Presentation of a research project
and call for its funding:

Searching for Room Temperature Superconductors

Version 38 from 1 August 2011

Dr. Frank Lichtenberg / Physicist

www.novam-research.com

novam@nlp-nicoletta.de

Abstract / Summary

The interesting and fascinating physical phenomenon of superconductivity appears, until now, only at very low temperatures and therefore its technical application is limited to relatively few areas. If it is possible to create materials which are superconducting at room temperature, then this could initiate a revolution in technology. More than 10 years fundamental research, experience, knowledge and ideas in the field of special materials (oxides) lead to the conviction that superconductivity at room temperature is possible, and together with Global Scaling – a new knowledge and holistic approach in science – to an extended approach on the search for room temperature superconductors.

This presentation is divided into a main part (28 pages) and an appendix (38 pages). A content overview of this presentation is shown on the following pages 3 and 4.

Content overview

Main part

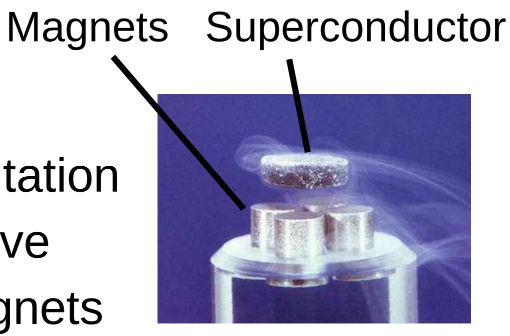
Content overview (continued)

Appendix

Superconductivity: Special physical phenomenon of some materials which appears below a material-specific low temperature T_c

---

- The superconducting state shows several special features such as
  - Electrical DC resistance disappears, i.e. lossless current transport
  - Levitation above magnets



- Very interesting for research, science and technology
- Cooling down to low temperatures is expensive ⇨ T_c preferably as high as possible
- For decades the alloy Nb_3Ge was that material with the highest T_c , namely – 250 ℃, and the search for materials with higher T_c was unsuccessful

Recommended reading:

- www.superconductors.org
- Book “Supraleitung:Grundlagen und Anwendungen“ by W. Buckel and R. Kleiner (in German)

Superconductivity: 1986 surprising breakthrough in Switzerland concerning higher T_c and type of materials

- J. G. Bednorz and K. A. Mueller from the IBM Zurich Research Laboratory discovered in oxides [1] with the chemical composition $(La,Ba)_2CuO_4$ superconductivity with T_c = – 238 °C, i.e. 12 °C higher than that of Nb_3Ge. For their discovery they received in 1987 the Nobel Prize in physics.

K. A. Mueller
and
J. G. Bednorz

Image:
www.uzh.ch/news/articles/2006/2005.html

[1] Oxides are chemical compounds between oxygen (O) and metals

- Worldwide avalanche of research activities of unprecedented extent

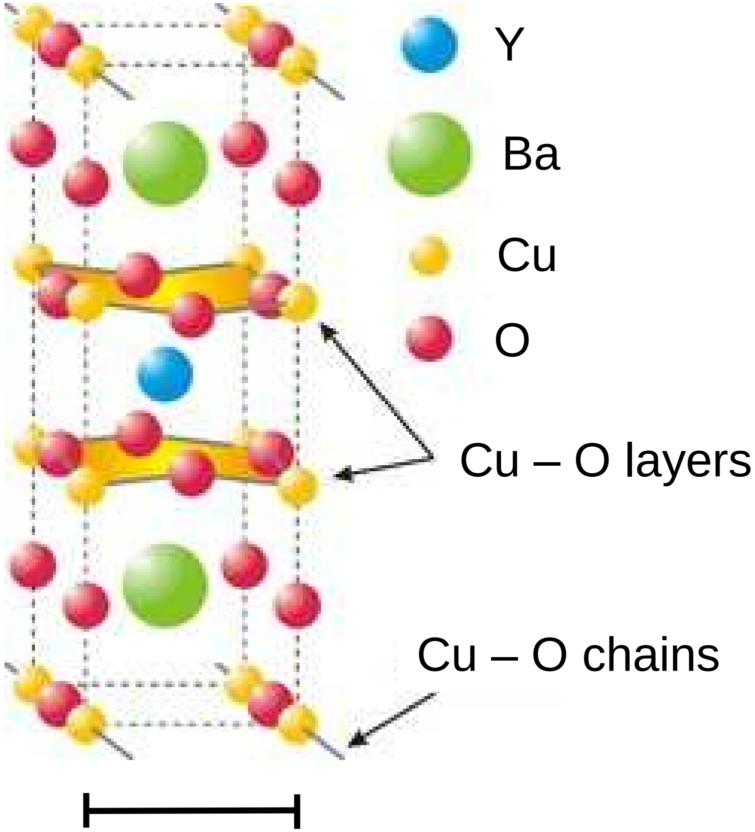
  ⇨ Discovery of further oxides with higher T_c which are likewise based on copper (Cu), e.g. $YBa_2Cu_3O_7$ with T_c = – 182 °C which can be cooled by liquid nitrogen (– 196 °C) in a relatively simple and cost-effective way

  ⇨ March 1987 in the New York Hilton Hotel: Meeting of about 2000 physicists owing to superconductivity, known as “Woodstock in Physics“.
  Wave of enthusiasm due to superconductivity **!**

Recommended reading: Nobel lecture of J. G. Bednorz and K. A. Mueller:
http://nobelprize.org/nobel_prizes/physics/laureates/1987/bednorz-muller-lecture.pdf

Crystal structure (crystallographic unit cell) of the high-T_c superconductor $YBa_2Cu_3O_{7-y}$

- Layered crystal structure
- T_c = – 182 ℃ and thus its superconductivity can be maintained in a relatively simple and cost-effective way by using liquid nitrogen which has a temperature of – 196 ℃
- T_c depends on oxygen deficiency y , highest value for y ≈ 0.07

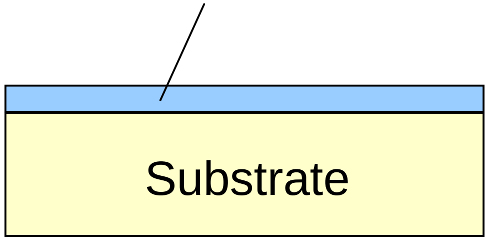


≈ 0.4 nm

1 nm = 10^{-6} mm = 0.000001 mm

Image:
www.fom.nl/live/imgnew.db?55473

Some different manifestations of solid matter like oxides



Thin films

Molds made from pressed and sintered powder

Crystal

Superconductivity – Applications

- Areas of applications depend on chemical and mechanical properties of the superconducting material (raw materials, preparation, processing …) and specific features of the superconducting state

- Examples of already realized industrial applications of so-called high-T_c superconductors which are based on copper (Cu) and oxygen (O) such as $YBa_2Cu_3O_7$ which is cooled by liquid nitrogen:
  - Measurement and sensor technology: Detection of very weak magnetic fields, e.g. for material testing, searching for ores, medicine
  - Communication technology: Microwave filters
  - Electrical engineering: Generators • Motors (e.g. for ship propulsion) • Strong electromagnets (e.g. for separation of ores) • Cabels for current transport

- Superconductors also have an application potential in the area of computer technology

- **Recommended reading:** “High-Temperature Superconductors Get to Work“ by A. P. Malozemoff, J. Mannhart and D. Scalapino, Physics Today 4 (2005) 41 – 47

- For further applications see page 33

Superconductivity – A quantum physical phenomenon

- Superconductivity does not only mean DC resistance R = 0 but comprises other phenomena, e.g. special magnetic properties like the so-called Meissner effect (see page 32), which cannot be explained solely by R = 0
- Peculiar quantum physical state of the so-called conduction electrons
- Conduction electrons: delocalized • responsible for the metallic behavior of the electrical resistivity • energetically located in close vicinity to the highest occupied states / energies, i.e. in the vicinity of the so-called Fermi energy
- Conduction electrons form pairs, so-called Cooper pairs, which consists of two electrons
- Cooper pairs form a coherent state (Bose-Einstein condensation) so that the electrons have a strong tendency to behave in the same manner or to stay in the same state
- Pair formation requires an attractive interaction between the electrons which usually repel each other because of their negative electric charge
- Attractive interaction under special conditions which are realized in some materials
  - e.g. via the so-called electron-phonon interaction, i.e. the interaction between negatively charged electrons and the oscillations of the positively charged ions of the crystal lattice
  - another possibility e.g. via so-called excitonic superconductivity, see pages 54 – 56
- For many superconductors it is not yet clarified how superconductivity comes about

Superconductivity – The presently highest T_c (established value)

Until now (July 2011) the highest established value of T_c is still – 135 ℃. This is achieved by a copper (Cu) - based oxide with a layered crystal structure and complex chemical composition, namely $Hg_{0.8}Tl_{0.2}Ba_2Ca_2Cu_3O_{8+y}$, which was reported in 1995 by P. Dai et al. in Physica C / Superconductivity 243 (1995) 201 – 206.

Often unverified reports and rumors about materials with higher T_c . For example, in the website www.superconductors.org another Cu - based oxides with higher T_c values are presented. The currently (July 2011) highest T_c claim is +18 ℃. The presented indications for superconductivity appear as relatively weak and until now they do not represent established values.

The currently highest T_c for materials without Cu:

- This is – 220 ℃ which is achieved by an iron (Fe) - based oxide with a layered crystal structure, namely $GdFeAsO_{1-y}$. Its crystal structure is of the ZrCuSiAs type and consists of alternating Fe – As and Gd – O layers.

  Reference: J. Yang et al. in Superconducting Science and Technology 21 (2008) 1 – 3

- For the special case of superconductivity with T_c of about – 180 ℃ in the system Na – W – O see page 57

Note: The most common units of temperature T are ℃ and K . They are related by the simple conversion formula T [K] = T [°C] + 273 K

Superconductivity – A vision

Superconductivity at room temperature !

For example a material with $T_c = +\,90\,^{\circ}\mathrm{C}$

- No cooling required ⇨ Applications possible in many areas
- **Probably –** i.e. dependent on the properties of the material and the superconducting state **– a revolution in technology** including the possibility of the development of fundamentally new and entirely unexpected things

  ⇨ Superconductivity in everyday life / in everyday devices !?

Own experimental research work in the field of special oxides

Motivation: Searching for (new) oxides with interesting electric, magnetic and structural properties, especially searching for new superconductors

1989 – 1992: Doctoral thesis in the department of Dr. J. Georg Bednorz at the IBM Zurich Research Laboratory / Switzerland

1997 – 2007:

- Research scientist in the department of Prof. Dr. Jochen Mannhart at the Institute of Physics of the University of Augsburg / Germany
- Setup of three laboratories and construction of a particular procedure for the preparation of special oxides, especially with respect to a precise adjustability and control of the oxygen content of so-called reduced niobates and titanates
- Preparation of about 500 different oxides – especially in crystalline form via the melt – and study of their physical and structural properties
- Many interesting scientific results
- No indications for superconductivity with high T_c , but … see next page …

Own experimental research work in the field of special oxides

- Number of possible chemical compositions is practically infinite and only a few of them have the potential to create superconductivity (at room temperature)
- Still many ideas about interesting and unexplored chemical compositions and crystal structure types in connection with the search for room temperature superconductors
- Potential for room temperature superconductivity in a special group of oxides:
  - electronically and structurally low-dimensional oxides which are not based on copper (Cu) but on titanium (Ti), niobium (Nb) or tungsten (W)
  - so-called excitonic superconductivity
  - more about that on pages 54 – 56 and in chapter 5.4 of the following cited article
- Comprehensive scientific article about the own research work in the field of special oxides: Progress in Solid State Chemistry 36 (2008) 253 – 387: www.novam-research.com/resources/Most_recent_paper_on_special_oxides_2008.pdf

Since January 2011:

- Research scientist in the group of Prof. Dr. Nicola Spaldin at the Department of Materials of the ETH Zurich / Switzerland

A new issue on the search for room temperature superconductors

Extension of the previous approach and considerations by insights from Global Scaling – a new knowledge and holistic approach in science:

- 2005: Course in Global Scaling lectured by Dr. H. Mueller

- Intuitively gained hypothesis in 2005 / 2006:

  Creation of room temperature superconductivity by a resonance-like interaction between an everywhere present background field – see e.g. Global Scaling – and a special material with an appropriate crystal structure and chemical composition

- 2006 / 2007:

  Finding an useful appearing approach how to use Global Scaling to isolate such chemical compositions and crystal structure types which favor the potential for room temperature superconductivity

  ⇨ Guideline for further research is given by Global Scaling plus that which is presented on pages 13, 14 and 37 – 63 and in a comprehensive scientific article published in Progress in Solid State Chemistry <u>36</u> (2008) 253 – 387

Global Scaling – A new knowledge and holistic approach in science

The following statements and information about Global Scaling are based on

- the website of the Global Scaling Research Institute: www.global-scaling-institute.de
- an introduction into Global Scaling – the so-called Global Scaling Theory Compendium – which can be downloaded from www.global-scaling-institute.de
- the author‘s
    - participation in an overall 13 - day course in Global Scaling in 2005 lectured by Dr. H. Mueller at the Global Scaling Research Institute / Germany
    - attendance of several presentations at the open-door week at the Global Scaling Research Institute in Munich / Germany from 26 April – 2 May 2010. For the event program of this open-door week see www.novam-research.com/resources/Global-Scaling_Open-door- week_2010.pdf

