



UNIVERSITÄT ROSTOCK

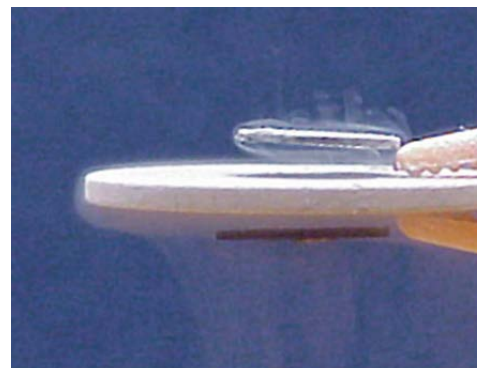
**Mathematisch-Naturwissenschaftliche Fakultät
Institut für Chemie
Abteilung Anorganische Festkörperchemie**

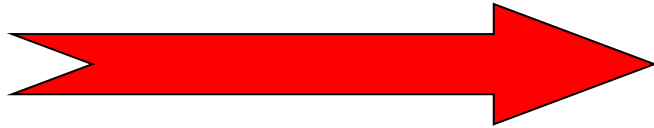
Prof. Dr. Martin Köckerling

Vorlesung

Anorganische Chemie VI – Materialdesign

Heute: Supraleitung



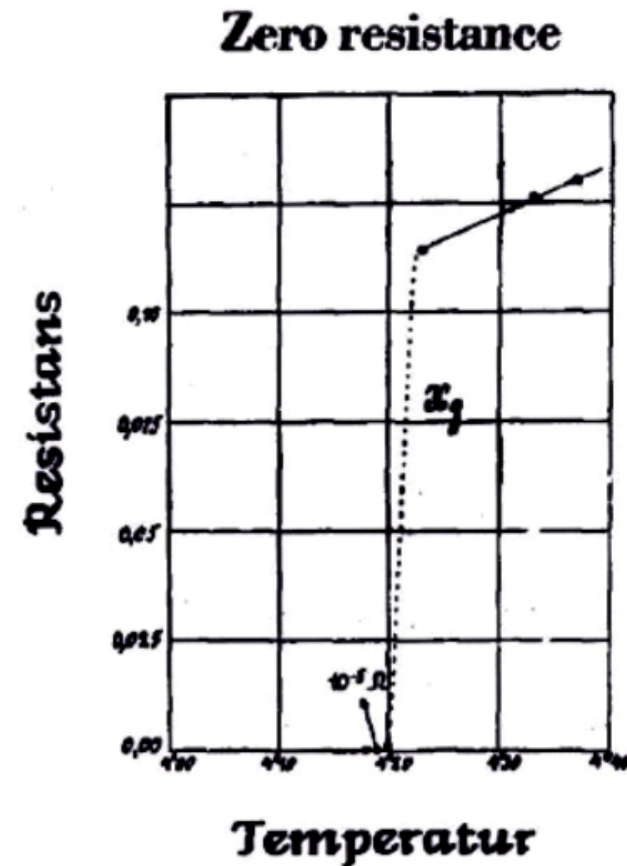


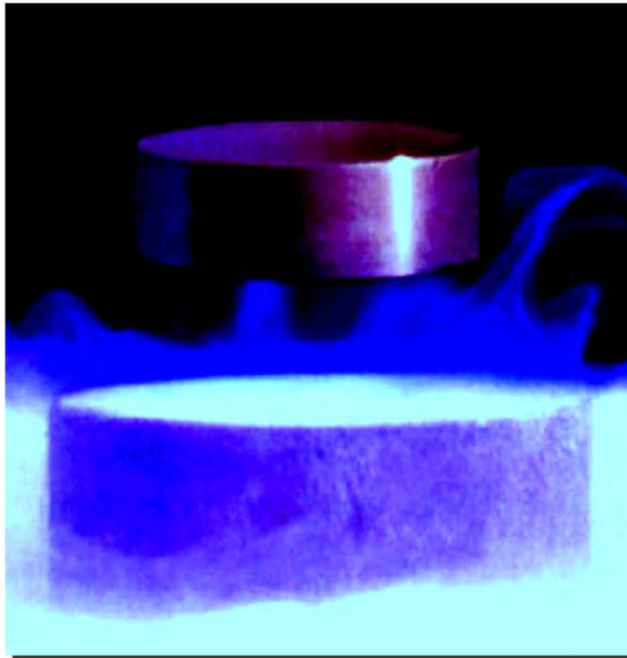
Magnet über supraleitendem Material



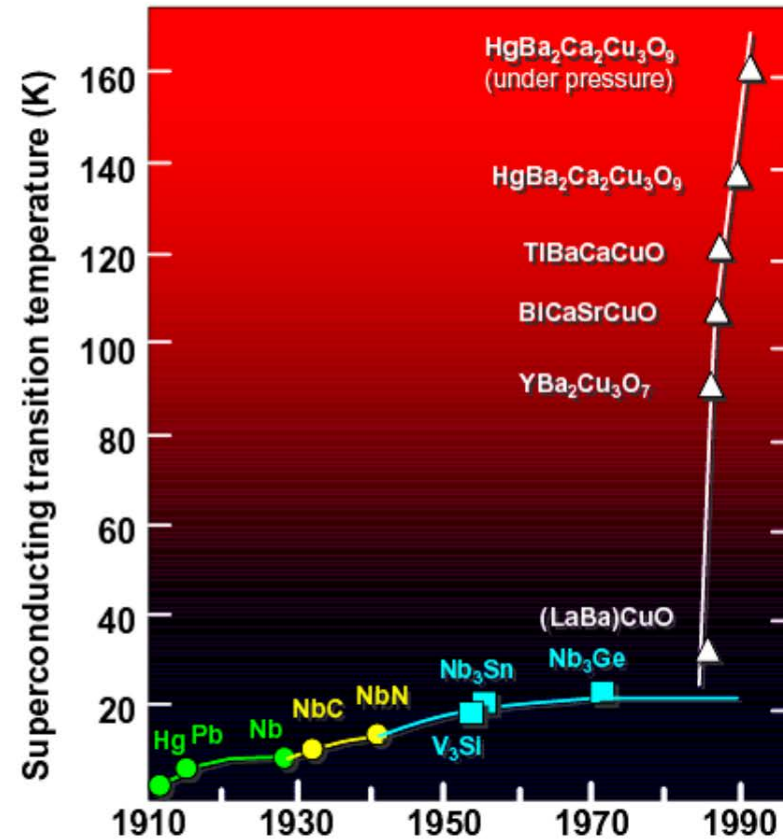


