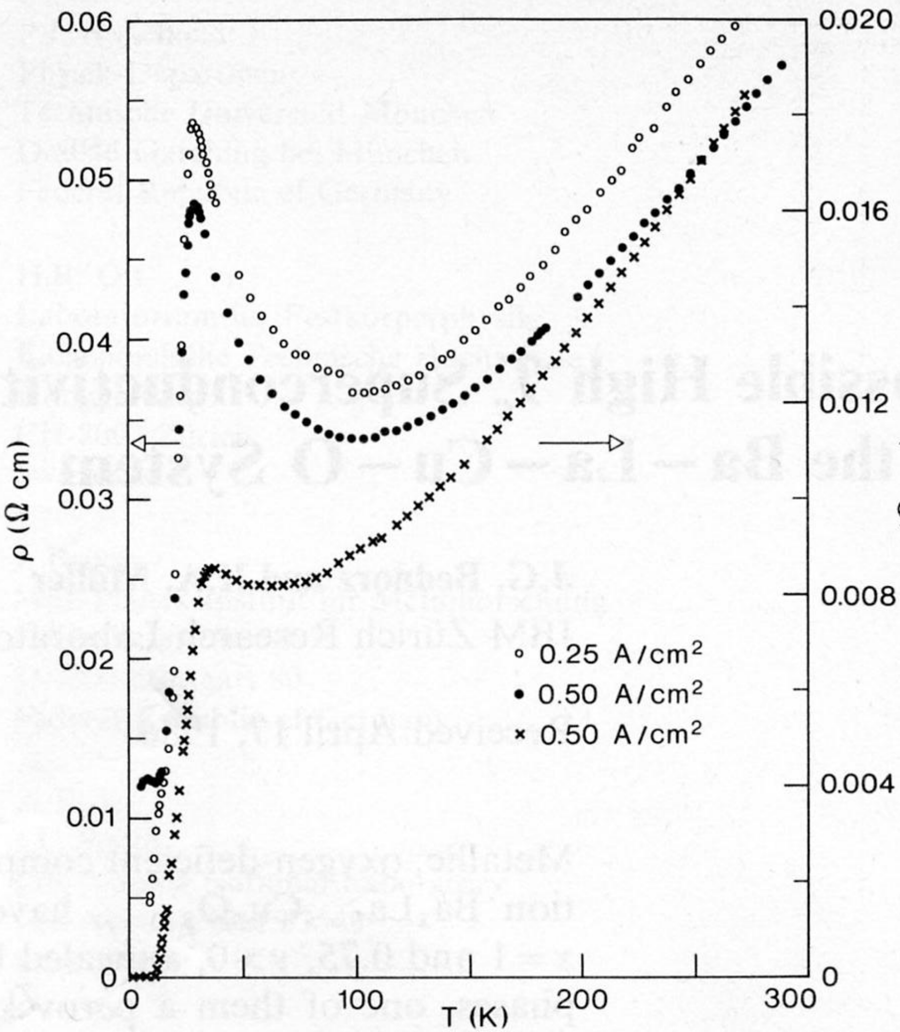


Fig. 1. Temperature dependence of resistivity in $Ba_xLa_{5-x}Cu_5O_{5(3-y)}$ for samples with $x(Ba) = 1$ (upper curves, left scale) and $x(Ba) = 0.75$ (lower curve, right scale). The first two cases also show the influence of current density

"$Ba_xLa_{5-x}Cu_5O_{5(3-y)}$"

W rzeczywistości był to to perowskit o stechiometrii $La_{2-x}Ba_xCu_2O_4$

Odkrycia niespodziewane

Kapica (1959) zdefiniował odkrycia niespodziewane jako takie, których nie można było ani przewidzieć, ani w pełni wyjaśnić w ramach wcześniej istniejących teorii. Według Kapicy w ciągu poprzednich 200 lat zdarzyło się tylko osiem takich niespodziewanych odkryć:

- Prąd elektryczny (Galvani, 1780)
- Efekt magnetyczny prądu elektrycznego (Oersted, 1820)
- Zjawisko fotoelektryczne (Hertz, 1887)
- Negatywny wynik doświadczenia Michelsona-Morleya (1887)
- Elektron (J. J. Thomson, 1897)
- Promieniotwórczość (Becquerel, 1896)
- Promieniowanie kosmiczne (Hess, 1912)
- Rozszczepienie uranu (Hahn i Strassmann, 1938)

Można zapewne dyskutować słuszność wyboru Kapicy (Dlaczego nie są włączone promienie X ?, dlaczego na liście jest elektron ?) i z pewnością można tę listę już rozszerzyć o kilka dalszych pozycji:

Cząstki dziwne (Rochester i Butler ,1947)

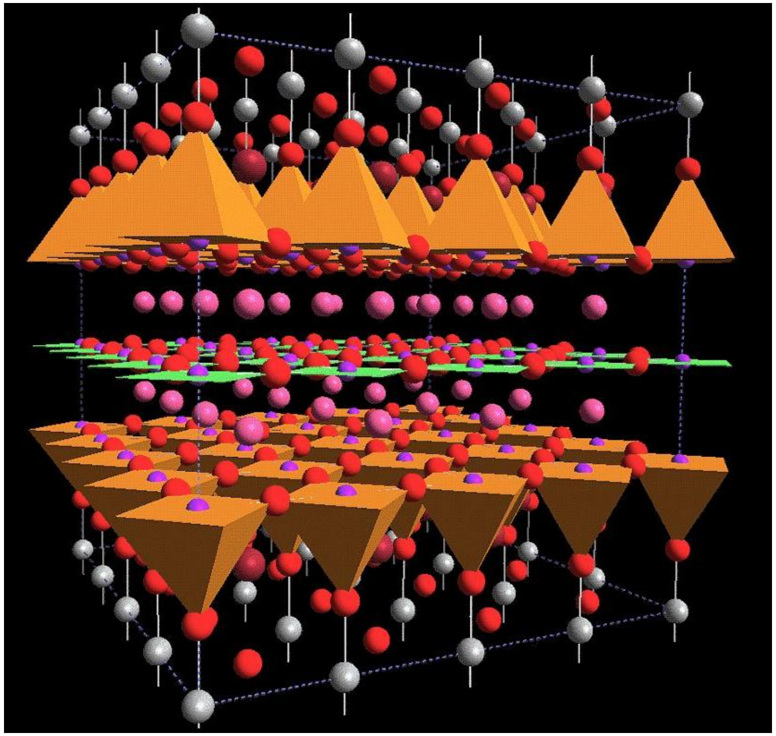
Kwazary (Schmidt, 1963)

Nadprzewodnictwo przy wysokich temperaturach (Bednorz i Müller, 1986)

z K.Wróblewski, Historia Fizyki

Inne WTN

214	$La_{2-x}Ba_xCuO_4$	35K	*1*
	$La_{2-x}Sr_xCuO_4$	38K	*1*
	$(La_{2-x}Sr_x)CaCu_2O_6$	60K	*2*
123	$YBa_2Cu_3O_7$	92K	*2*
2201	$Bi_2Sr_2CuO_6$	20K	*1*
2212	$Bi_2Sr_2CaCu_2O_8$	85K	*2*
2223	$Bi_2Sr_2Ca_2Cu_3O_{10}$	110K	*3*
	$TlBa_2CaCu_2O_7$	80K	*1*
	$TlBa_2Ca_2Cu_3O_9$	110K	*2*
	$TlBa_2Ca_2Cu_4O_{11}$	122K	*3*
	$HgBa_2CuO_4$	94K	*1*
	$HgBa_2Ca_2Cu_3O_8$	135K	*3*