Global Scaling – A new knowledge and holistic approach in science

Some essential statements of Global Scaling:

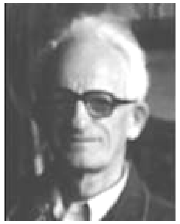
- In the universe / nature / vacuum there is an everywhere present background field in form of (eigen) oscillations (standing waves) which have a significant influence on the constitution of all processes, structures and systems in the universe, nature and (workable) technology
- On the logarithmic axis of every physical scale – such as length [m] , mass [kg] , time [s] , frequency [Hz] , temperature [℃] and am perage [A] – there is an universal distribution of certain positions and zones, the so-called Fundamental Fractal (see pages 20 – 22 and 66), which have a special meaning and a potential effect, e.g. a high or low resonance or oscillation capability. If, which and how many of these positions and zones actually unfold their corresponding effects depends on the details of the specific system or process and on external conditions.
- Particles such as protons and electrons are considered as vacuum resonances, i.e. they are an oscillation state of the physical vacuum
- In the universe there is a synchronicity in which all particles and matter are intimately involved. This is revealed, for example, by noise spectra of electronic components which show at different loactions simultaneously the same fine structure.
- Every part of the universe, e.g. an atom, comprises the entire information of the universe

Global Scaling – A new knowledge and holistic approach in science

- Some important key words of Global Scaling:

  scale invariance • logarithm • fractal • fractal structures • Fundamental Fractal • continued fractions • (eigen) oscillations • nodes • gaps • resonance • proton resonance • vacuum resonance • synchronicity • frequency distributions • probability • compression • decompression • non-linear and fractal course of time

- Global Scaling rest, among others, upon the results of very comprehensive studies – e.g. by Prof. Simon E. Shnoll et al – of frequency distributions of many different physical, chemical and biological processes and phenomena such as radioactive decay and body masses of biological species. These studies revealed the existence of formerly unexplored physical laws and effects.



Simon E. Shnoll

Hartmut Mueller

- Global Scaling was developed by Dr. Hartmut Mueller

- If you read or hear about Global Scaling for the first time, then it may take somewhat time to grasp its (unaccustomed) way of thinking, approach, concepts and insights

Global Scaling – A new knowledge and holistic approach in science

- Global Scaling phenomena are a feature of complex and open systems or processes and are less or not at all apparent in “simple and isolated“ systems or processes

- Global Scaling allows access to complex tasks / problems / systems and is applicable in many areas such as engineering, physics, biology, (holistic) medicine, architecture, economy, optimization, prognosis, psychology …

- A Global Scaling analysis of an existing system or process may lead to a deepened understanding of its specific parameters, features and behavior

- Sketch of the approach when Global Scaling is applied with respect to the modification of an existing system or the creation of a new system:

  Question at the beginning: Is Global Scaling relevant for the corresponding task / problem / system ? • Assuming yes, then consider the positions of its associated physical quantities relative to the positions and zones which are given by the Fundamental Fractal (see page 20 – 22 and 66) • Identify the adjustable and non-adjustable quantities or parameters of the corresponding task / problem / system • To obtain a certain desirable result it is necessary to get an idea, hypothesis or intuition at which positions in the Fundamental Fractal the adjustable quantities or parameters have to be placed.

Global Scaling – A sketch of the Fundamental Fractal on the level n_0 and n_1

Fundamental Fractal: Universal distribution or pattern of certain positions and zones which have – on every physical scale – a special meaning and a potential effect

Consider logarithmic axis: $z = \ln \frac{x}{y}$

x = physical quantity or number (ratio or set) under consideration
y = calibration unit of the considered physical scale such as length [m] or mass [kg]

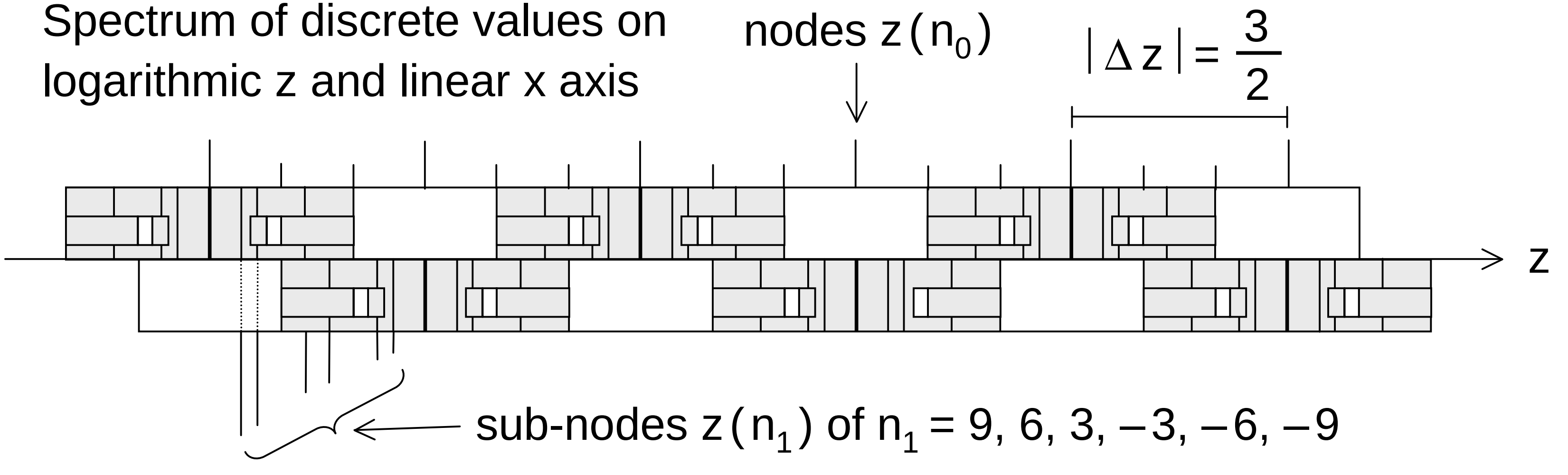
The positions of so-called nodes and sub-nodes – one of their potential effects is a high resonance or oscillation capability – are generated by a special continued fraction:

$$z = \ln \frac{x}{y} = \frac{3n_0}{2} + \cfrac{2}{n_1 + \cfrac{2}{n_2 + \ddots}}$$

$n_0 = \pm k \qquad n_1 = \pm 3j \qquad k\,,\, j = 0, 1, 2, 3 \ldots$

range of nodes and sub-nodes: $n_0 \pm 1\ ,\ n_1 \pm 1$

Spectrum of discrete values on logarithmic z and linear x axis



Global Scaling – A section of the Fundamental Time Fractal on the level n_0

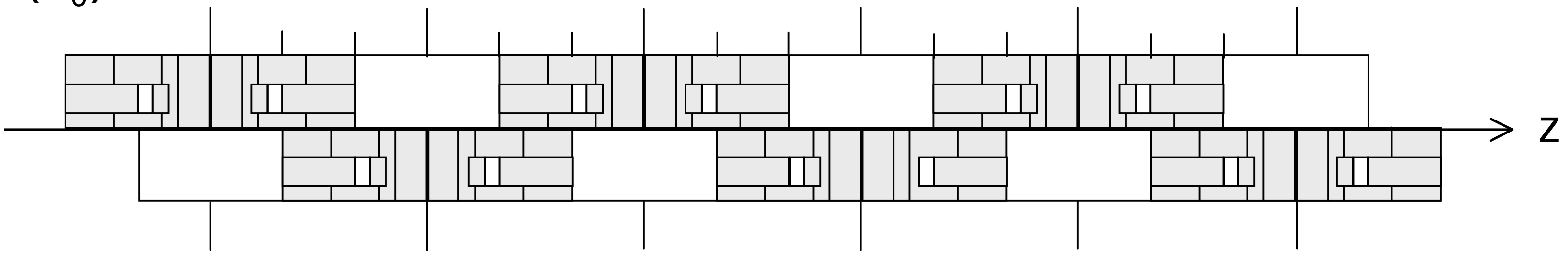
$$z = \ln \frac{x}{y} = \frac{3 n_0}{2} \qquad n_0 = 0\ ,\ \pm 1\ ,\ \pm 2\ ,\ \pm 3\ \ldots$$

x = time, e.g. elapsed time after the creation of an object or birth of a human being

y = calibration unit = $1 / f_p = \lambda_p / c = 7.01515 \times 10^{-25}$ s

f_p = proton frequency , $\lambda_p = h / (2 \pi c\, m_p)$ = reduced Compton wave length of the proton

Node positions $z(n_0)$ or $x(n_0)$ in the time fractal mark with high probability important points of change in the course of a process, independent of its nature



nodes $z(n_0)$: 69 70.5 72 73.5 75 76.5

nodes $x(n_0)$: 7.5 days 34 days 5 months 1.9 years 8.3 years 37 years

Highest age of Stone Age men

Examples of their relevance:

At the age of 7 days a fertilized egg nests itself in the uterus

Statistical maxima of product failure

Based on statistical results life insurances distinguish between people below and above 37 years

Global Scaling – A section of the Fundamental Temperature Fractal on level n_0

A possible view of (the distribution of) the T_c‘s of superconductors

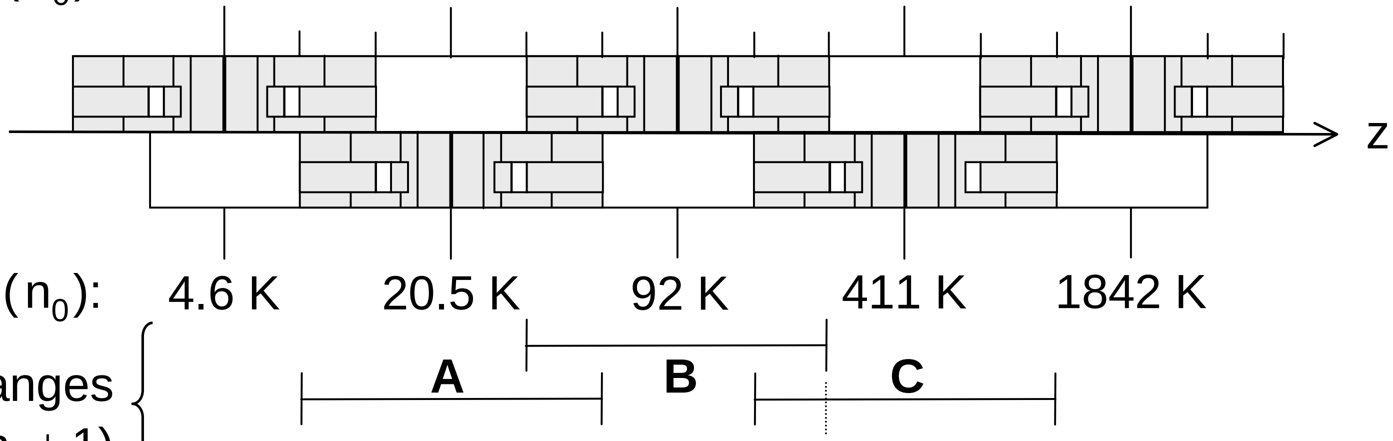
$z = \ln \frac{x}{y} = \frac{3 n_0}{2}$ $\quad n_0 = 0, \pm 1, \pm 2, \pm 3 \ldots$

x = transition temperature T_c [K]

y = calibration unit = $m_p c^2 / k = 1.08882 \times 10^{13}$ K

Node positions $z(n_0)$ or $x(n_0)$: high probability of tendency change, event attractor

Borders $z(n_0 \pm 1)$ or $x(n_0 \pm 1)$ of nodes: development limit



nodes $z(n_0)$: -28.5 -27 -25.5 -24 -22.5

nodes $x(n_0)$: 4.6 K 20.5 K 92 K 411 K 1842 K

borders / ranges of nodes $x(n_0 \pm 1)$

249 K

A: classical superconductors such as Nb_3Ge, typical T_c‘s about 20 K

B: high-T_c superconductors based on Cu and O such as $YBa_2Cu_3O_7$, typical T_c‘s about 100 K, often reports of indications for $T_c \approx 240$ K but unverified because difficult to reproduce → upper T_c limit of Cu-O-based superconductors ?

C: T_c‘s of next generation superconductors ? Typical T_c‘s about 400 K ?