- Discovered by **Kamerlingh Onnes** in 1911 during first low temperature measurements to liquefy helium
- Whilst measuring the resistivity of “pure” Hg he noticed that the electrical resistance dropped to zero at 4.2K
- In 1912 he found that the resistive state is restored in a magnetic field or at high transport currents





"Superconductivity is perhaps the most remarkable physical property in the Universe" David Pines



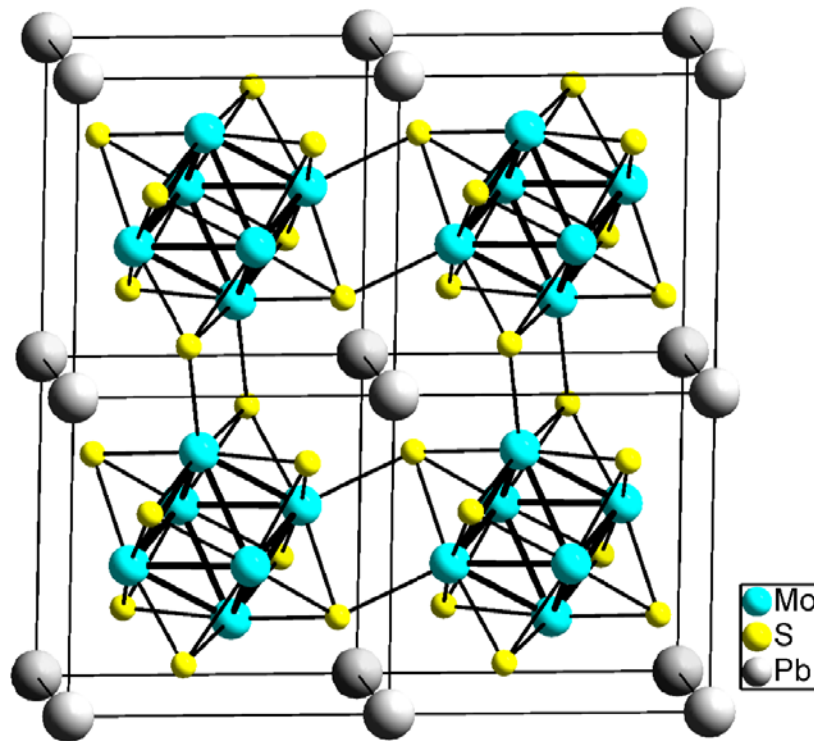
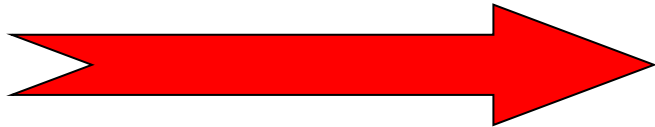


Vielfältige technische Anwendungsmöglichkeiten, z.B.:



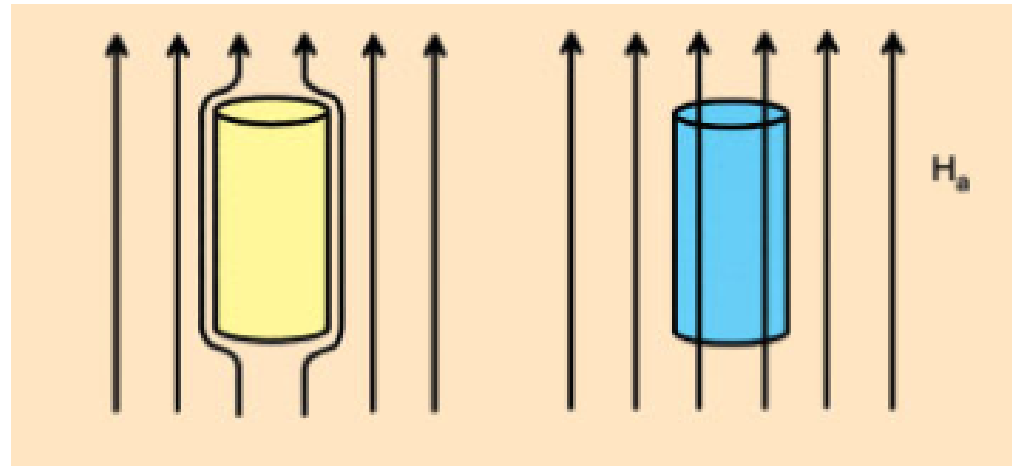
Materialien mit supraleitenden Eigenschaften

1. Elemente (Nb, 9.2 K).
2. Intermetallische Phasen (Nb_3Ge , 23 K)
(UPd_2Al_3 , 2 K)
3. Chalcogenide (LaMo_6Se_8 , 11 K)
4. Boride (ErRh_4B_4 , 8.8 K)
(MgB_2 , 40 K)
5. Oxide ($\text{Tl}_2\text{Ba}_2\text{Ca}_2\text{Cu}_3\text{O}_{10}$, 125 K)
($\text{HgBa}_2\text{Ca}_2\text{Cu}_3\text{O}_{8+\delta}$, 133 K $\xrightarrow{\text{HP}}$ 164 K)
6. Organische Substanzen ($(\text{Rb/Tl})_x\text{C}_{60}$, 45 K)
($\text{Rb}_2\text{CsC}_{60}$, 33 K)
7. Oxopnictide



Etwas Theorie – einige Begriffe

Meißner-Ochsenfeld-Effekt: Verdrängung der Magnetfeldlinien aus dem Inneren eines Supraleiters

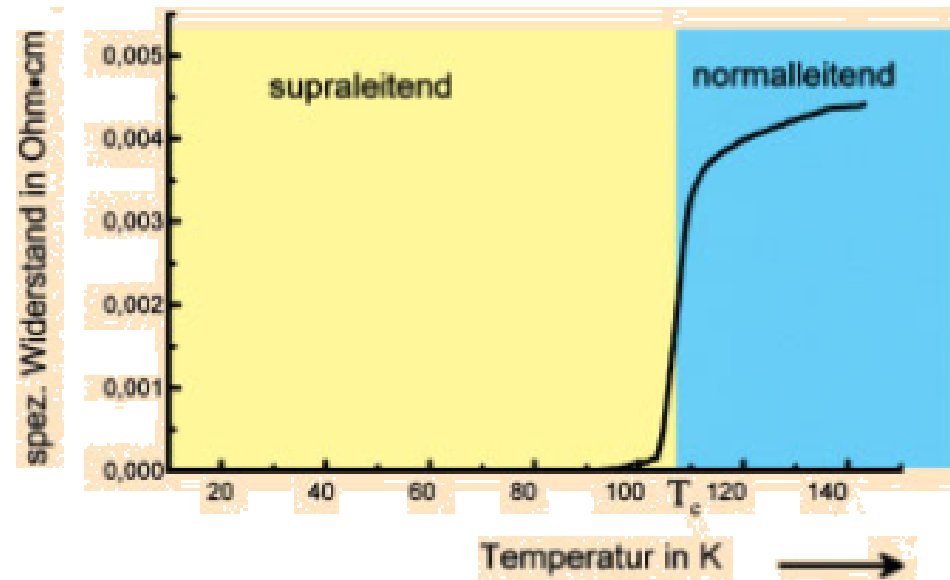


BCS-Theorie: Bardeen, Cooper, Schrieffer (Nobelpreis 1972),
Elektronen-Phononen-Kopplung:
Cooper-Paare

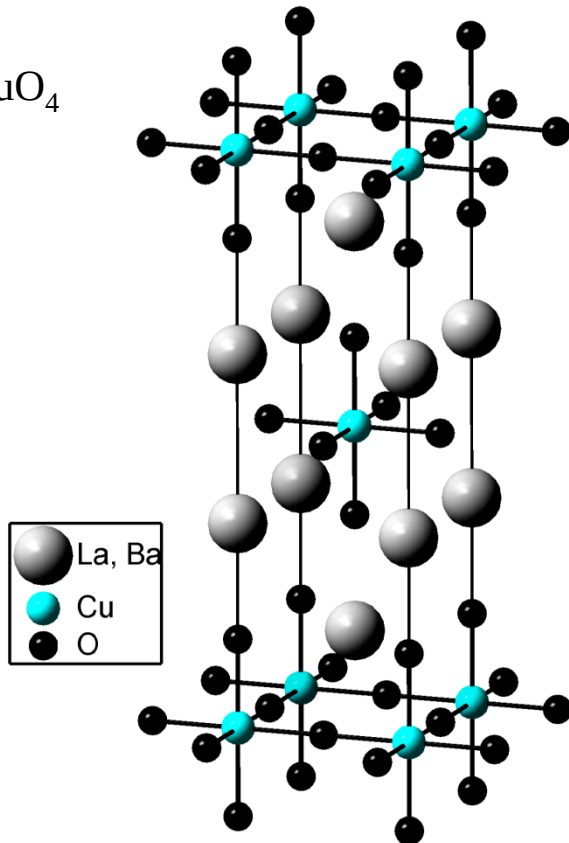
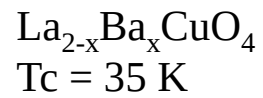