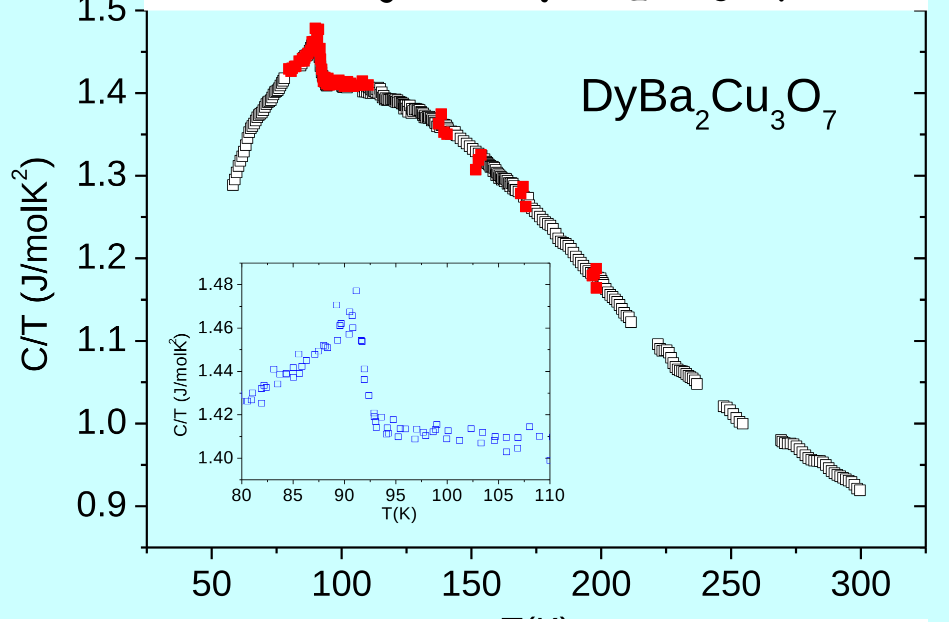


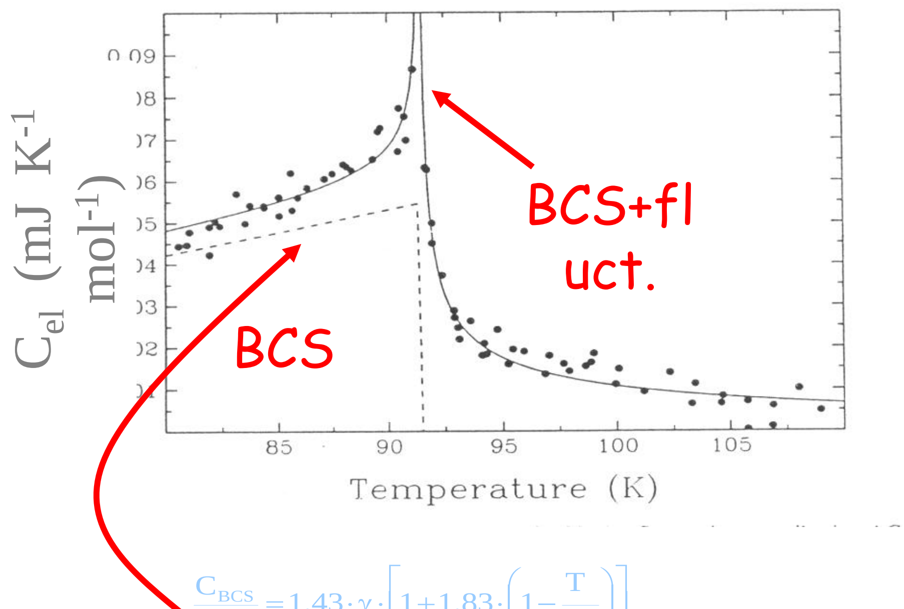
$HgBa_2Ca_2Cu_3O_8$

Liczba płaszczyzn CuO_2

Tymi się zajmujemy

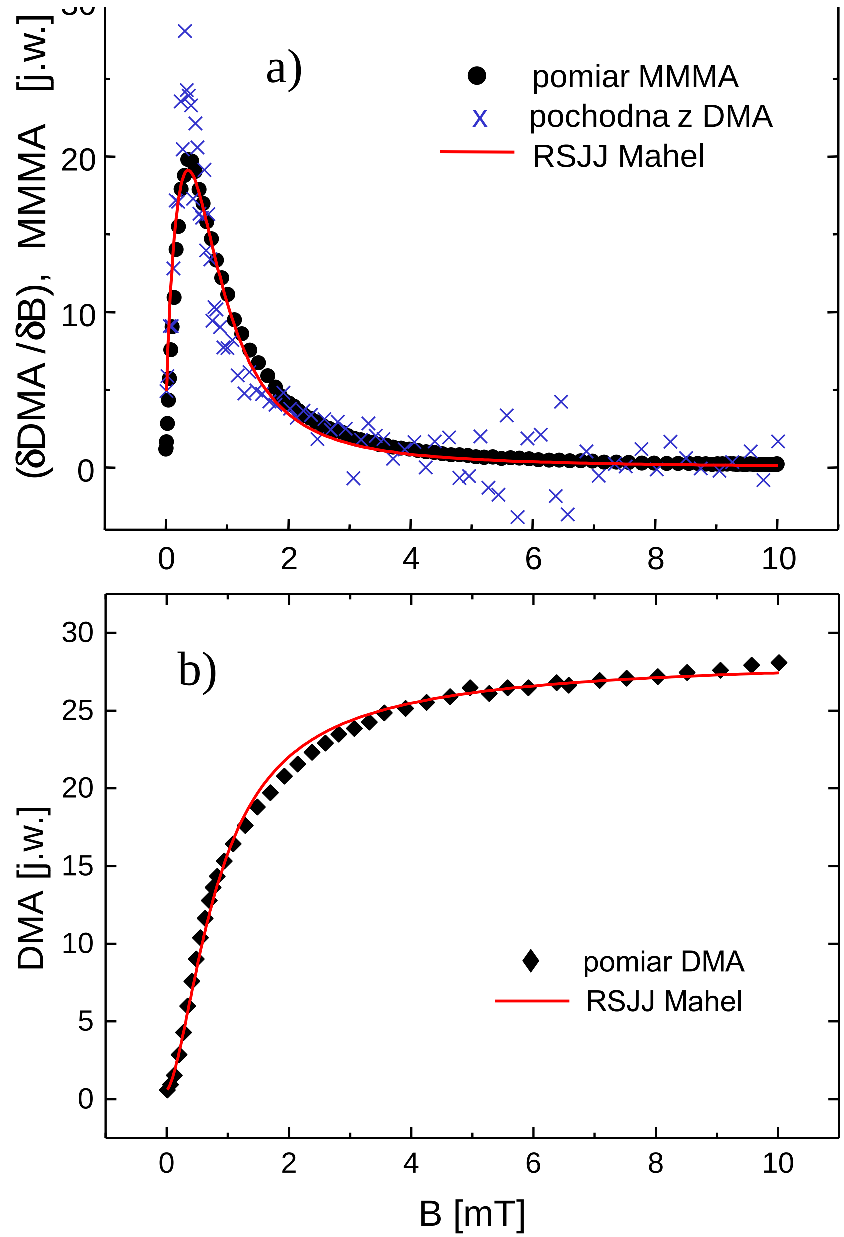
Fluktuacje : $DyBa_2Cu_3O_7$





$$\frac{C_{BCS}}{T} = 1.43 \cdot \gamma \cdot \left[1 + 1.83 \cdot \left(1 - \frac{T}{T_C}\right)\right]$$

Absorpcja mikrofal przez złącza J-J



J.Niewolski i inni (2001)

A. Kozłowski, Z. Tarnawski, A. Kołodziejczyk, J. Chmist, T. Ścieżor, R. Zalecki Physica C 184 (1991) 113

ROK	T_c (K)	MATERIAŁ	UWAGI

Nadprzewodniki „niekonwencjonalne", „egzotyczne"?

2000 0.4 UGe_2, S. S. Saxena et all "Superconductivity on the border of itinerant-electron ferromagnetism in UGe_2 ", Nature 406, 587, 2000

2001 0.25 URhGe D. Aoki et all. "Coexistence of superconductivity and ferromagnetism in URhGe", Nature 413, 613, 2001.

2001 40 MgB_2 dwuprzerwowy J. Nagamatsu et al, Nature 410, 63 (2001)

2001 2 Fe pod cisnieniem. K.Shimizu et al.. Superconductivity in the non-magnetic state of iron under pressure, Nature 412, 316-318 (19 Jul 2001)

2002 20 Li Superconductivity in compressed lithium at 20 K, K. Shimizu et al.. Nature 419, 597-599 (10 Oct 2002), (Superconductivity in oxygen K. Shimizu, Nature 393, 767-769 (25 Jun 1998))

2003 5 $Na_xCoO_2yH_2O$ **mokre nadprzeodniki**, Takada et al, Nature (London) 422, 53 (2003); J.Cava et al.., PRL (2004) 247001, Klimczuk PG Gdańsk

2004 4 C:B diament **pod ciś.100 atm,** E.A.Ekimov et al.,Nature 428 (2004)542

2006 0.35 Si:B, 11%, E. Bustarret et al. Superconductivity in heavily doped silicon, Nature 444 (2006) 465

2004 1 $Ca_{2-x}Sr_xRuO_4$ **i in.Ruteniany**, S.Nakatsui et al. PRL 93 (2004) 146401

2005 45 $Ag_5Pb_2O_6$ –type I dirty superconductor, S. Yonezawa, and Y. Maeno cond-mat/0509018, 1 Sep 2005

ROK	T_c (K)	MATERIAŁ cd	UWAGI

-------------------wkład polski z ostatnich lat -----------------------------

2002 2.2 **Mo_3Sb_7** Bukowski Z., Badurski D., Stępień-Damm J., Troć R., SSC 123(2002) 283 + kilkanaście późniejszych prac INTiBS PAN

B.Wiendlocha i inni PRB 78 (2008) 060507(R), C.Candolfi,... J.Toboła, B.Wiendlocha, S.Kaprzyk, PR B 79 (2009) 035114, Wiendlocha B, J Tobola, Sternik M, Kaprzyk S, Parlinski K , Oleś A M, Phys.Rev. B 78 (2008) 060507; Superconductivity of Mo_3Sb_7 from first principles, doktorat B. Wiendlochy (2009), AGH Kraków