Global Scaling – Applications

- Large potential to create novel and advantageous technologies such as
  - Novel or more effective ways of power generation
  - Transmission of energy and data without electromagnetic pollution
  - Transmission of data and communication with an unique level of data security
  - Contactless detection of raw materials down to 10 km below the earth‘s surface
- Examples of already existing and running demonstration models which are ready for prototype development or production:
  - Data transmission system with an unique level of data security
  - Satellite-independent positioning system which also works in closed rooms and below the surface of the earth
  - Water splitting system which generates hydrogen and oxygen with significant less power than conventional electrolyzers
- An already commercially available Global Scaling product is “ProtoLight“ – a special light source for medical applications such as accelerated wound healing
- Further information see www.global-scaling-institute.de

ProtoLight

Image: www.global-scaling-institute.de/57-1-ProtoLight.html

Global Scaling – Information and education

- Website of the Global Scaling Research Institute: www.global-scaling-institute.de
- An introduction into Global Scaling – the so-called Global Scaling Theory Compendium – can be downloaded from www.global-scaling-institute.de
- Paper "Fractal Scaling Models of Resonant Oscillations in Chain Systems of Harmonic Oscillators“ by H. Mueller in Progress in Physics 2 (2009) 72 – 76: www.ptep-online.com/index_files/2009/PP-17-13.PDF
- Paper "Fractal Scaling Models of Natural Oscillations in Chain Systems and the Mass Distribution of Celestial Bodies in the Solar System" by H. Mueller in Progress in Physics 1 (2010) 62 – 66: www.ptep-online.com/index_files/2010/PP-20-10.PDF
- Paper "Fractal Scaling Models of Natural Oscillations in Chain Systems and the Mass Distribution of Particles" by H. Mueller in Progress in Physics 3 (2010) 61 – 66: www.ptep-online.com/index_files/2010/PP-22-10.PDF
- Information about the German-language book “Global Scaling – Basis eines neuen wissenschaftlichen Weltbildes“ (in German): www.novam-research.com/resources/Global_Scaling_Buch_Info.pdf
- New, comprehensive and advanced form of education: see www.global-scaling-institute.de for further details
- Website of C. Buerger‘s engineering office: www.ibgs.info

Global Scaling and the search for room temperature superconductors

- Intuitively gained hypothesis:

  Creation of room temperature superconductivity by a resonance-like interaction between an everywhere present background field and a special material with an appropriate crystal structure and chemical composition

- Brief outline of an useful appearing approach how to use Global Scaling to isolate such chemical compositions and crystal structure types which favor the potential for room temperature superconductivity:

  Preparation of such materials whose readily accessible material parameters are located at special positions in the Fundamental Fractal (see pages 20 – 22 and 66). For example, this could mean that some material parameters are placed at positions with a potentially high resonance or oscillation capability, whereas others are placed at positions with a potentially low resonance or oscillation capability. Examples of readily accessible material parameters are the number and mass of atoms in the crystallographic unit cell, the lattice parameters and the chemical composition. This approach leads to a significant reduction of the number of useful appearing chemical compositions. Nevertheless, there are still many possibilities because there are various conceivable configurations of material parameters in the Fundamental Fractals which could favor the creation of room temperature superconductivity.

Global Scaling and the search for room temperature superconductors

Notes:

- For any task or question in which Global Scaling is applied, “conventional“ knowledge, experiences, results and ideas play an equal role. Therefore that which is presented on the pages 13, 14 and 37 – 63 about special oxides is still considered as relevant for the search for room temperature superconductors.

- Global Scaling can, if an useful appearing approach exists, also be applied to the search for room temperature superconductors among non-oxide materials such as organic conductors or metal-hydrogen compounds (see also pages 34 and 54 for these examples of non-oxide materials)

Closing words

A positive evolution of mankind and earth does not come about solely by scientific and technological progress, but requires rather the development of the “qualities of the heart“ such as compassion, peace, unconditional love, dignity, freedom, tolerance …

About the author

- Born **1962** in Bremen (Germany). **1983 – 1989:** Study of physics at the University of Heidelberg (Germany)
- **1989 – 1992:** Doctoral thesis in the department of Dr. J. Georg Bednorz at the IBM Zurich Research Laboratory (Switzerland). Doctorate / PhD at the University of Zurich in 1991. **Field of work:** Synthesis of oxides – especially in crystalline form via the melt – and study of their properties, solid state chemistry / physics.
- **1992 – 1997:** Research scientist in the nickel metal hydride technology department of Dr. Uwe Koehler at the research center of the battery company VARTA (Germany). Two months stay as guest scientist in Tokyo (Japan) at the TOSHIBA Battery Company within a collaboration between VARTA und TOSHIBA. **Field of work:** Hydrogen storage alloys and nickel metal hydride batteries.
- **1997 – 2007:** Research scientist in the department of Prof. Dr. Jochen Mannhart at the Institute of Physics of the University of Augsburg (Germany). **Field of work:** Setting up a new laboratory, synthesis of oxides – especially in crystalline form via the melt – and study of their properties, solid state chemistry / physics.
- **2005:** Participation in an overall 13 - day course in Global Scaling lectured by Dr. Hartmut Mueller at the Global Scaling Research Institute (Germany).
- **2007 – 2010:** Freelance work, autonomous occupation with subjects in the area of (an extended) physics / science, and creation and updating of several presentations and papers • Creation and updating of the website www.novam-research.com with the aim to disseminate information, presentations, papers and links about fundamentally new developments in science and technology such as entirely novel energy technologies
- **Since January 2011:** Research scientist in the group of Prof. Dr. Nicola Spaldin at the Department of Materials of the ETH Zurich (Switzerland): www.theory.mat.ethz.ch/people/senior_scientists/lfrank . **Field of work:** Setting up a new laboratory, synthesis of oxides and study of their properties, crystal growth via the melt, solid state chemistry / physics
- **Miscellaneous:** Author / Co-author of 70 scientific publications which are listed in the following link: www.novam-research.com/resources/Publications.pdf • Participation in several congresses and meetings about entirely novel energy technologies in Germany, Switzerland, Austria and Hungary
- **Name & Address:** Frank Lichtenberg • Ferdinand-Hodler-Strasse 16 • CH – 8049 Zurich • Switzerland
  Phone +41 (0)43 539 95 68 • novam@nlp-nicoletta.de • www.novam-research.com

Appendix (on the following pages 30 – 66)

On the following pages 31 – 36:

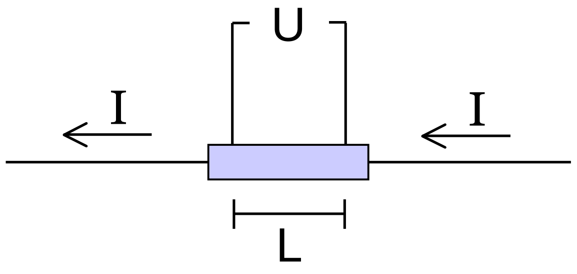
More about superconductivity

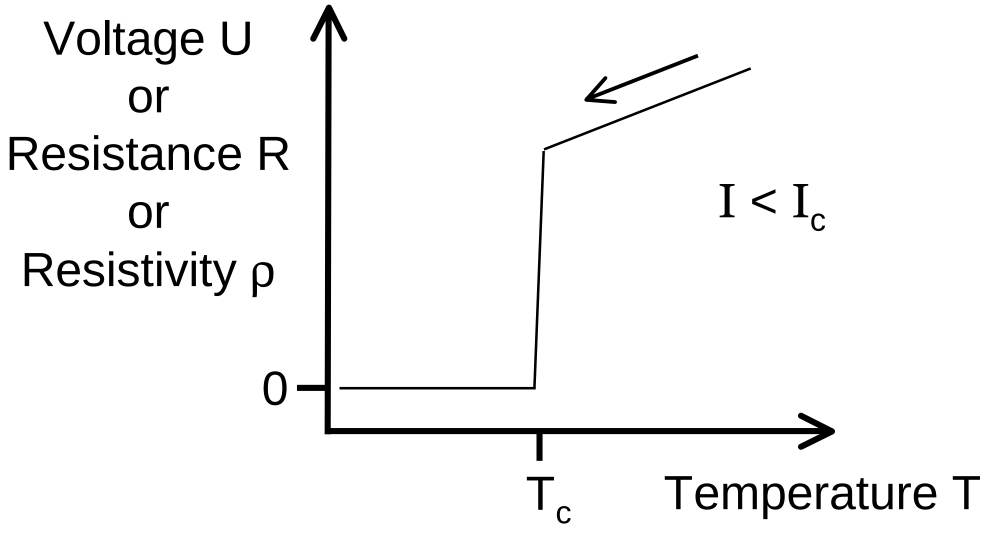
- The verification of superconductivity: Zero resistance and Meissner effect
- Applications in the area of entirely novel energy technologies
- Do man-made room temperature superconductors already exist ?
- Superconductivity and ECE Theory

The verification of superconductivity: The first of two essential features

Zero resistance

DC current I through sample: Measurement of voltage drop U at various temperatures





resistance $R = \dfrac{U}{I}$

specific resistance or resistivity $\rho = R\,\dfrac{A}{L}$

current density $j = \dfrac{I}{A}$ L = length A = cross sectional area

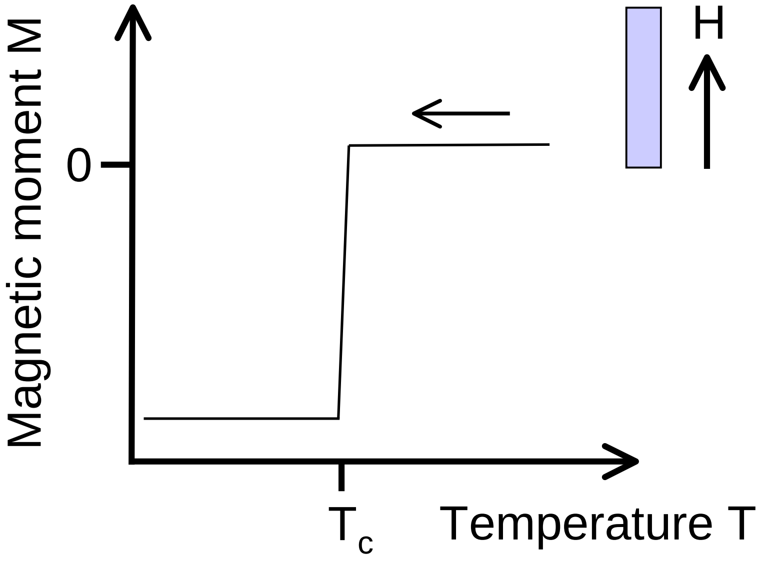
Notes: For $I > I_c$ or $j > j_c$ the superconductivity disappears

I_c or j_c is the so-called critical current or critical current density

For example, for $YBa_2Cu_3O_7$ the critical current density j_c at T = – 196 °C is of the order of 10^6 A / cm^2

The verification of superconductivity: The second of two essential features

Meissner effect



Cooling down of the sample in an external static magnetic field H: Below T_c superconducting currents emerge in a thin surface layer of the sample. These currents create a negative magnetic moment M, i.e. M is antiparallel to H which is called diamagnetic behavior. This magnetic moment M generates an associated magnetic field which is exactly opposite to H so that the total interior field of the sample vanishes.
This so-called Meissner effect results from a peculiar quantum physical state of the conduction electrons and cannot be explained solely by a DC resistance R = 0.

Notes:

- The levitation of a superconductor above a magnet (see page 5), or vice versa, is due to the fact that a superconductor is a (strong) diamagnet. Levitation in static magnetic fields without supply of energy is possible by a diamagnetic body in a spatially inhomogeneous magnetic field. See, for example, the paper “Levitation in Physics“ by E. H. Brandt in Science <u>243</u> (1989) 349 – 355.
- For H > H_c or H_{c2} the superconductivity disappears. H_c (for so-called type I superconductors) or H_{c2} (for so-called type II superconductors) is the so-called critical field. For example, for $YBa_2Cu_3O_7$ the critical field H_{c2} at T = – 196 °C is of the order of 10 Tesla. For comparison: The earth‘s magnetic field is of the order of 5×10^{-5} Tesla = 0.5 Gauss (1 Tesla = 10^4 Gauss)

Superconductivity – Applications in the area of entirely novel energy technologies

Several applications of superconductors are presented on page 9.

Also in the area of entirely novel technologies, see e.g.
www.novam-research.com/resources/Call_to_fund_an_independent_research_facility.pdf ,
superconductors – especially room temperature superconductors – have an application potential. See, for example,

- page 2 in an abstract by H. V. Wenz / IEM Nova
  about the so-called Field Force Machine:
  www.novam-research.com/resources/Field-Force-Machine_IEM-Nova_2010.pdf
- pages 1 and 2 in a German-language abstract by H. V. Wenz / IEM Nova
  about the so-called Field Force Machine:
  www.novam-research.com/resources/Feldkraftmaschine_IEM-Nova_2010.pdf
- section 5.1. / pages 69 – 73 in a paper by Prof. C. W. Turtur about
  the conversion of vacuum energy into mechanical energy:
  www.wbabin.net/physics/turtur1e.pdf

Do man-made room temperature superconductors already exist ?

So-called Ultraconductors reported by Chava Energy LLC:

- See www.chavaenergy.com/how/ultraconductors
- Organic polymer materials with measured zero resistance, i.e. resistivity $\rho < 10^{-11}\ \Omega$ cm
- Several anomalous electric properties such as absence of heat generation under high current
- Chava Energy continues the development of these patented materials with respect to applications and commercialization

Special metal – hydrogen materials reported by two German patent applications:

- "Offenlegungsschriften" DE 101 09 973 A1 and DE 10 2008 047 334 A1 published in 2002 and March 2010 (in German):
  See http://depatisnet.dpma.de/DepatisNet/depatisnet?action=pdf&docid=DE000010109973A1
  and http://depatisnet.dpma.de/DepatisNet/depatisnet?action=pdf&docid=DE102008047334A1
- Materials are described in the context of cold fusion and show measured zero resistance
- Further information about these materials only for licensees

In both cases: So far no public reports or statements of the presence of the Meissner effect (see page 32). Therefore it appears presently not clear if these interesting materials are really superconductors.