Kritische Magnetfeldstärke

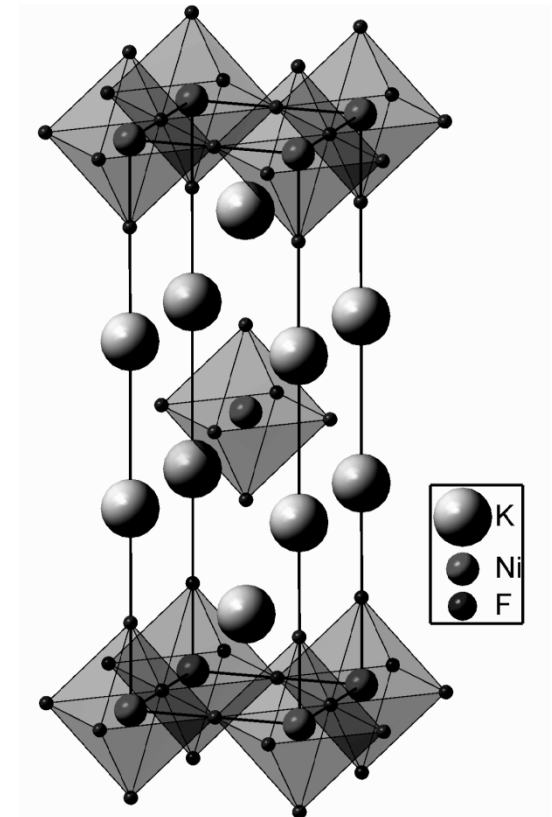
Kritische Stromstärke



Hochtemperatur-Supraleiter: Bednorz/Müller (Nobelpreis 1987)