2008 4.6 **$ThPt_4Ge_{12}$** D.Kaczorowski, V.H.Tran, Superconductivity in ...filled skutterudite $ThPt_4Ge_{12}$ PRB 77 (2008) 180504 + kilka dalszych prac

2009 0.68 **Ce_2PdIn_8** D.Kaczorowski, D.Gnida, A.P.Pikul, VH Tran, Superconductivity in a HF AF Ce_2PdIn_8 PRL 103 (2009) 027003

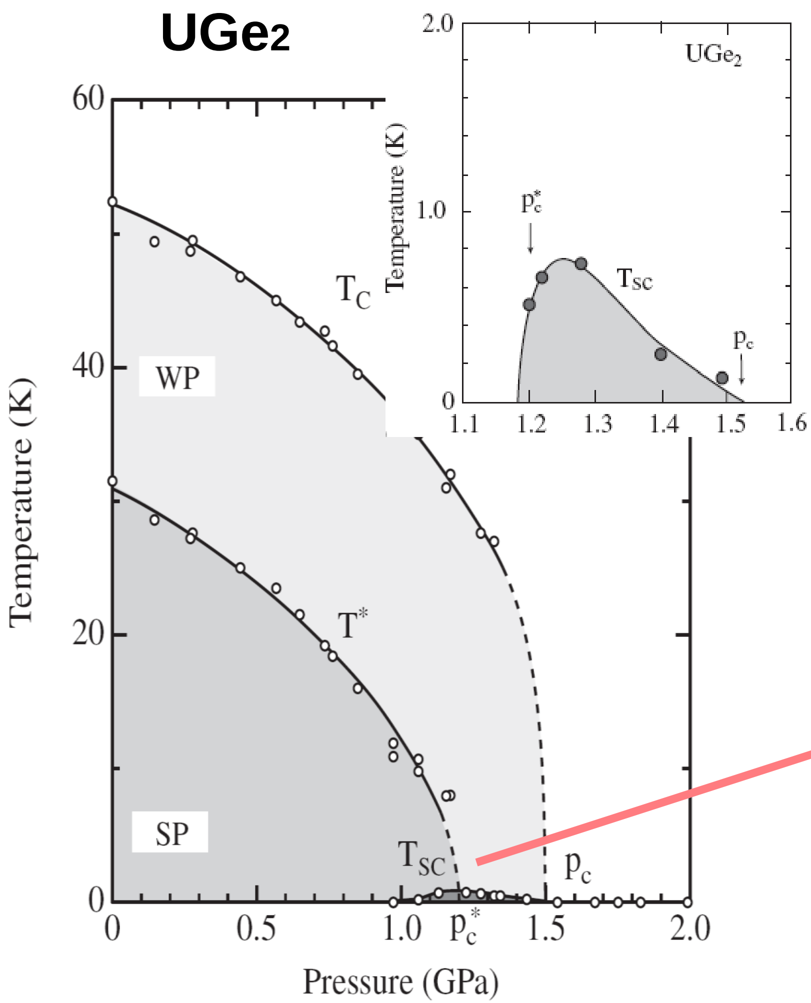
Współistnienie nadprzewodnictwa z ferromagnetyzmem !

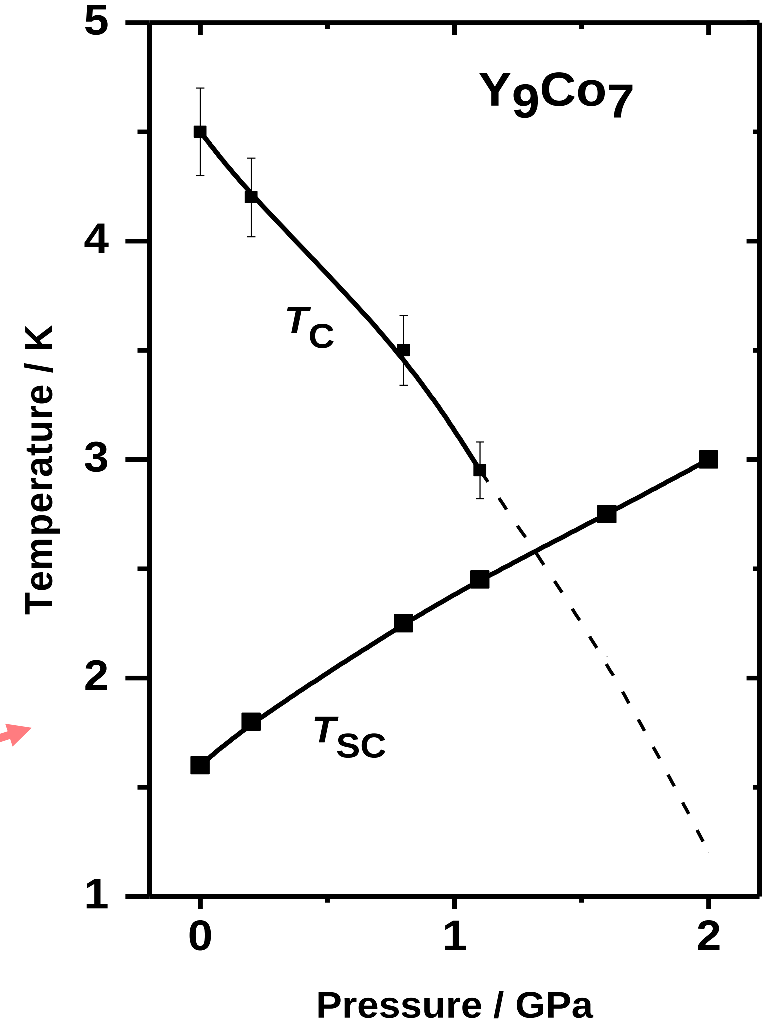
2000 0.4 **UGe_2** , S. S. Saxena et all "Superconductivity on the border of itinerant-electron ferromagnetism in UGe_2 ", Nature 406, 587, 2000

2001 0.25 **URhGe** D. Aoki et all. "Coexistence of superconductivity and ferromag-netism in URhGe", Nature 413, 613, 2001.