Superconductivity and ECE Theory

The intuitively gained hypothesis how superconductivity at room temperature may come about (see pages 15 and 25), namely

> by a resonance-like interaction between an everywhere present background field – see e.g. Global Scaling – and a special material with an appropriate crystal structure and chemical composition

seems to be supported by a statement from the so-called ECE Theory which is possibly related to the hypothesis above:

> “… One of the important practical consequences is that a material can become a superconductor by absorption of the inhomogeneous and homogeneous currents of ECE space-time …“
>
> Cited from page 97 of the ECE uft paper No. 51 “ECE Generalizations of the d‘Alembert, Proca and Superconductivity Wave Equations …“ by M. W. Evans: www.aias.us/documents/uft/a51stpaper.pdf

What is the ECE Theory ?

- ECE stands for Einstein, Cartan and Evans and represents an unified field theory which allows a common description of the electromagnetic, gravitational, weak and strong nuclear forces
- Developed by Prof. Myron W. Evans by starting from Albert Einstein‘s Theory of General Relativity and the mathematic research work of the mathematician Elie Cartan

Myron W.
Evans

- Some important statements:
  - Gravitation is related to curvature of space-time
  - Electromagnetism is related to torsion of space-time
  - Coupling between electromagnetism and gravitation
  - Extended electrodynamics with resonance phenomena via so-called spin connection ⇨ Possibility of extracting usable energy from space-time
- Comprehensive information about ECE Theory in the website www.aias.us
- For an introduction into ECE Theory see the article by H. Eckardt and L. G. Felker: www.aias.us/documents/eceArticle/ECE-Article_EN.pdf

On the following pages 38 – 63:

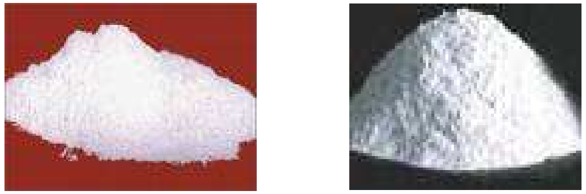
More about the own research work in the field of special oxides

- Sample preparation and oxides of the type $A_nB_nO_{3n+2}$ – also about their potential to create high-T_c or room temperature superconductors

- Title, abstract and table of contents of a comprehensive scientific article on special oxides

Sample preparation of oxides

Starting materials: Commercially available oxides (e.g. Titanium oxide TiO_2), carbonates (e.g. Calcium carbonate $CaCO_3$) and, if necessary, metals (e.g. Niobium Nb) in form of powders



Powder

Analytical balance

Agate mortar

Crucible and boats made from high-temperature ceramics

Laboratory furnaces

typical temperatures 900 – 1400 °C

Mixing of the starting materials → Heating-up of the powder mixture → Chemical solid state reaction → Formation of new oxides

Sample preparation of oxides A_yBO_x with B = Ti , Nb or Ru

General process for reduced, mixed-valent, conducting titanates or niobates, i.e. $Ti^{(4-w)+}$, $3d^w$ or $Nb^{(5-w)+}$, $4d^w$ with $w > 0$:

1. Example of fully oxidized starting materials: $SrCO_3$, La_2O_3 and TiO_2 or Nb_2O_5
   Pre-reaction / calcination of finely ground powder mixture at 1200 – 1300 ℃ in Air

↓

2. Addition of a reduced component like TiO or Nb
   Pressing finely ground powder mixture into two rods
   Sintering rods at 1300 – 1400 ℃ in Argon

↓

3. Floating zone melting in Argon

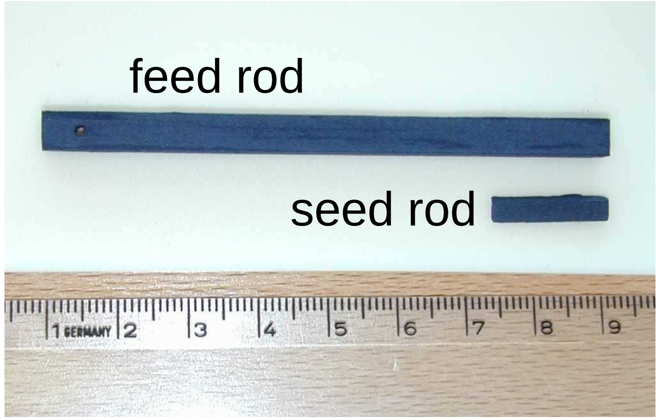
Determination of oxygen content x by thermogravimetry

Structural analysis by powder x-ray diffraction

Fully oxidized, insulating titanates (Ti^{4+}, $3d^0$) or niobates (Nb^{5+}, $4d^0$) and conducting Sr_2RuO_4 (Ru^{4+}, $4d^4$) } All 3 steps in Air

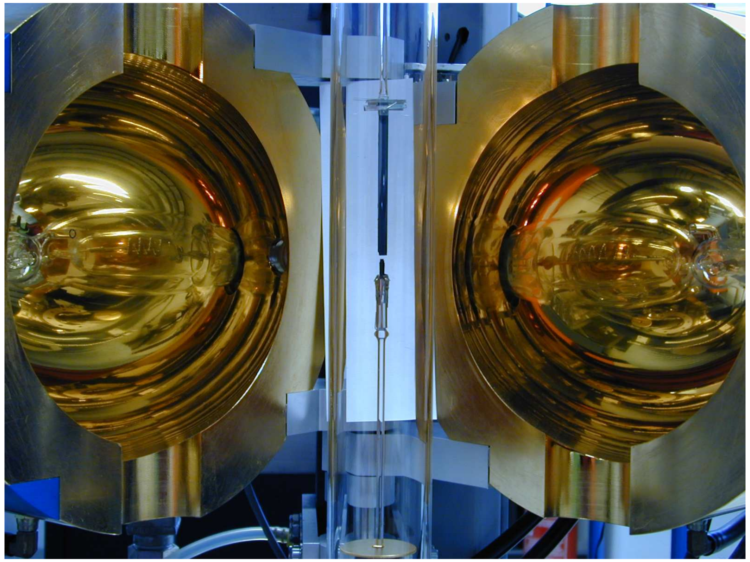
Lichtenberg et al:
Progress in Solid State Chemistry 36 (2008) 253 and 29 (2001) 1 and 30 (2002) 103

Sample preparation of oxides in crystalline form by floating zone melting

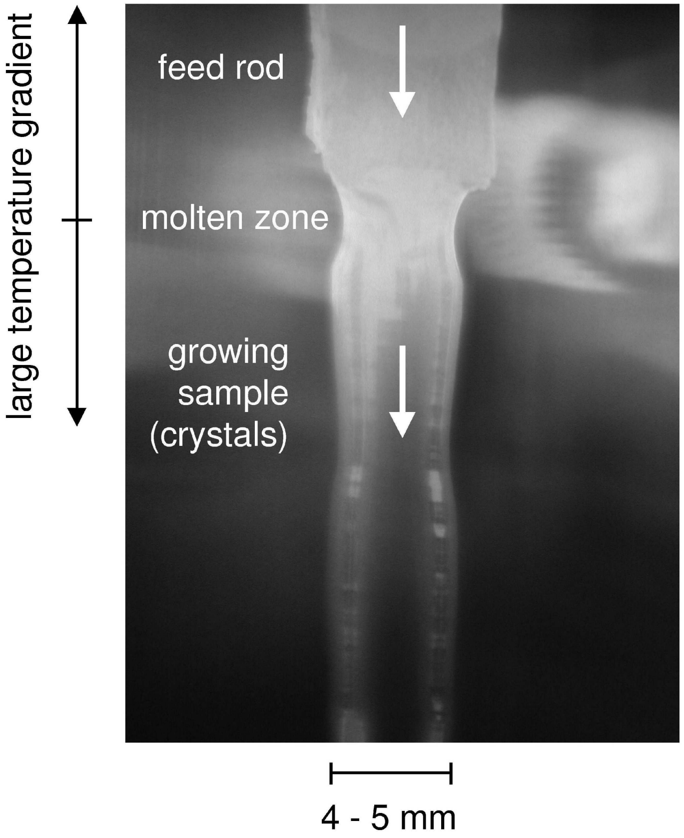


Polycrystalline sintered rods

Good and relatively large crystals arise usually only if the solidification is (nearly) congruent, i.e. if the melt and the solidified material have (nearly) the same chemical composition. If this is true depends on the chemical composition and is often not known or predictable, especially for unexplored chemical compositions.

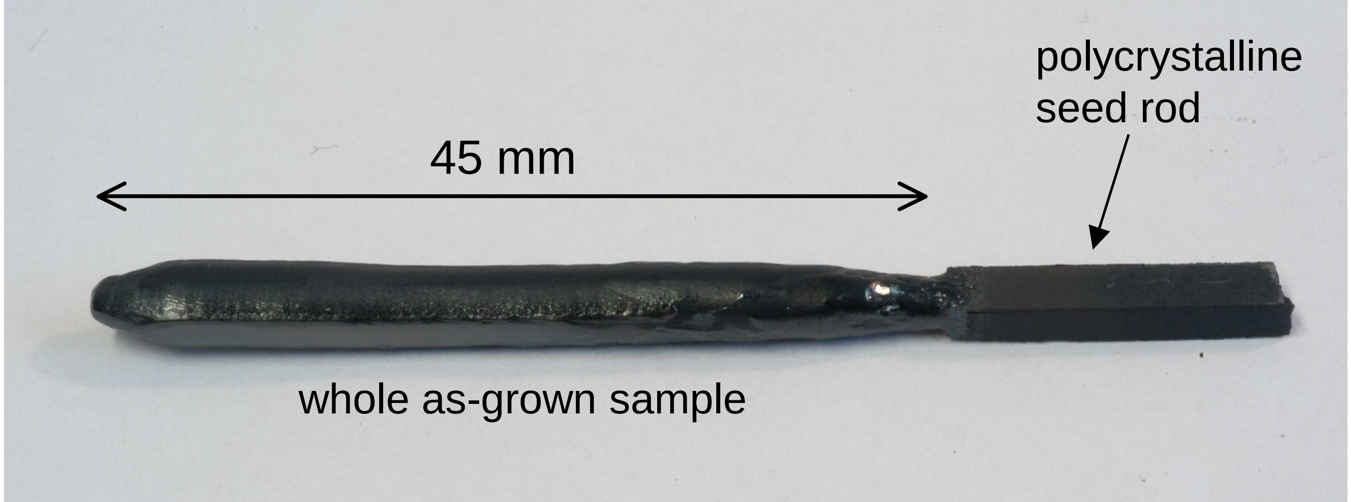


Optically heated floating zone melting furnace

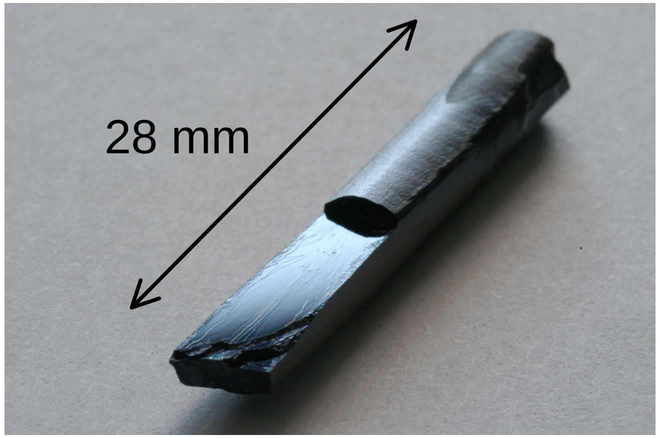


Samples / Crystals grown by floating zone melting

Example: Blue-black electrical conducting oxide $Ca_4EuNb_5O_{17}$ ($n = 5$ of $A_nB_nO_{3n+2}$)