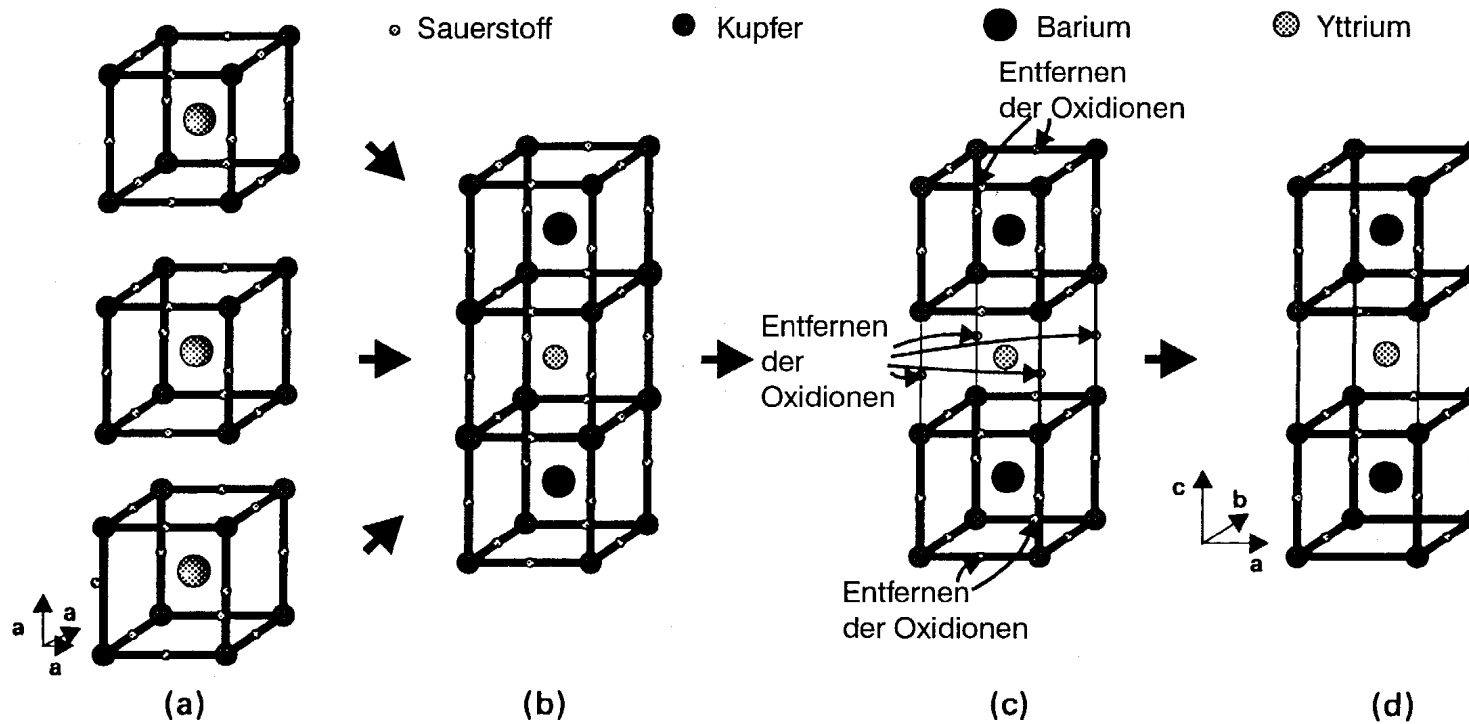


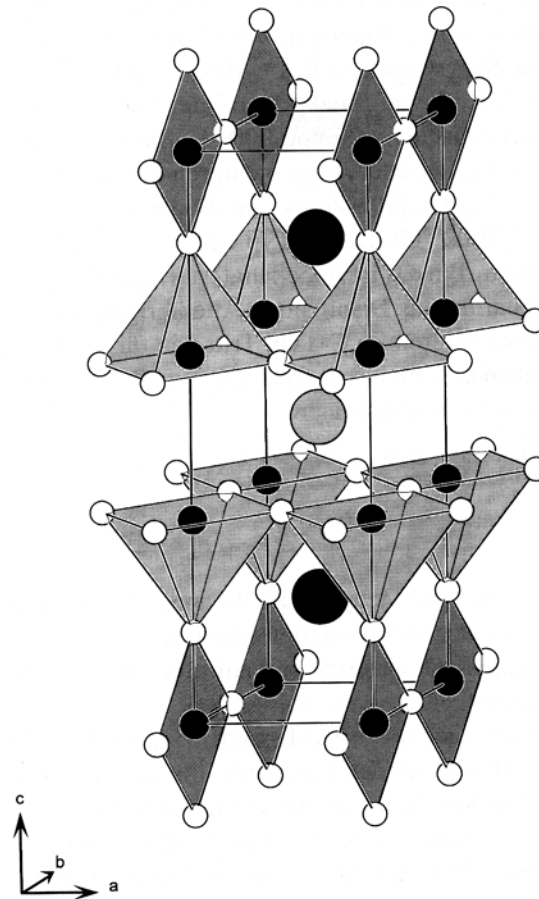
abgeleitet von K_2NiF_4 :