2007 0.5 **UCoGe**, N.T.Huy et al.., PRL 99 (2007) 067006 ≅ **Y_9Co_7**

PROBLEM 1: Współistnienie FM i SC

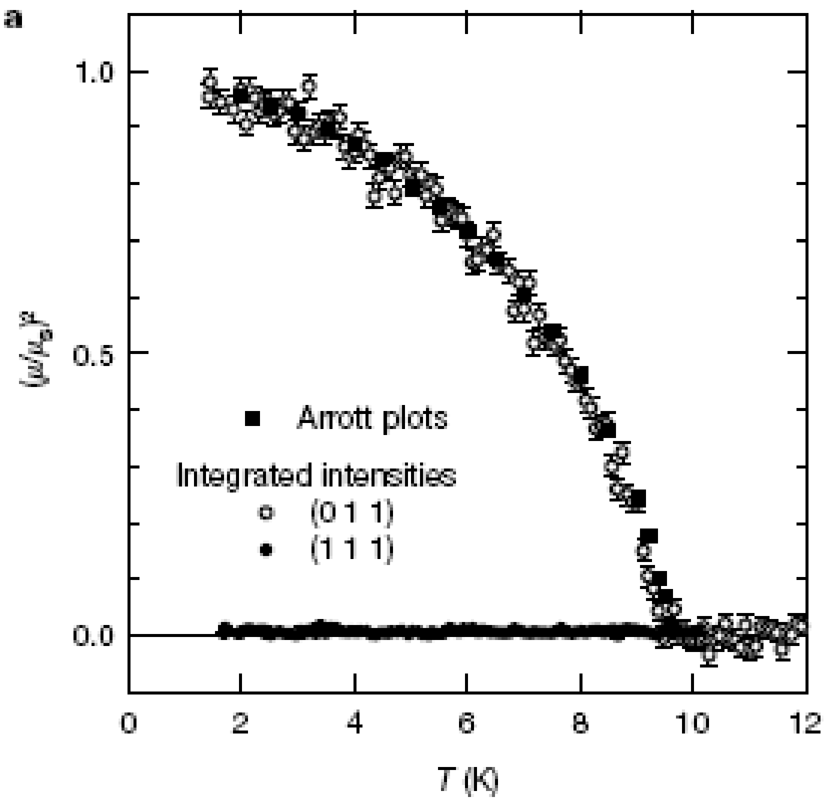


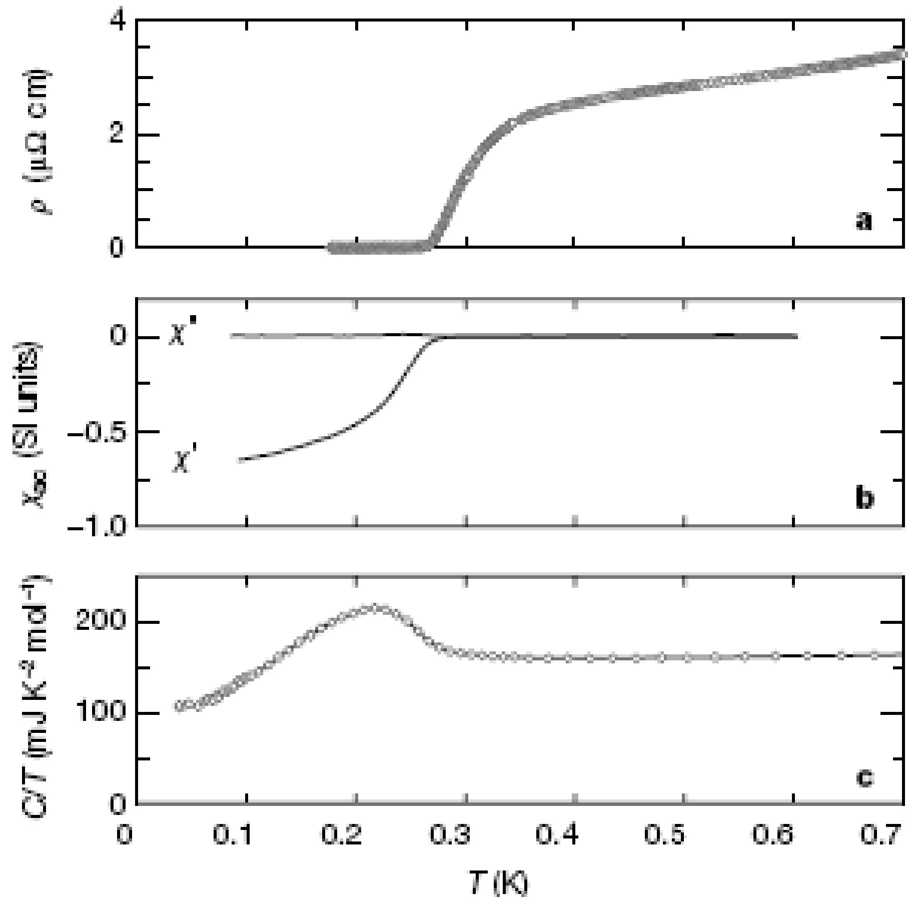


S. S. Saxena, et all. "*Superconductivity on the border of itinerant-electron ferromagnetism in UGe$_2$*", *Nature* **406**, 587, 2000.

A.Kołodziejczyk, C. Sułkowski, *J. Phys. F: Met. Phys.* **15**, 1151, 1985
C. Y. Huang, C. E. Olsen, W. W. Fuler, J. H. Huang, S. A. Wolf, *Solid State Commun.* **45**, 795, 1983.

URhGe

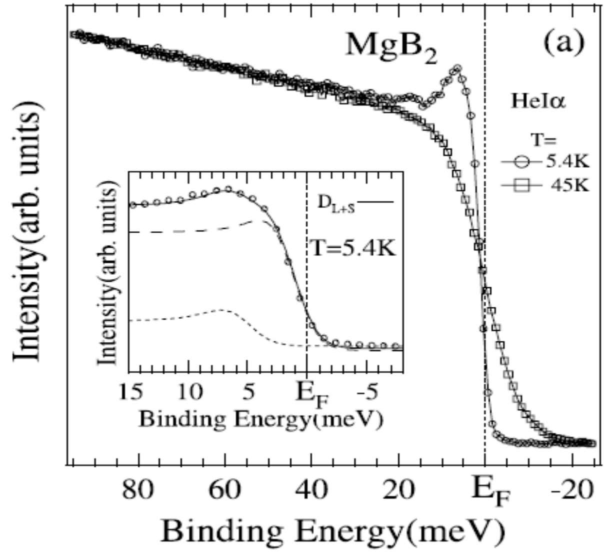




***T*c = 10 K** ***T*sc ≅ 0.3 K**

D. Aoki, A. Huxley, E. Ressouche, D. Braithwaite, J. Floquet, J. P. Brison, E. Lhotel, C. Paulsen, "Coexistence of superconductivity and ferromagnetism in URhGe", *Nature* **413**, 613, 2001

ica C 385 (2003) 85–90



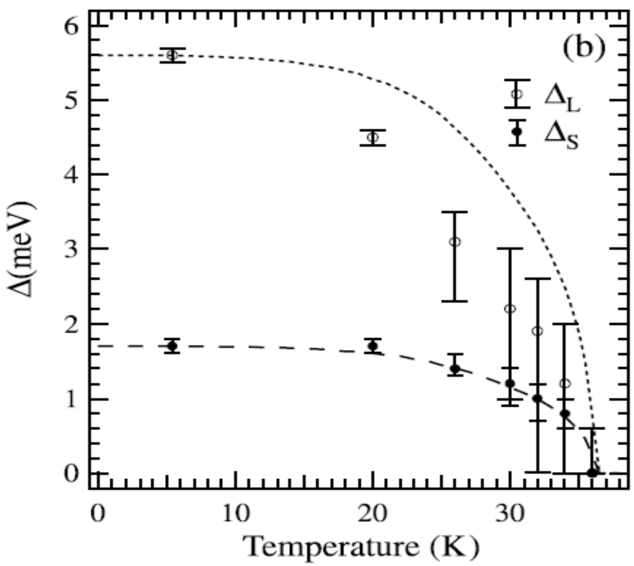
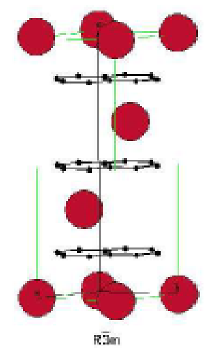
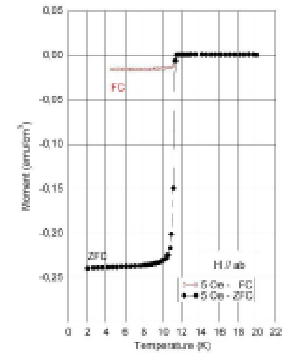


Fig. 3. (a) Temperature dependent photoemission spectra (5.4 and 45 K) near E_F of the MgB_2 polycrystal. Energy resolution is 3.8 meV. The inset shows the enlarged spectrum near E_F taken at 5.4 K. The spectrum is fitted by assuming two different gaps. (b) Temperature dependence of the estimated gaps and the BCS predicted curves (dashed and dotted curves). The data are from Ref. [28].

Nadprzewodnik z grafitu

Wapń wstawiony między płaszczyzny grafitu prowadzi do nadprzewodnictwa z $T_c = 11,5$ K.

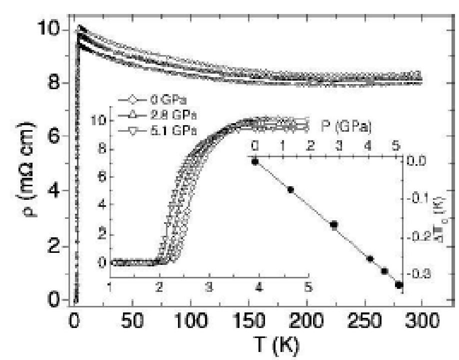




/ N. Emery et al, *Phys. Rev. Lett.* **95**, 087003 (2005) /

Najtwardszy nadprzewodnik

Diament domieszkowany borem (synteza pod ciśnieniem 100 tys. atmosfer) staje się nadprzewodnikiem w $T_c = 4$ K.



/ E.A. Ekimov et al, *Nature* **428**, 542 (2004) /

Przeźrocza z
T. DOMAŃSKI, UMCS Lublin
http://kft.umcs.lublin.pl/doman/lectur

Superconductivity on the border of weak itinerant ferromagnetism in UCoGe (2007r)