part of the as-grown sample



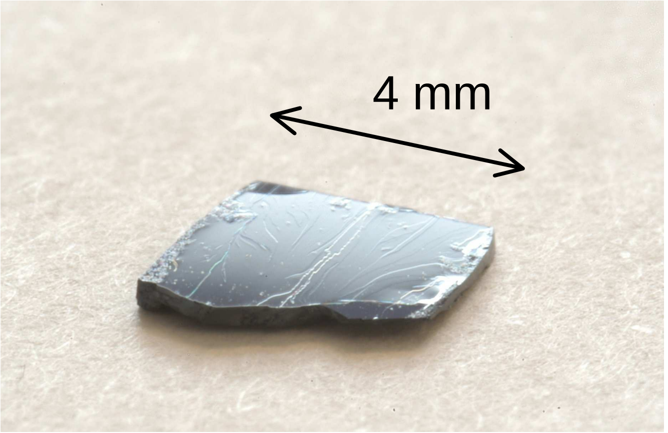


plate-like crystal obtained by crushing / cleaving the as-grown sample

Lichtenberg et al , Progress in Solid State Chemistry 36 (2008) 253

Sketch of the perovskite-related structure of $A_nB_nO_{3n+2} = ABO_x$

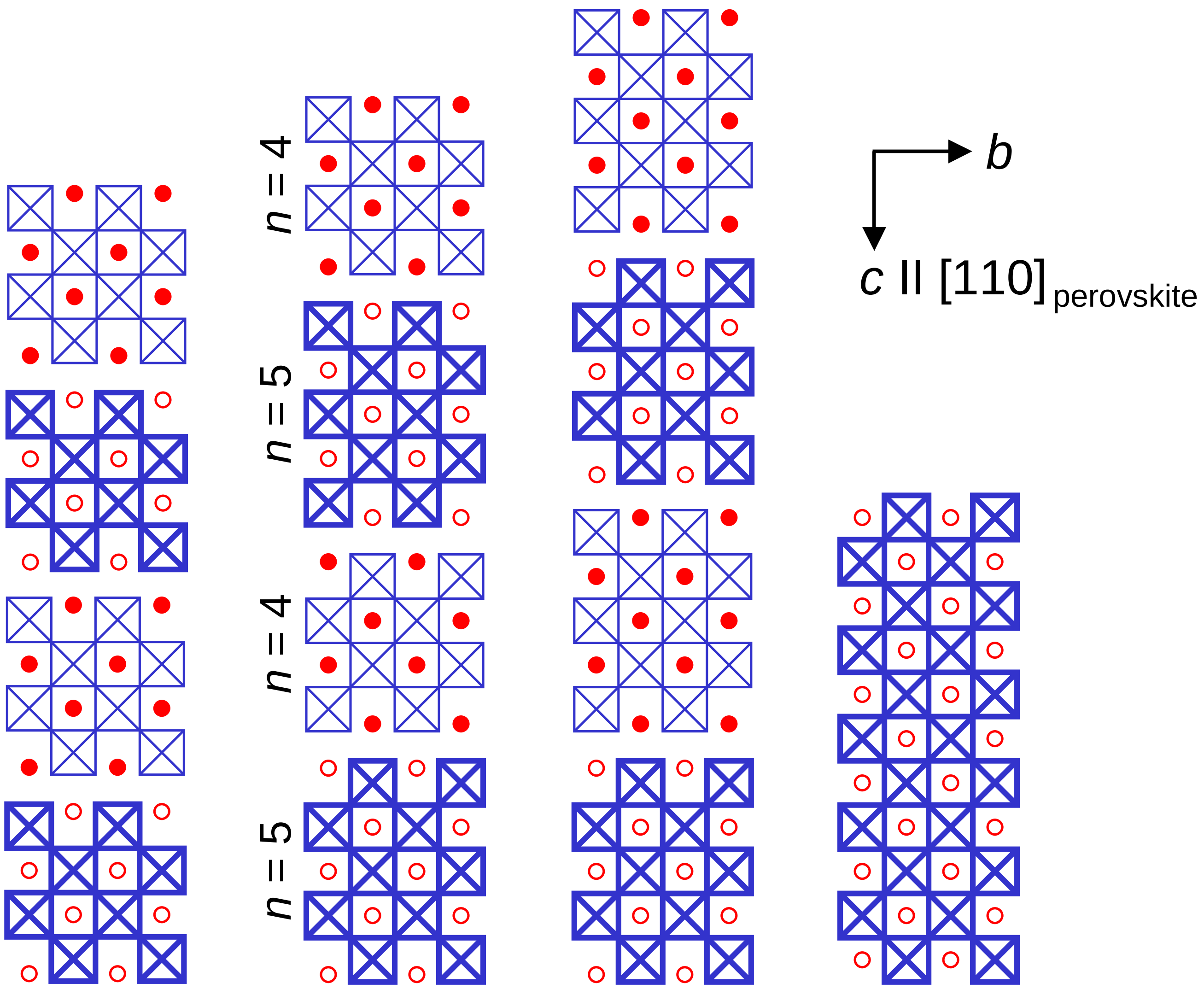
B = Ti, Nb, Ta

⊠ = BO_6 octahedra (O located at corners, B hidden in center)

n = layer thickness = number of BO_6 octahedra along c-axis per layer

Existence of non-integral series members such as n = 4.5:

Ordered intergrowth of layers with different thickness



	$n = 4$	$n = 4.5$	$n = 5$	$n = \infty$
	$ABO_{3.50}$	$ABO_{3.44}$	$ABO_{3.40}$	ABO_3 perovskite
compositional examples:	$SrNbO_{3.50}$	$SrNbO_{3.44}$	$SrNbO_{3.40}$	$SrNbO_3$

BO_6 octahedra (O located at corners, B hidden in center) = ⊠ ◇

Sketch of the pronounced structural anisotropy of $A_nB_nO_{3n+2} = ABO_x$ by using n = 5 as example

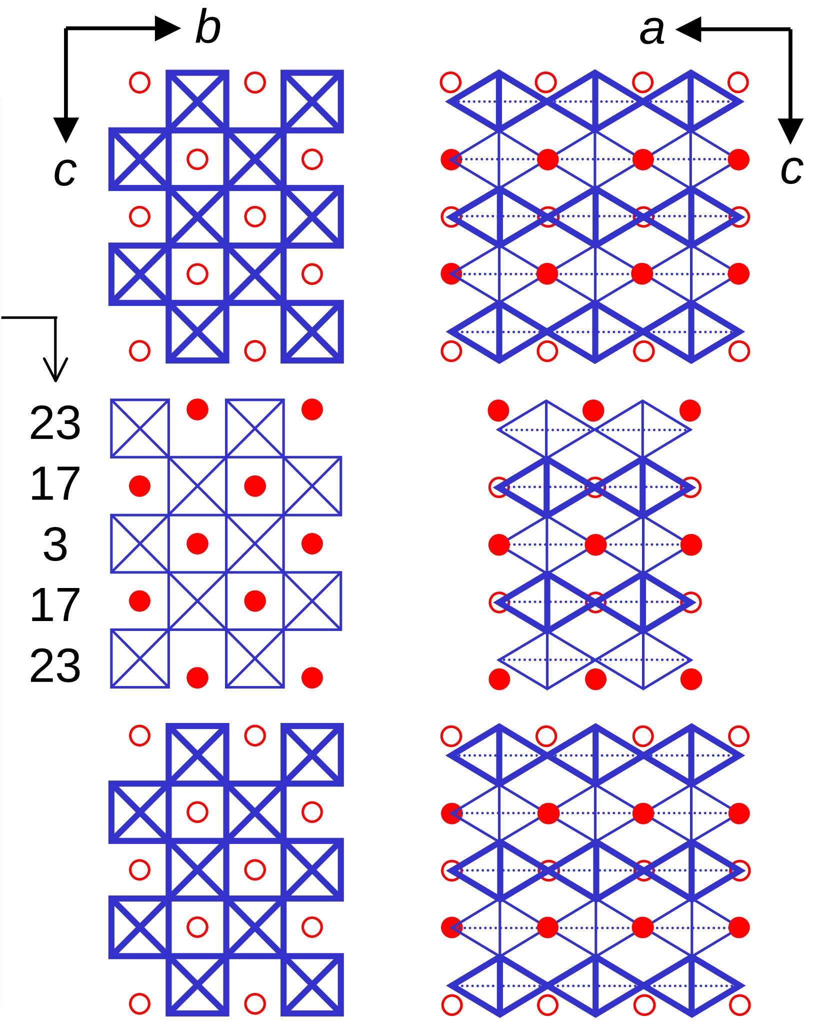
B – O linkage:

- zig-zag along b-axis
- chains along a-axis
- interruptions along c-axis
  ⇨ layered crystal structure

Distortion of BO_6 octahedra in percent

typical values for n = 5

Often significant influence of distortions on physical properties



$A_5B_5O_{17} = ABO_{3.40}$ (n = 5)

Some features of $A_nB_nO_{3n+2}$ = ABO_x insulators (B = Ti^{4+}, Nb^{5+}, Ta^{5+}):

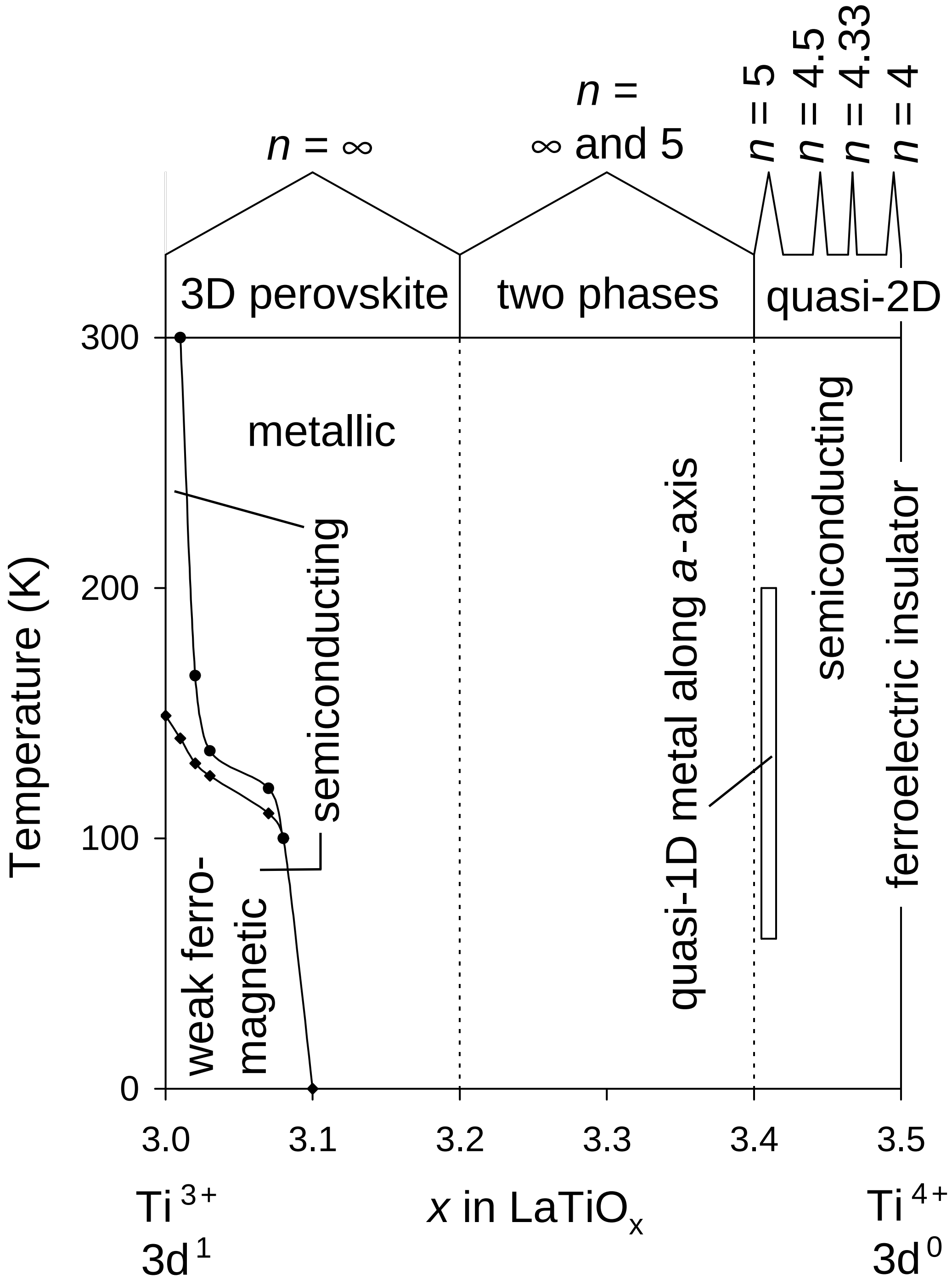
- The highest-T_c ferroelectrics are $n = 4$ types , e.g. $LaTiO_{3.50}$ (T_c = 1770 K)
  Nanamatsu et al , Ferroelectrics 8 (1974) 511
- Ferroelectrics: even n = 2, 4, 6 – Antiferroelectrics: odd $n = 5$
- Compounds with non-integral n (see page 53),
  e.g. $CaNb_{0.89}Ti_{0.11}O_{3.44}$ ($n = 4.5$) Nanot et al , J. Solid State Chem. 28 (1979) 137
- Compounds known for n = 2 , 3 , 4 , 4.33 , 4.5 , 5 , 6 , 7
- Complex structural details like incommensurate modulations,
  e.g. in $SrNbO_{3.50}$ ($n = 4$) Daniels et al , Acta Cryst. B 58 (2002) 970
- Possibility of limited concentration of ions B' = Al^{3+}, Fe^{3+} … at B site:
  $B = (Ti, Nb, Ta)_{1-y}B'_y$ with $y \leq 0.33$

$A_nB_nO_{3n+2}$ = ABO_x electronic conductors: No reports before 1991

The only exception: Structural study on conducting $CaNbO_x$ ($3.4 \leq x < 3.5$)

Physical properties not studied

Hervieu et al , J. Solid State Chem. 11 (1974) 272



Systematic study of $A_nB_nO_{3n+2}$ electronic conductors started by study of melt-grown $LaTiO_x = La_nTi_nO_{3n+2}$