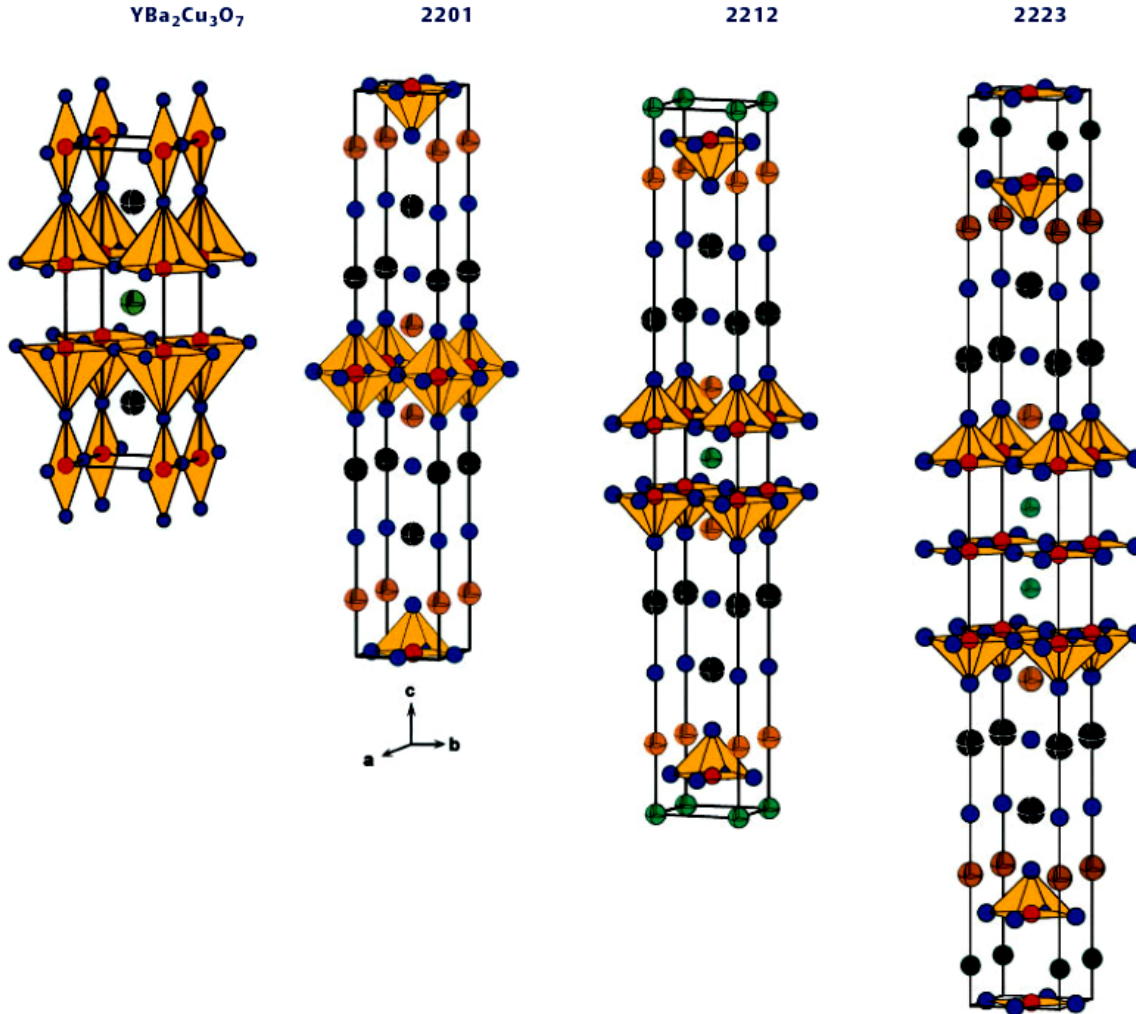


1-2-3-Supraleiter: $\text{YBa}_2\text{Cu}_3\text{O}_{7-x}$ $T_c = 93 \text{ K}$, $0 < x < 1$ (Sdp. N_2 77 K)

$3 \text{ ABX}_3 \implies (\text{A}_3)(\text{B}_3)(\text{X}_9) \implies (\text{YBa}_2)(\text{Cu}_3)(\text{O}_7\Diamond_2)$ (Perowskit)







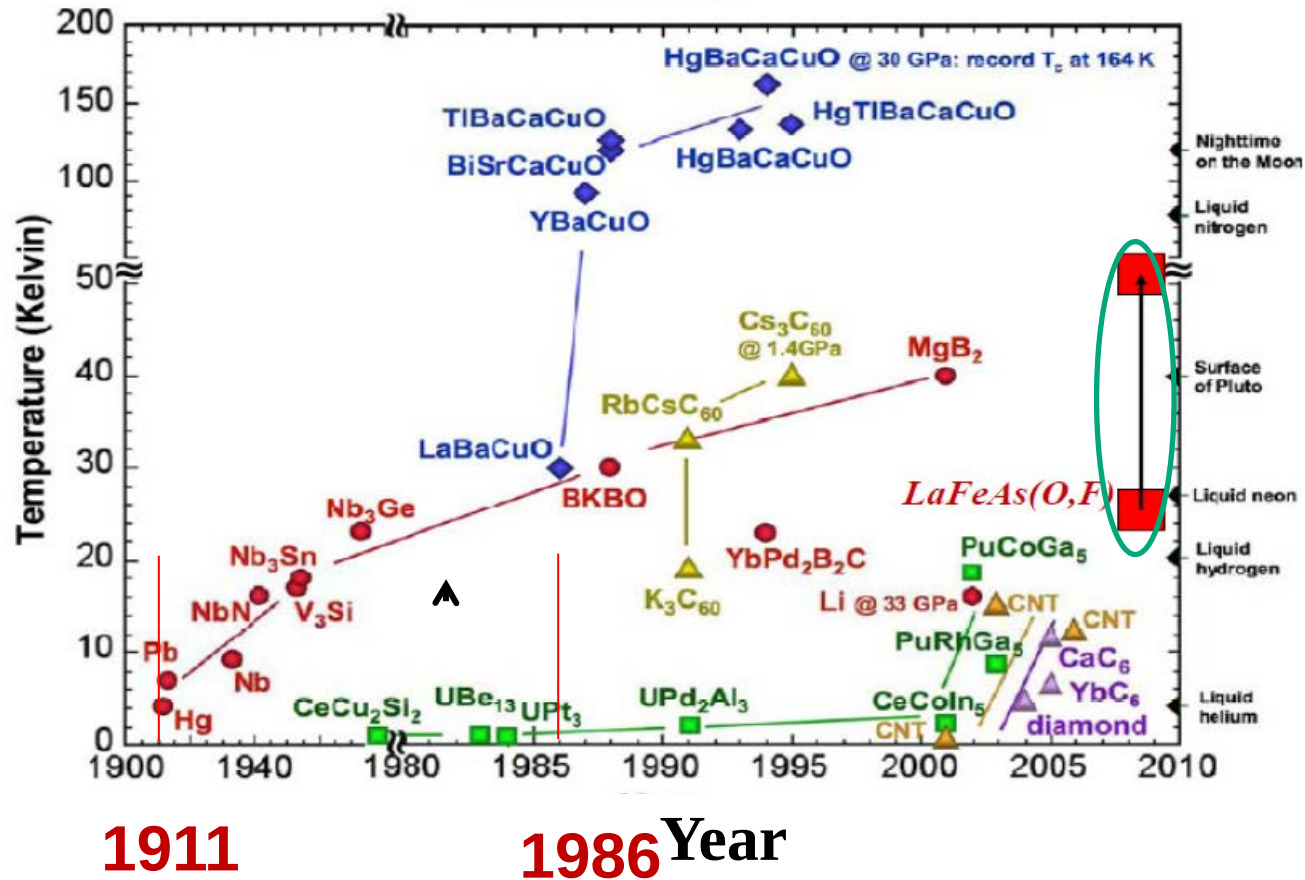
Idealisierte Elementarzellen von Bi₂Sr₂Ca₀Cu₁O₆ (2201), Bi₂Sr₂Ca₁Cu₂O₈ (2212), Bi₂Sr₂Ca₂Cu₃O₁₀ (2223) mit zwei Formeleinheiten (von links nach rechts). Cu-Atome sind rot, O-Atome blau, Sr-Atome braun, Bi-Atome schwarz und Ca-Atome sind grün gezeichnet.