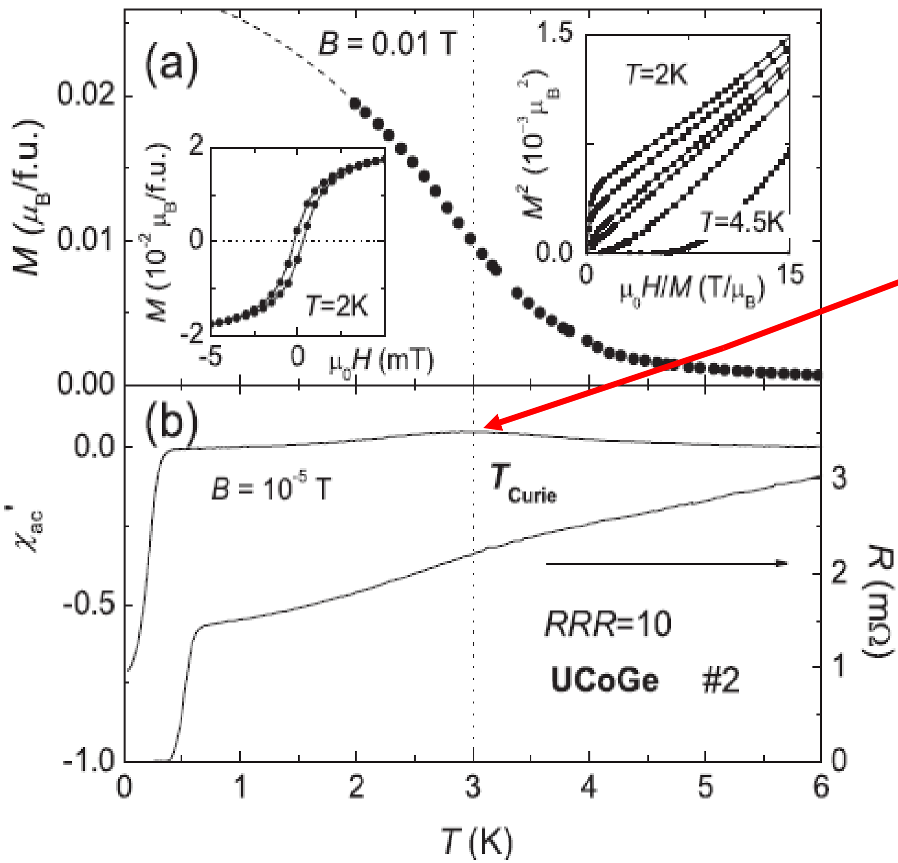


FIG. 1. Magnetic and SC properties of UCoGe sample 2. (a) Magnetization M as a function of T in a field B of 0.01 T. The dashed line extrapolates to $m_0 \approx 0.03\mu_B$ for $T \rightarrow 0$. The Curie temperature $T_C = 3$ K is marked by the dotted vertical line. Left inset: Hysteresis loop $M(B)$ at $T = 2$ K with coercive field of 0.3 mT. Right inset: Arrott plot of magnetization isotherms at $T = 2.0$, 2.4, 2.8, 3.0, 3.5, and 4.5 K (from top to bottom). (b) ac susceptibility χ'_{ac} (left axis) (in $B = 10^{-5}$ T), and resistance R (right axis) as a function of T. The maximum in χ'_{ac} and the broad hump in R locate T_C. SC for sample 2 is found below 0.61 K in $R(T)$ and below 0.38 K in $\chi'_{ac}(T)$.

N.T.Huy et al.., PRL 99 (2007) 067006

Y_9Co_7 1980r

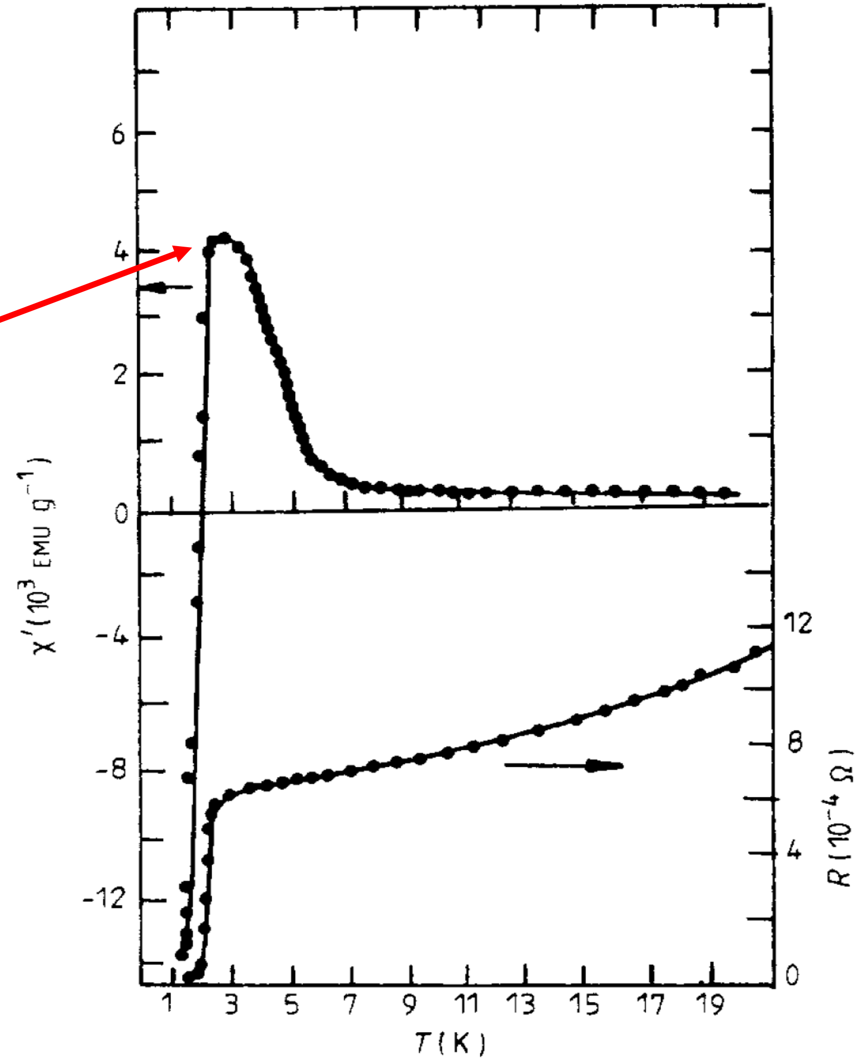


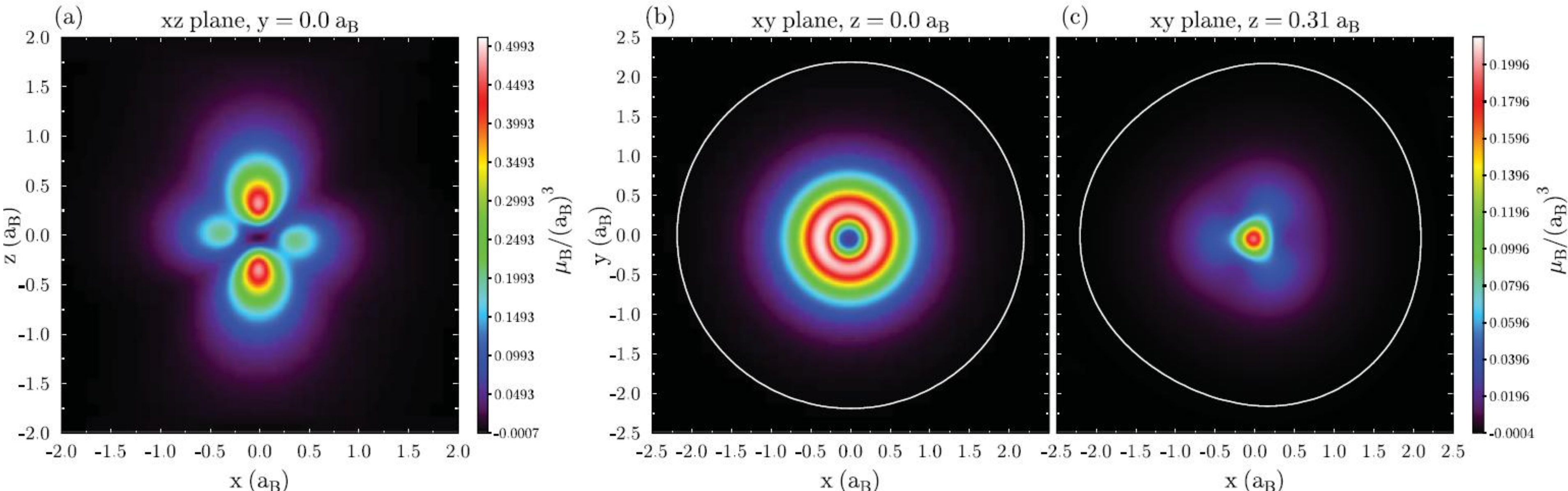
Figure 1. The AC susceptibility χ' and the AC resistance R

A.Kolodziejczyk et al.., J.Phys.F (1980) 333

PHYSICAL REVIEW B **83**, 094408 (2011)

Electronic structure, magnetism, and spin fluctuations in the superconducting weak ferromagnet Y_4Co_3

B. Wiendlocha,* J. Tobola, S. Kaprzyk, and A. Kolodziejczyk



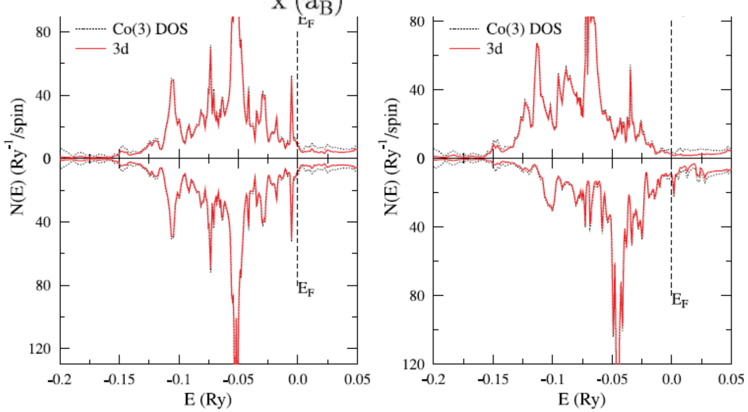


FIG. 4. (Color online) Comparison of the Co(3) partial DOS from non-spin-polarized (left) and spin-polarized (right) calculations. Peak under E_F in nonmagnetic state is well visible.