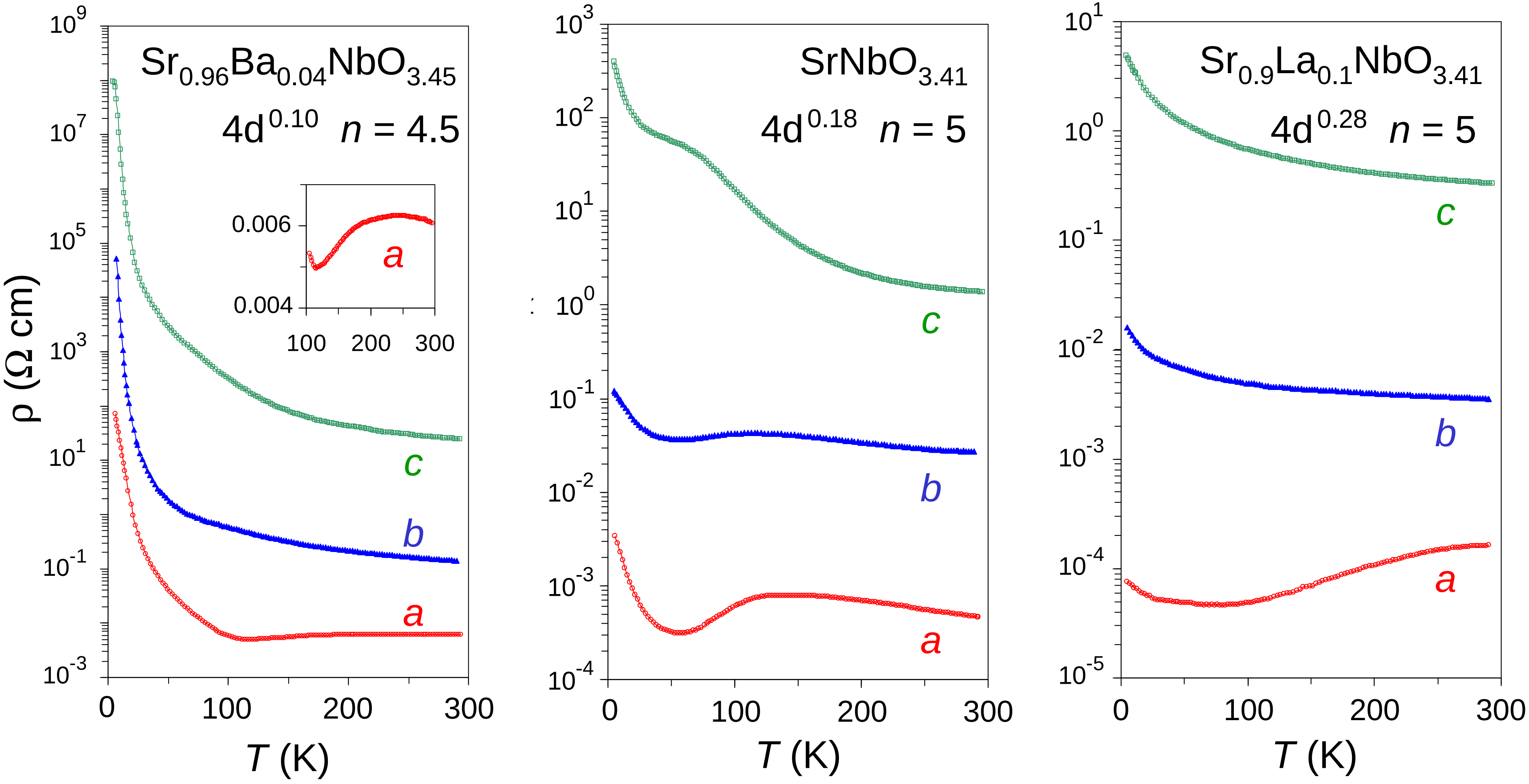
Physical and / or structral properties depend sensitively on oxygen content x

Lichtenberg et al
Z. Phys. B 82 (1991) 211
Prog. Solid State Chem. 29 (2001) 1

Williams et al
J. Solid State Chem.
93 (1991) 534 & 103 (1993) 375

Kuntscher et al
Phys. Rev. B 67 (2003) 035105

Resistivity ρ(*T*) of some $A_nB_nO_{3n+2}$ = ABO_x niobates along *a* - , *b* - and *c* - axis

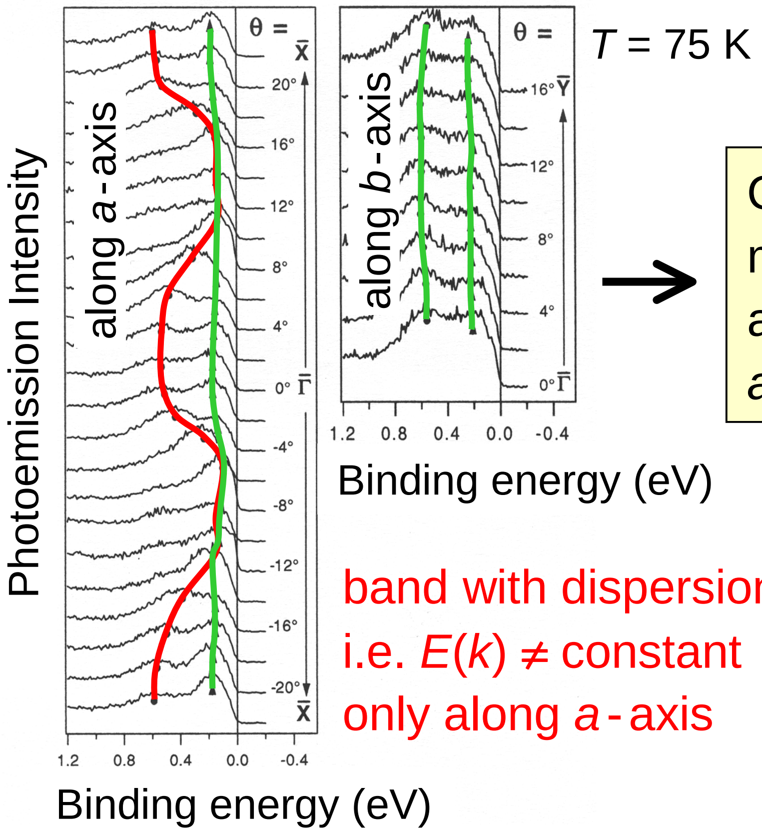


- Highly anisotropic conductors
- Quasi-1D metal along *a* - axis
- Metal-to-semiconductor transition at low *T*

Lichtenberg et al , Progress in Solid State Chemistry 29 (2001) 1

Comprehensive studies on $A_nB_nO_{3n+2}$ = ABO_x niobates by angle-resolved photoemision (ARPES) and optical spectroscopy: Example *n* = 5 type $SrNbO_{3.41}$

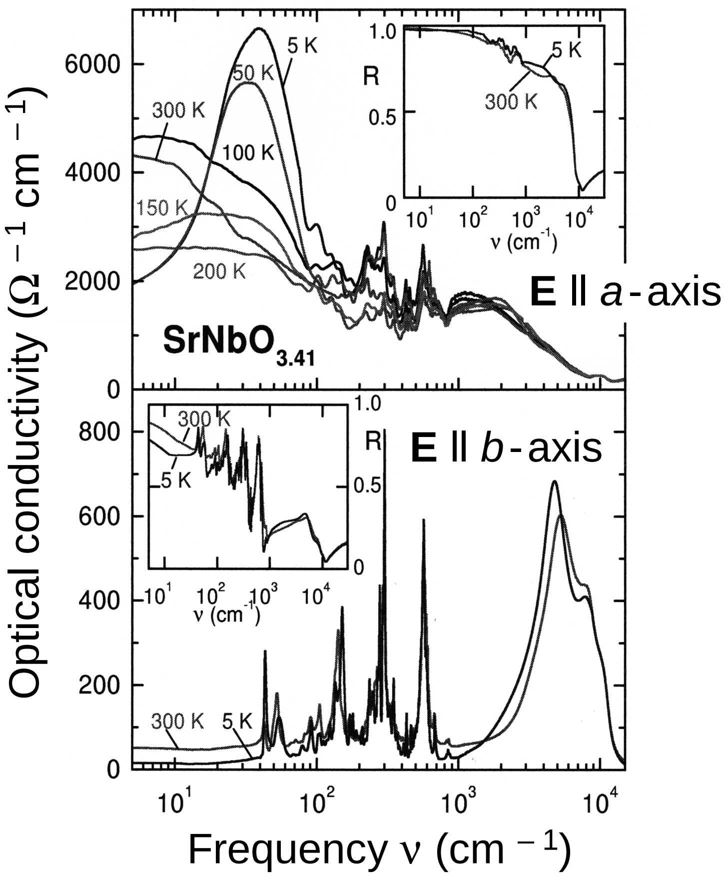
ARPES probes occupied electronic states and their dispersion *E*(*k*), *k* = *k*(θ)



band with dispersion
i.e. *E*(*k*) ≠ constant
only along *a*-axis

→ Quasi-1D metal along *a*-axis ←

Inset: Reflectivity *R*(ν)



- Metal-to-semiconductor transition at *T* < 100 K
- High-resolution ARPES at 25 K, resistivity ρ(*T*) & optical conductivity → Semiconducting state with extremely small energy gap Δ ≈ 5 meV, the smallest Δ of all known quasi-1D metals
- Experimental findings appear inconsistent with Peierls or 1D Mott-Hubbard picture

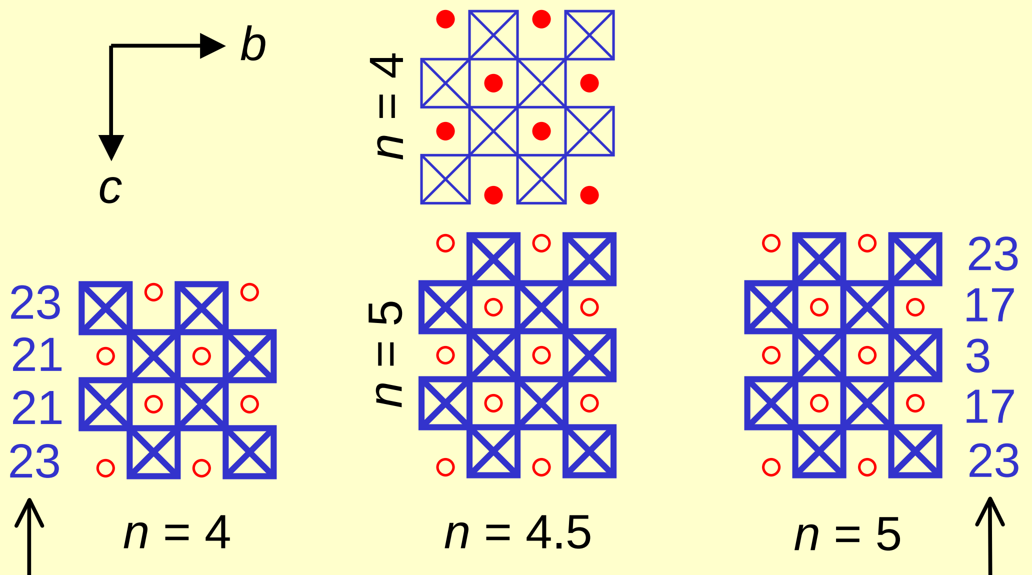
Kuntscher et al: Phys. Rev. B 61 (2000) 1876 & 70 (2004) 245123 and Phys. Rev. Lett. 89 (2002) 236403

Comprehensive studies on $A_nB_nO_{3n+2}$ = ABO_x niobates by ARPES, optical spectroscopy, resistivity measurements and electronic band structure calculations

$n = 4$	$Sr_{0.8}La_{0.2}NbO_{3.50}$	$4d^{0.20}$
$n = 4.5$	$SrNbO_{3.45}$	$4d^{0.10}$
$n = 5$	$SrNbO_{3.41}$	$4d^{0.18}$
$n = 5$	$Sr_{0.9}La_{0.1}NbO_{3.41}$	$4d^{0.28}$

$n = 4$ → weak quasi-1D metal
no energy gap at low T along a-axis

$n = 4.5$, $n = 5$, $n = 5$: quasi-1D metals
small energy gap at low T along a-axis



typical distortions of BO_6 octahedra (%)

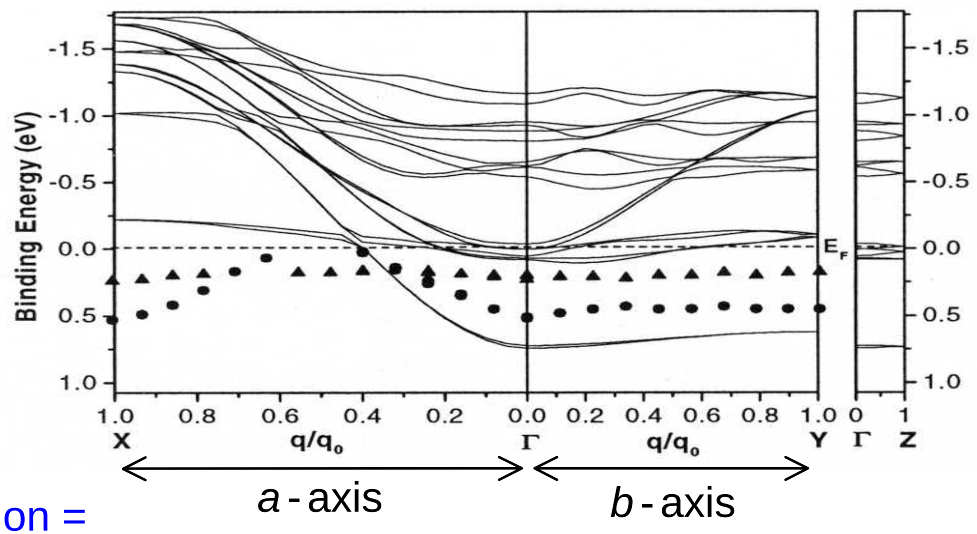
Special role of layers which are 5 NbO_6 octahedra thick:

Electrons from the Nb ions located in the central, almost undistorted octahedra contribute most to the metallic character

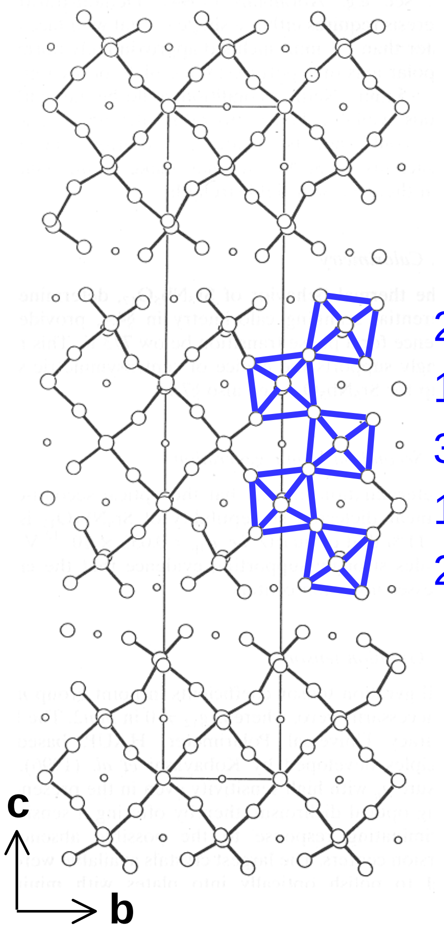
Kuntscher et al: Phys. Rev. B 61 (2000) 1876 & 70 (2004) 245123 and Phys. Rev. Lett. 89 (2002) 236403
Lichtenberg et al: Prog. Solid State Chem. 29 (2001) 1

LDA calculations of the electronic band structure of the *n* = 5 quasi-1D metal $SrNbO_{3.41}$

Good agreement with results from angle-resolved photoelectron spectroscopy (ARPES) with respect to lowest band



$$\text{NbO}_6\text{ octadedron distortion} = \frac{(\text{largest Nb – O distance}) - (\text{smallest Nb – O distance})}{\text{average Nb – O distance}}$$



23 %
17 %
3 %
17 %
23 %

Nb atoms of least distorted octahedra contribute most to the electronic density of states (DOS) at the Fermi energy E_F

Quasi-1D features along *a* - axis related to octahedra distortions

LDA predicts further bands around E_F which disperse along *a* - and *b* - axis, but they are not observed by ARPES: Subtle structural details ? Electronic correlations ? ARPES resolution ?

Kuntscher et al
Phys. Rev. B
61 (2000) 1876

Winter et al
J. Phys. Cond. Matter
12 (2000) 1735

Abrahams et al
Acta Cryst. B
54 (1998) 399

Lichtenberg et al
Prog. Solid State Chem.
29 (2001) 1

A special feature of $A_nB_nO_{3n+2} = ABO_x$ quasi-1D metals

Structural, compositional and electronical proximity to (anti)ferroelectric insulators !

This distinguishes them from all other known quasi-1D metals such as $K_{0.3}MoO_3$, $Li_{0.9}Mo_6O_{17}$, $NbSe_3$, $(SN)_y$ and organic conductors like TTF-TCNQ

Examples:

n = 4: ferroelectric $SrNbO_{3.5}$ ($4d^{0}$) → weak quasi-1D metal $Sr_{0.8}La_{0.2}NbO_{3.5}$ ($4d^{0.2}$)

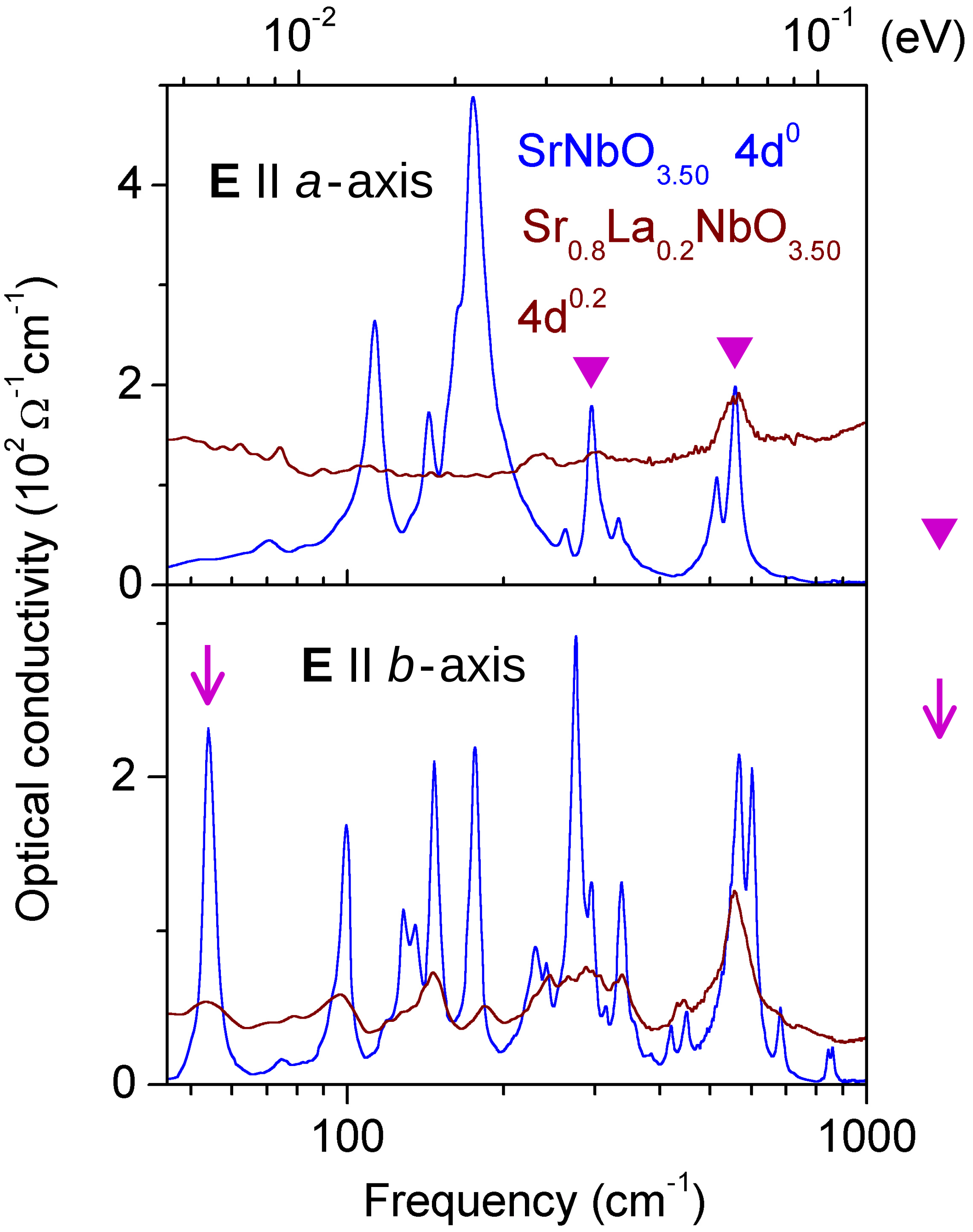
n = 5: antiferroelectric $SrNb_{0.8}Ti_{0.2}O_{3.4}$ ($4d^{0}$) → quasi-1D metal $SrNbO_{3.4}$ ($4d^{0.2}$)

Intrinsic coexistence of metallic conductivity and large dielectric polarizability feasible in $A_nB_nO_{3n+2}$ systems !?

Usually these both features exclude each other

Intrinsic coexistence of these both features might be useful for the creation of new high-T_c superconductors

The experimental observations presented on the following pages 51 – 53 support the presence of such an intrinsic coexistence …



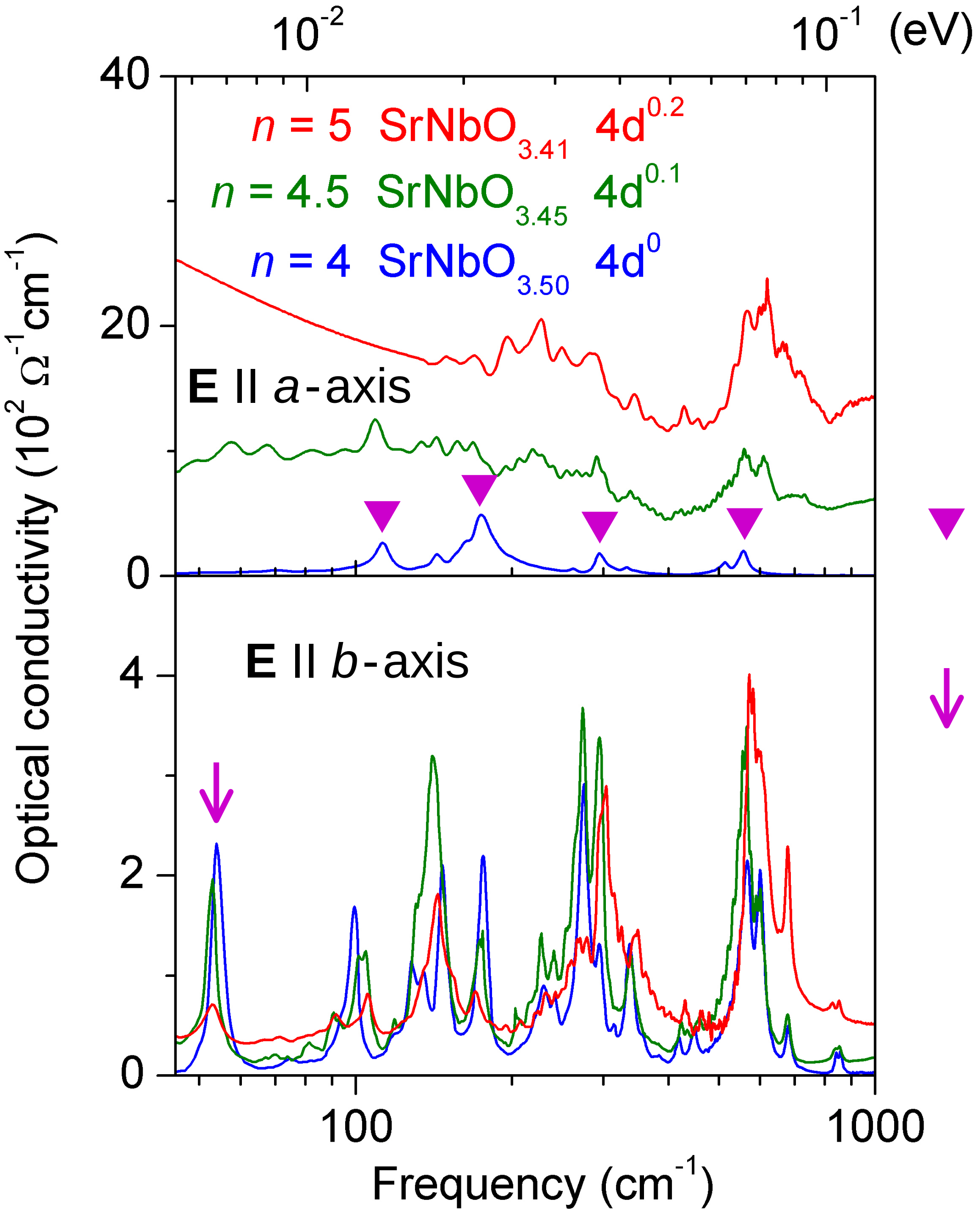
Optical conductivity at *T* = 300 K along *a*- and *b*-axis of *n* = 4 ferroelectric insulator $SrNbO_{3.50}$ and *n* = 4 weak quasi-1D metal $Sr_{0.8}La_{0.2}NbO_{3.50}$

▼ = phonon peaks which survive in the conducting oxide

↓ = ferroelectric soft mode (phonon peak associated with ferroelectric phase transition)

Ferroelectric soft mode peak occurs also in the weak quasi-1D metal !

Kuntscher et al
Phys. Rev. B 70 (2004) 245123



Optical conductivity at *T* = 300 K along *a*- and *b*-axis of *n* = 4 ferroelectric insulator $SrNbO_{3.50}$, *n* = 4.5 quasi-1D metal $SrNbO_{3.45}$ and *n* = 5 quasi-1D metal $SrNbO_{3.41}$

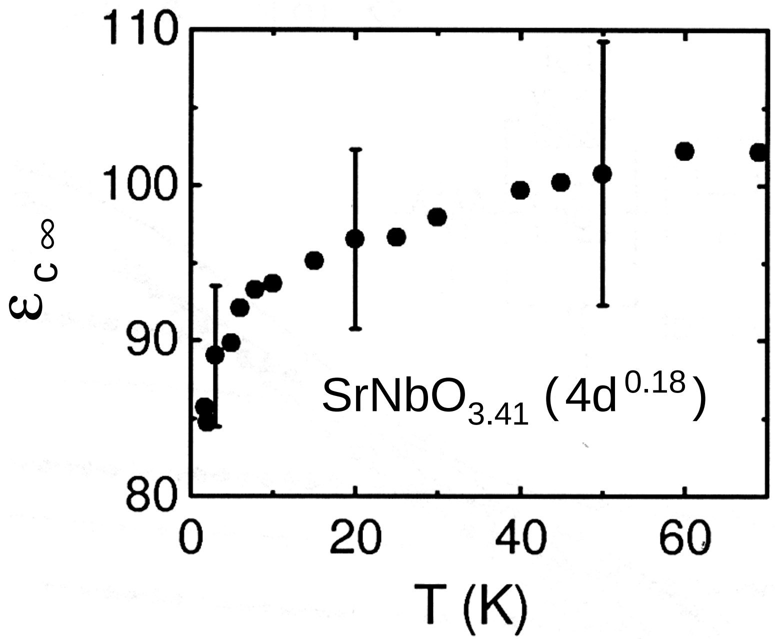
▼ = phonon peaks which survive in the conducting oxides

↓ = ferroelectric soft mode (phonon peak associated with ferroelectric phase transition)

Ferroelectric soft mode peak occurs also in the quasi-1D metals !