Substanz	Anzahl benachbarter CuO ₂ -Schichten, n	Übergangstemperatur in K
Bi ₂ Sr ₂ CuO _{6+δ}	1	10
Bi ₂ Sr ₂ CaCu ₂ O _{8+δ}	2	ca. 80
(Bi,Pb) ₂ Sr ₂ Ca ₂ Cu ₃ O _{10+δ}	3	110



Supraleiter

Materials



Supraleitfähigkeit in Oxopnictiden

LnOFePn

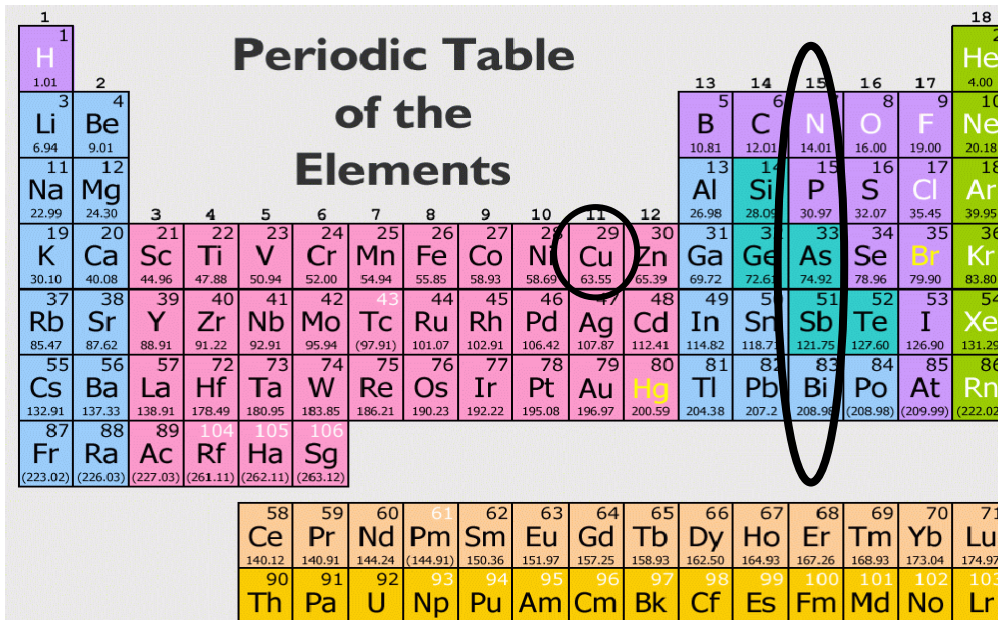
Ln = Selten-Erd

Pn = Pnictogen

(5. HG)