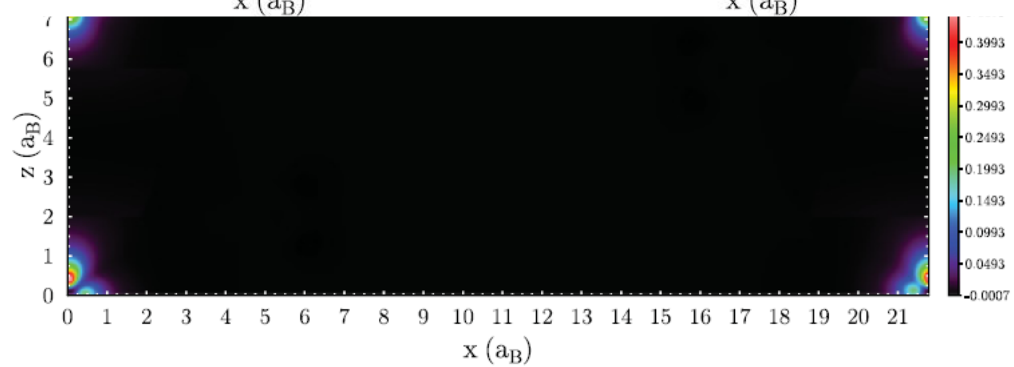


FIG. 8. (Color online) Spin-magnetization distribution in the $y = 0$ plane (face of the unit cell), showing that the charge density in the large areas of the unit cell is almost not polarized.

ROK T_c (K) MATERIAŁ UWAGI

Nadprzewodniki z żelazem....?

2008 **25-55** **$La[O_{1-x}F_x]$ FeAs**, Kamihara Y, Watanabe T, Hirano M, Hosono H
Iron-based layered superconductor La[O1-xFx] FeAs (x=0.05-0.12) with Tc=26 K. J Am Chem Soc 130:3296 (2008), Frontier Research Center, Tokyo Institute of Technology,

2008 **8** **Fe_xSe_{1-x}**, Superconductivity in the PbO-type structure α–FeSe, Fong-Chi Hsu+11, PNAS September 23, 105 (2008) 14262
Institute of Physics, Academia Sinica, Taipei 115, Taiwan

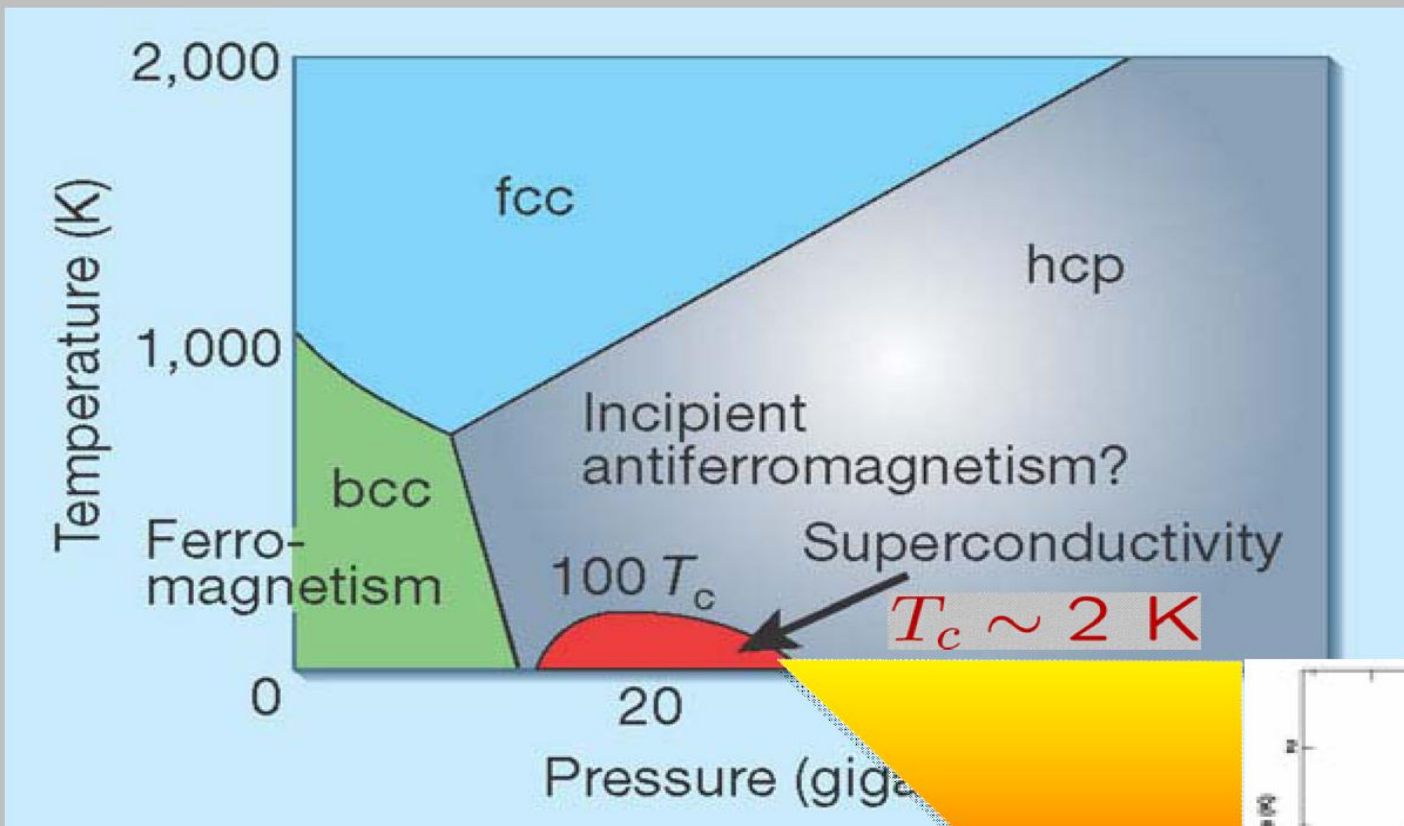
2008 **26** **$(Ca_{1-x}Na_x)Fe_2As_2$** Parasharam Maruti Shirage et all, Superconductivity at 26 K in.... 2008 The Japan Society of Applied Physics published online August 1, 2008 Tsukuba, Ibaraki

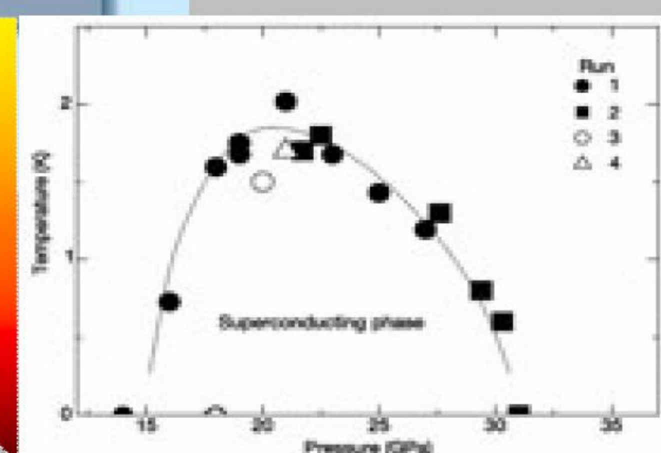
2010 **30** **$K_xFe_2Se_2$**, Jiangang Guo+8,Superconductivity in the iron selenide $K_xFe_2Se_2$ (0x1.0), PHYSICAL REVIEW B 82, 180520R (2010),Research & Development Center for Functional Crystals, Beijing National Laboratory for Condensed Matter Physics,Institute of Physics, Chinese Academy of Sciences, National Centre for Nanoscience and Technology,

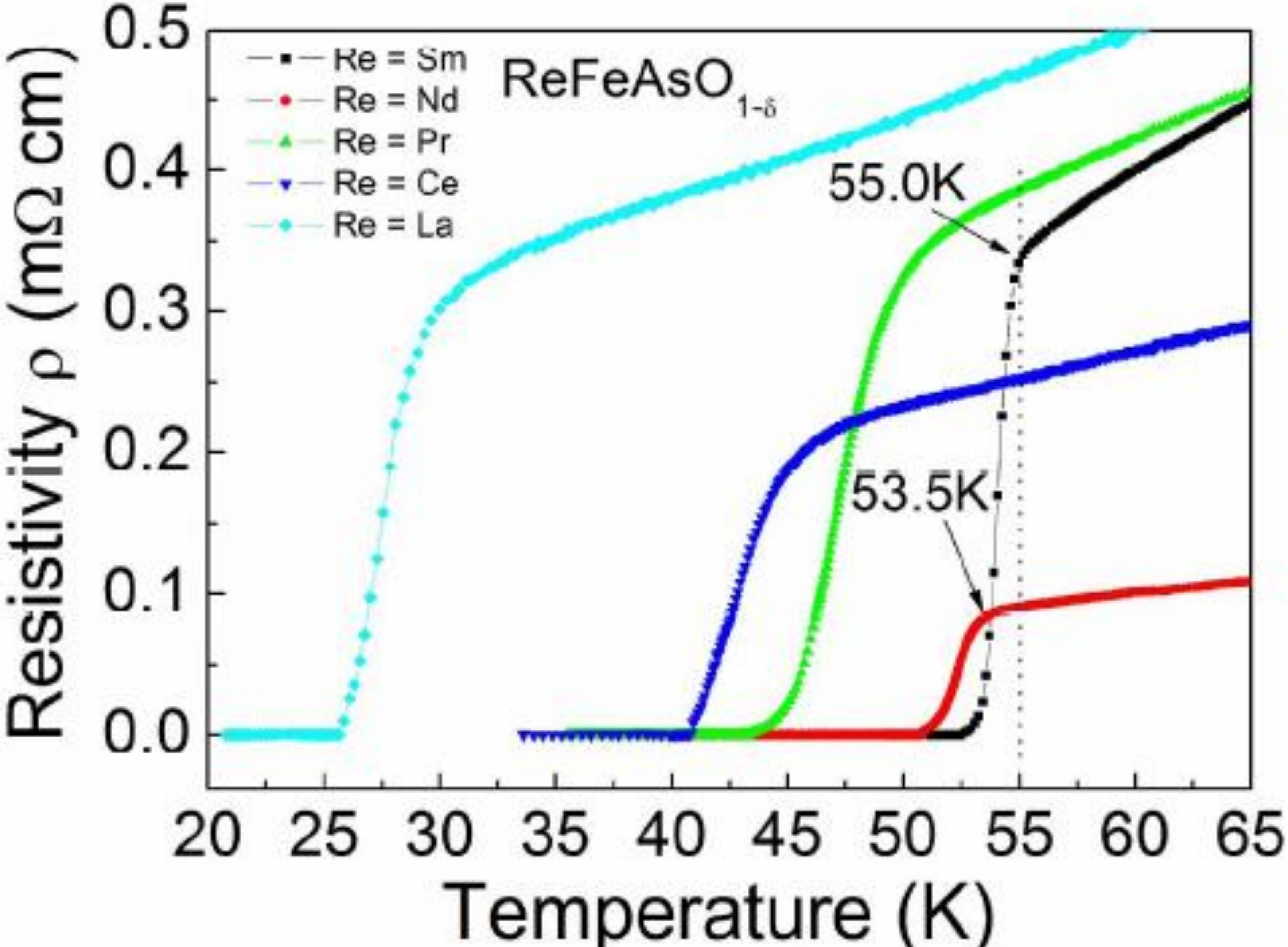
Superconductivity in Fe

K. Shimizu *et al.* *Nature* **412**, 316-31

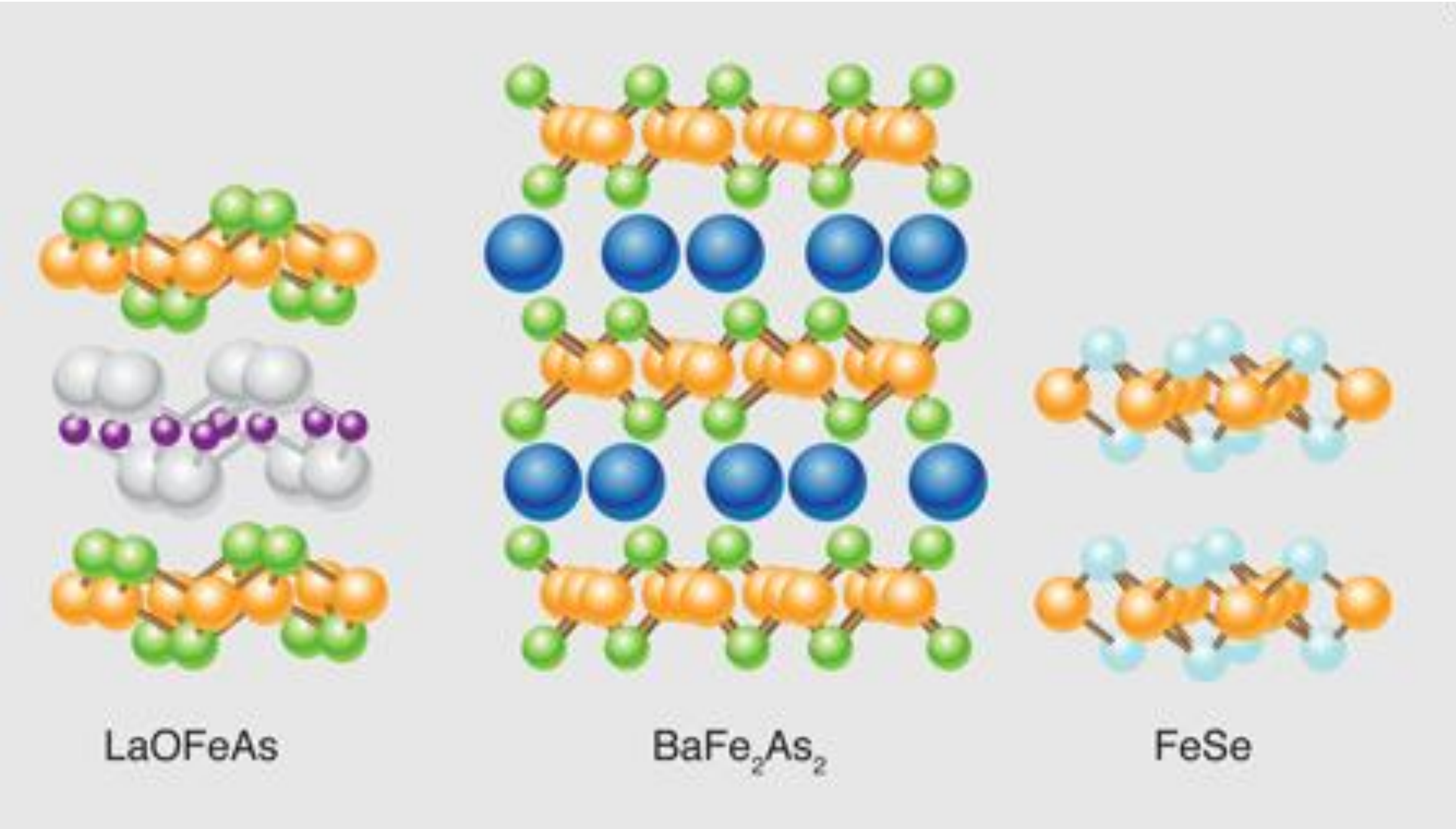
(2001)







Iron-Based Layered Superconductor La[O1-xFx]FeAs (x) 0.05-0.12)with Tc) 26 K
Yoichi Kamihara,*,† Takumi Watanabe,‡ Masahiro Hirano,†,§ and Hideo Hosono†,‡,§
J. AM. CHEM. SOC. 9 VOL. 130, NO. 11, 2008 **3297**



Even though it has a much simpler crystal structure, FeSe (right) has many of the same magnetic and electronic properties (including superconductivity) as the iron-based pnictide superconductors (left, center). Fe (orange), As (green), La (white), O (purple), Ba (dark blue), Se (light blue

[1] F. C. Hsu, J. Y. Luo, K. W. Yeh, T. K. Chen, T. W. Huang, P. M. Wu, Y. C. Lee, Y. L. Huang, Y. Y. Chu, D. C. Yan, and M. K. Wu, arXiv:0807.2369 unpublished.