N, P, As, Sb, Bi

Periodic Table of the Elements



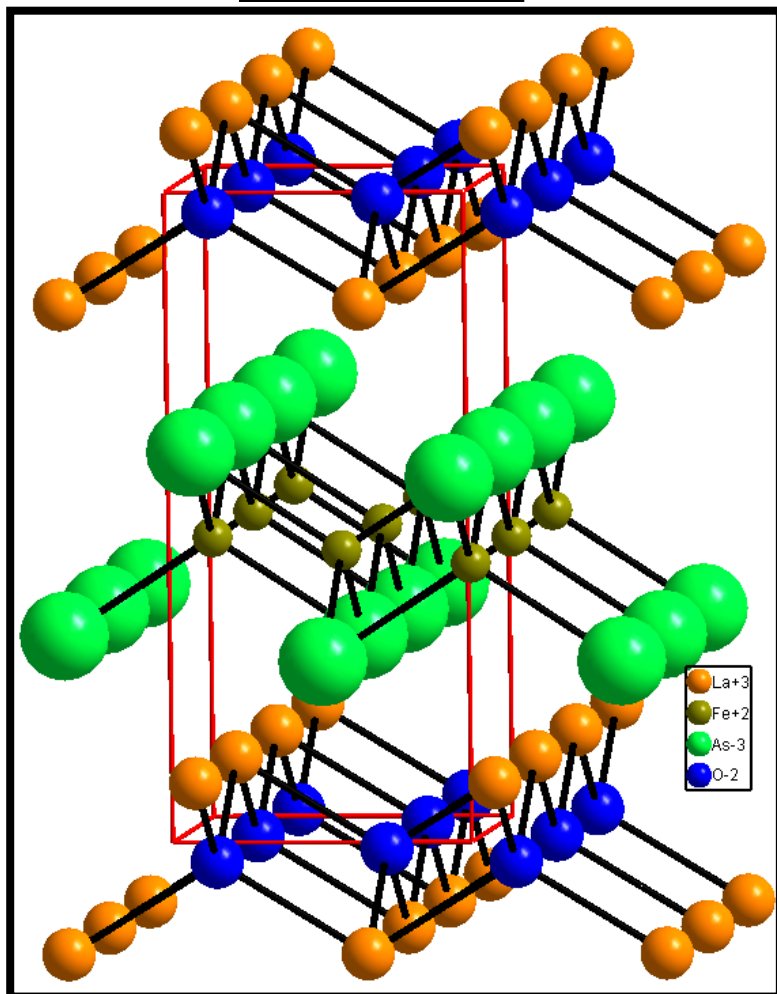
1 H 1.01																	18 He 4.00
3 Li 6.94	4 Be 9.01											13 B 10.81	14 C 12.01	15 N 14.01	16 O 16.00	17 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.30											31 Al 26.98	32 Si 28.09	33 P 30.97	34 S 32.07	35 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.64	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (97.91)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.75	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (144.91)	62 Sm 150.36	63 Eu 151.97	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97	
87 Fr (223.02)	88 Ra (226.03)	89 Ac (227.03)	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237.05)	94 Pu (244.06)	95 Am (243.06)	96 Cm (247.07)	97 Bk (247.07)	98 Cf (251.08)	99 Es (252.08)	100 Fm (257.10)	101 Md (258.10)	102 No (259.10)	103 Lr (262.11)	
		104 Rf (261.11)	105 Db (262.11)	106 Sg (263.12)													

**Ferromagnetisches Fe und Supraleitfähigkeit:
Überraschung!!!!**

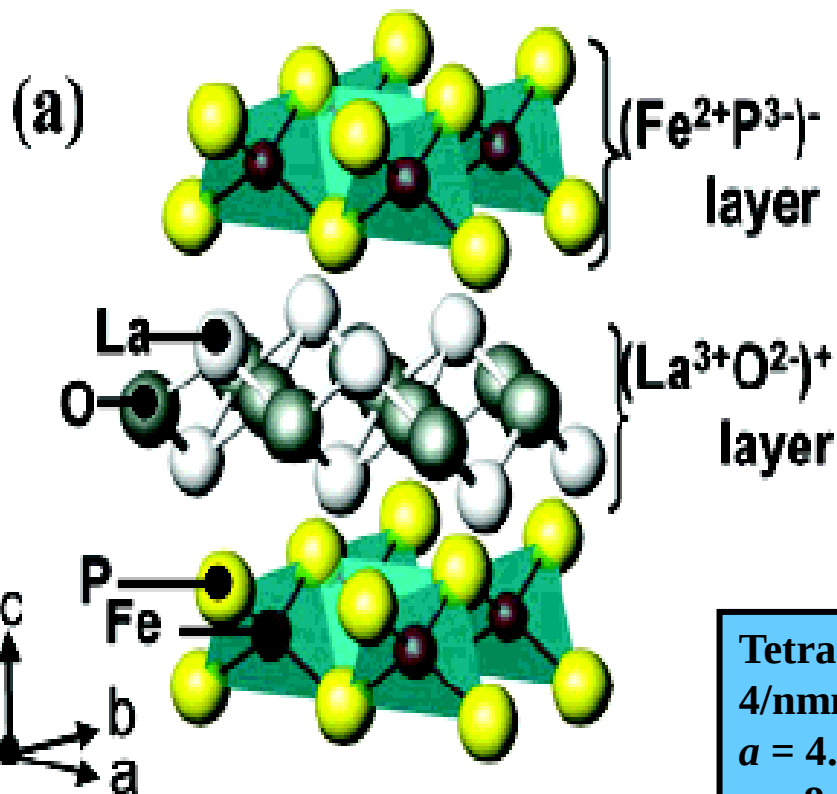
**LaOFeP, $T_c \sim 4$ K ,
LaO_{0.94}F_{0.06}FeP ~ 7 K**

LaONiP $T_c = \sim 3$ K

LnOFeAs



LaOFeP (1995) Jeitschko, J Alloys and Compds.
LaOFeAs (2000) Zimmer, Jeitschko et. al J A C



Tetragonal; P
4/nmm
 $a = 4.0353(0) \text{ \AA}$
 $c = 8.7409(1) \text{ \AA}$



Anwendungen:

- Energietransport
- Energiespeicherung (SMES = supermagnetic energy storage)
- Magnetschwebbahnen (MAGLEV = magnetic levitation train)
- Hochenergiephysik
- NMR (Kernspintomographie)
- SQUID (= superconducting quantum interference device)



- Elektromagnete, z.B. in NMR-Geräten, Kernspintomografen, Teilchenbeschleunigern