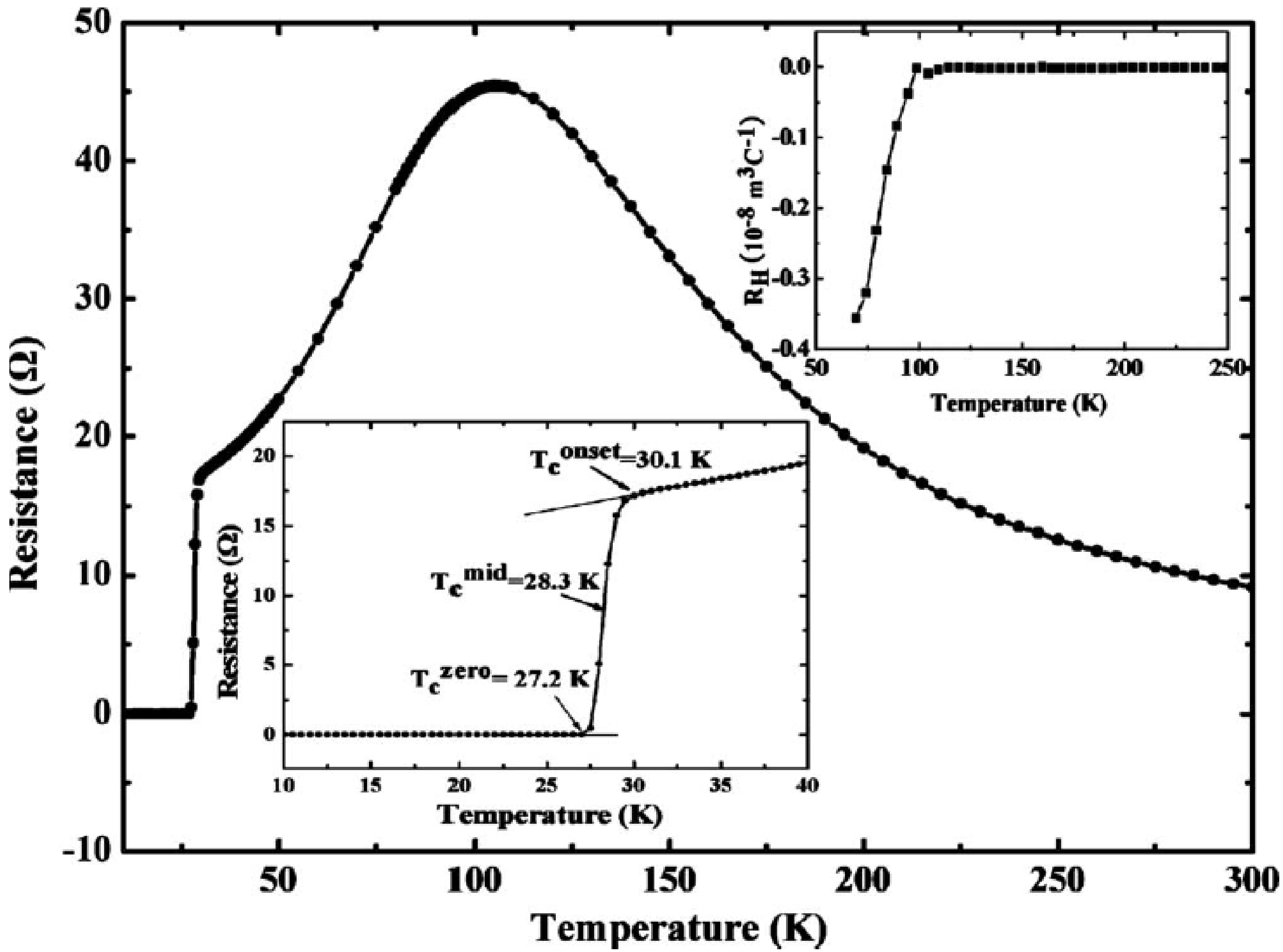
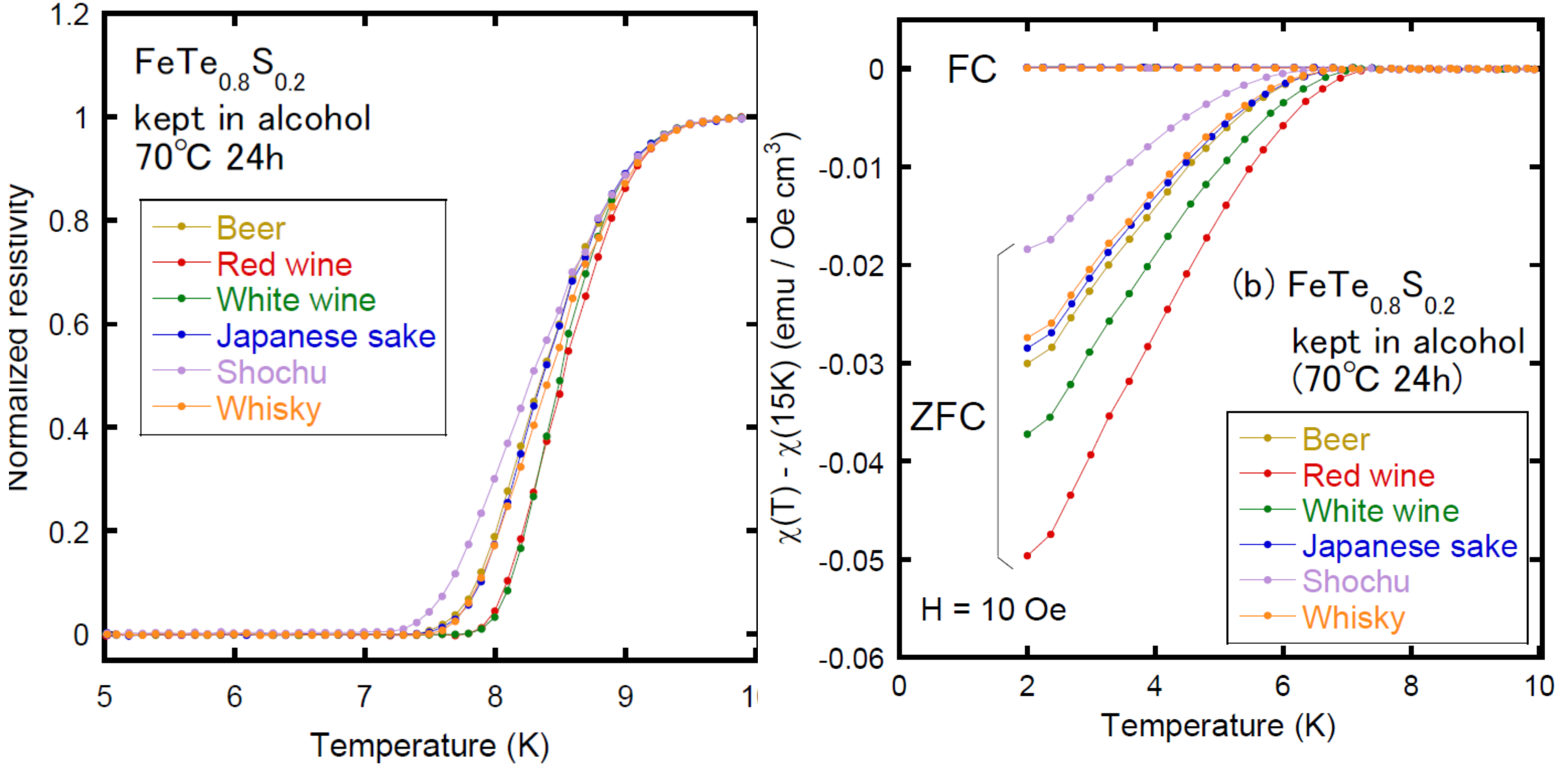


FIG. 3. The temperature dependence of electrical resistance for the $K_{0.8}Fe_2Se_2$ crystal sample. The lower inset shows the details of superconducting transition from 10 to 40 K. The upper inset shows temperature dependence of normal-state Hall coefficient for crystal sample.



Univ. Tsukuba

Superconductivity in $FeTe_{1-x}S_x$ induced by alcohol

Keita Deguchi[1,2,3], Yoshikazu Mizuguchi[1,2,3], Toshinori Ozaki[1,3],
Shunsuke Tsuda[1,3], Takahide Yamaguchi[1,3] and Yoshihiko Takano[1,2,3]

Podsumowanie

1911 Nadprzewodnictwo - Kamerlingh-Onnes

1938 Nadciekłość helu II - Kapitza

1948 Bardeen, Brattain, Shockley - tranzystor



1957 Bardeen, Cooper, Schrieffer - teoria nadprzewodnictwa



1958 Zjawisko Mössbauera

1962 Zjawisko Josephsona

1980 Kwantowe zjawisko Halla (von Klitzing, Dorda, Pepper)

1986 Nadprzewodnictwo przy wysokich T (Bednorz, Müller)


z K.Wróblewski, Historia Fizyki

Nagrody Nobla

Rok	Nazwiska	Za co?
1913	**Heike Kamerlingh - Onnes**	Odkrycie zjawiska nadprzewodnictwa
1962	**Lew Landau**	Wiele prac poświęcił nadprzewodnictwu
1972	**John Bardeeu** **Leon Cooper** **John Schrieffer**	Twórcy mikroskopowej teorii nadprzewodnictwa
1973	**Ivar Giaever** **Brian Josephson**	Elektronika tunelowa nadprzewodnictwa
1987	**Georg Bednorz** **Karl Miiller**	Materiały ceramiczne
1996	**Robert Curlow** **Richard Smalley** **Harold Kroto**	Odkrycie nowej odmiany węgla
2003	**Witalij Ginzburg, Alexei Abrikosov, Anthony James Leggett?**	Wkład w rozwój teorii nadprzewodnictwa i nadciekłości

Dziękuję za uwagę