Kuntscher et al
Phys. Rev. B 70 (2004) 245123

Intrinsic high-frequency dielectric permittivity of the *n* = 5 quasi-1D metal $SrNbO_{3.41}$ along *c*-axis



Large permittivity: $\varepsilon_{c\,\infty} \approx 100$

T > 70 K: measurement prevented by too high conductivity

Bobnar et al , Phys. Rev. B 65 (2002) 155115

T ≈ 70 K: Metallic along *a*-axis according to ARPES and resistivity $\rho(T)$

Kuntscher et al , Phys. Rev. B 70 (2004) 245123

Lichtenberg et al , Prog. Solid State Chem. 29 (2001) 1

→

Coexistence of large intrinsic high-frequency dielectric permittivity $\varepsilon_{c\,\infty}$ along *c*-axis and metallic behavior along *a*-axis !

Note: Largest possible intrinsic dielectric permittivity in non-ferroelectrics of the order of $\varepsilon_{\infty} \approx 100$!? Lunkenheimer et al , Phys. Rev. B 66 (2002) 052105

Potential for high-T_c superconductivity in $A_nB_nO_{3n+2}$ quasi-1D conductors from the perspective of so-called excitonic superconductivity

A hypothetical possibility to realize superconductivity at room temperature is given by the so-called excitonic mechanism of superconductivity (electron-electron mediated):

- Original proposal by W. A. Little for hypothetical **quasi-1D** organic conductors[1]:

  Conducting chains surrounded by electronically polarizable side branches

  - In: Novel Superconductivity , Plenum Press (1987) 341
  - J. de Physique Colloque C3 Suppl. No 6 (1983) 819
  - Int. J. Quantum Chemistry (Quantum Chemistry Symposium) 15 (1981) 545
  - Scientific American 212 (1965) 21
  - Phys. Rev. 134 (1964) A1416

- Original proposal by V. L. Ginzburg for **quasi-2D** systems:

  Thin metallic sheet surrounded by two dielectric layers

  - Sov. Phys. Uspekhi 72 (1970) 335

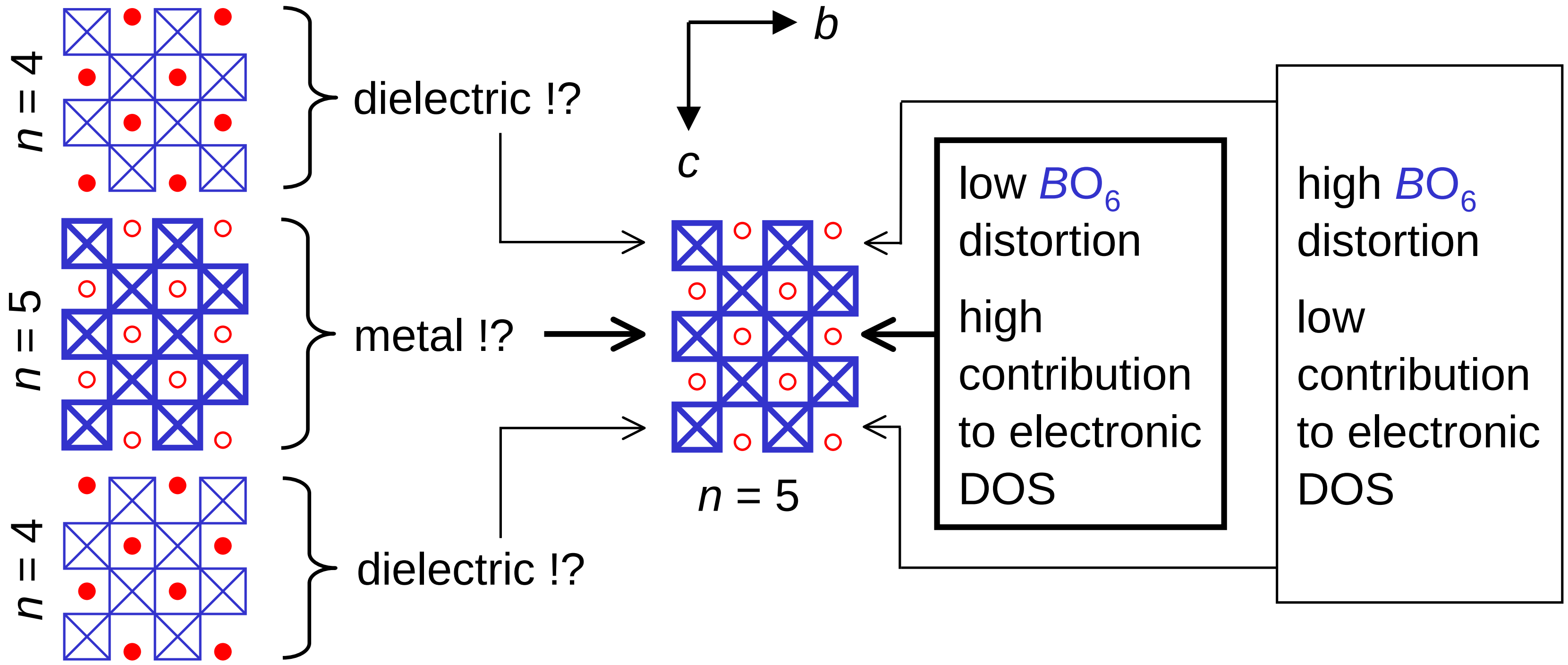
---

[1] In connection with organic conductors we also like to refer to the essay “Approaching an Ambient Superconductor“ by Robert B. Steele from 2005: www.chemexplore.net/BookP8s.pdf

Potential for high-T_c superconductivity in $A_nB_nO_{3n+2}$ quasi-1D conductors from the perspective of so-called excitonic superconductivity

Especially $n = 4.5$ and $n = 5$ interesting from W. Little‘s and V. Ginzburg‘s approach:

- quasi-2D crystal structure
- electronically quasi-1D by B – O chains and delocalized electrons along a - axis
- electronically polarizable units by electronic band structure, fluctuating valence states of rare earth ions at A site … ?!



dielectric !?

metal !?

dielectric !?

$n = 5$

low BO_6 distortion

high contribution to electronic DOS

high BO_6 distortion

low contribution to electronic DOS

$n = 4.5$

intrinsic heterostructure !? …

… but electronically quasi-1D

Lichtenberg et al

Prog. Solid State Chem. 36 (2008) 253

Searching for high-T_c and room temperature superconductors

1998 – 2007: Preparation of about 400 electrically conducting oxides with different chemical composition, but no indications for high-T_c superconductivity

However:

- Excitonic superconductivity only in a very small region of the compositional parameter space (W. A. Little, V. L. Ginzburg)
- “Therefore, synthesizing a room-temperature superconductor, one must pay attention to its structure: the ”distance” between failure and success can be as small as 0.01 Å in the lattice constant”.

Cited from Andrei Mourachkine‘s book “Room-Temperature Superconductivity“, 2004, page 292 and 293 (ISBN 1 – 904602 – 27 – 4)

Potential for high-T_c superconductivity in oxides with early transition metals like W, Nb or Ti

Superconducting islands with $T_c \approx 90$ K on the surface of Na-doped WO_3

Reich et al , J. Superconductivity 13 (2000) 855

- Strong experimental evidence for high-T_c superconductivity without Cu
- In spite of many efforts superconducting phase could not be identified
  ⇨ Research on Na – W – O was stopped

WO_3 (W^{6+}, $5d^0$):

- antiferroelectric insulator with $T_c \approx 1000$ K
- distorted ReO_3 type crystal structure – can be considered as distorted perovskite ABO_3 with absent A
- superconducting Na_yWO_x ($W^{(6-z)+}$, $5d^z$) closely related to WO_3

Speculation: Superconducting phase Na_yWO_x could be of the type $A_nB_nO_{3n+2}$

Lichtenberg et al , Prog. Solid State Chem. 36 (2008) 253

The numerous chemical compositions of $A_nB_nO_{3n+2} = ABO_x$

Many ways to modify the physical and structural properties
by a huge number of possible chemical compositions:

- A = Na , Ca , Sr , Ba , La …
- B = Ti , Nb , Ta …
- Variable oxygen content x
- Several kinds of non-stoichiometric modifications of a certain structure type n with respect to its ideal composition ABO_x with ideal oxygen content $x = 3 + 2/n$:
  - $A_{1-a}BO_x$ a = deficiency at A site
  - $AB_{1-b}O_x$ b = deficiency at B site
  - ABO_{x-d} d = deficiency at O site
  - ABO_{x+e} e = excess at O site
  - $A_{1-a}BO_{x-d}$ a = deficiency at A site , d = deficiency at O site
- If there are oxygen deficiencies or at least two different ions at the A (or B) site, then they can be partially or fully ordered

Lichtenberg et al , Prog. Solid State Chem. 36 (2008) 253

A comprehensive scientific article on special oxides: Title, authors and link

Synthesis, structural, magnetic and transport properties of layered perovskite-related titanates, niobates and tantalates of the type $A_nB_nO_{3n+2}$, $A'A_{k-1}B_kO_{3k+1}$ and $A_mB_{m-1}O_{3m}$

F. Lichtenberg , A. Herrnberger , K. Wiedenmann

Experimentalphysik VI, Center for Electronic Correlations and Magnetism (EKM),
Institute of Physics, Augsburg University, D - 86135 Augsburg, Germany

Published in Progress in Solid State Chemistry 36 (2008) 253 – 387

Link to the submitted version (content of submitted and published version are identical):
www.novam-research.com/resources/Most_recent_paper_on_special_oxides_2008.pdf

A comprehensive scientific article on special oxides: Abstract

Abstract: This article represents a continuation of a paper on $A_nB_nO_{3n+2}$ = ABO_x compounds which was published in 2001. This work reports also on oxides of the type $A'A_{k-1}B_kO_{3k+1}$ (Dion-Jacobson type phases) and hexagonal $A_mB_{m-1}O_{3m}$. The title materials have in common a layered perovskite-related structure whose layers are formed by corner-shared BO_6 octahedra. The three homologous series differ structurally in their orientation of the BO_6 octahedra with respect to the *c*-axis. This can be considered as a result from cutting the cubic perovskite ABO_3 structure along different directions followed by an insertion of additional oxygen, namely along the [100] , [110] and [111] direction for $A'A_{k-1}B_kO_{3k+1}$, $A_nB_nO_{3n+2}$ and $A_mB_{m-1}O_{3m}$, respectively. The materials, with emphasis on electrical conductors, were prepared by floating zone melting and characterized by thermogravimetric analysis, x-ray powder diffraction and magnetic measurements. On crystals of five different compounds the resistivity was measured along the distinct crystallographic directions. Concerning $A_nB_nO_{3n+2}$ this work is focussed on two topics. The first are materials with paramagnetic rare earth ions at the *A* site or transition metal ions such as Fe^{3+} at the *B* site. The second are non-stoichiometric compounds. Furthermore, we discuss issues like occupational order at the *B* site, the proximity of some materials to the pyrochlore structure, potential magnetic ordering, and a possible coupling between magnetic and dielectric properties. The oxides $A'A_{k-1}B_kO_{3k+1}$ gained attention during a study of the reduced Ba-(Ca,La)-Nb-O system which lead to conducting Dion-Jacobson type phases without alkali metals. Concerning hexagonal $A_mB_{m-1}O_{3m}$ the emphasis of this work are conducting niobates in the system Sr-Nb-O. The title materials have in common a quasi-2D (layered) structure and they are mainly known as insulators. In the case of electrical conductors, however, their transport properties cover a quasi-1D, quasi-2D and anisotropic 3D metallic behavior. Also temperature-driven metal-to-semiconductor transitions occur. A special feature of the quasi-1D metals of the type $A_nB_nO_{3n+2}$ is their compositional, structural and electronic proximity to non-conducting (anti)ferroelectrics. We speculate that these quasi-1D metals may have the potential to create new (high-T_c) superconductors, especially when they are viewed from the perspective of the excitonic type of superconductivity. Referring to literature and results from this work, a comprehensive overview on the title oxides and their properties is presented.

A comprehensive scientific article on special oxides: Table of contents

Table of contents (page numbering refers to the submitted version of the article)

A comprehensive scientific article on special oxides: Table of contents

Table of contents (continued) (page numbering refers to the submitted version of the article)

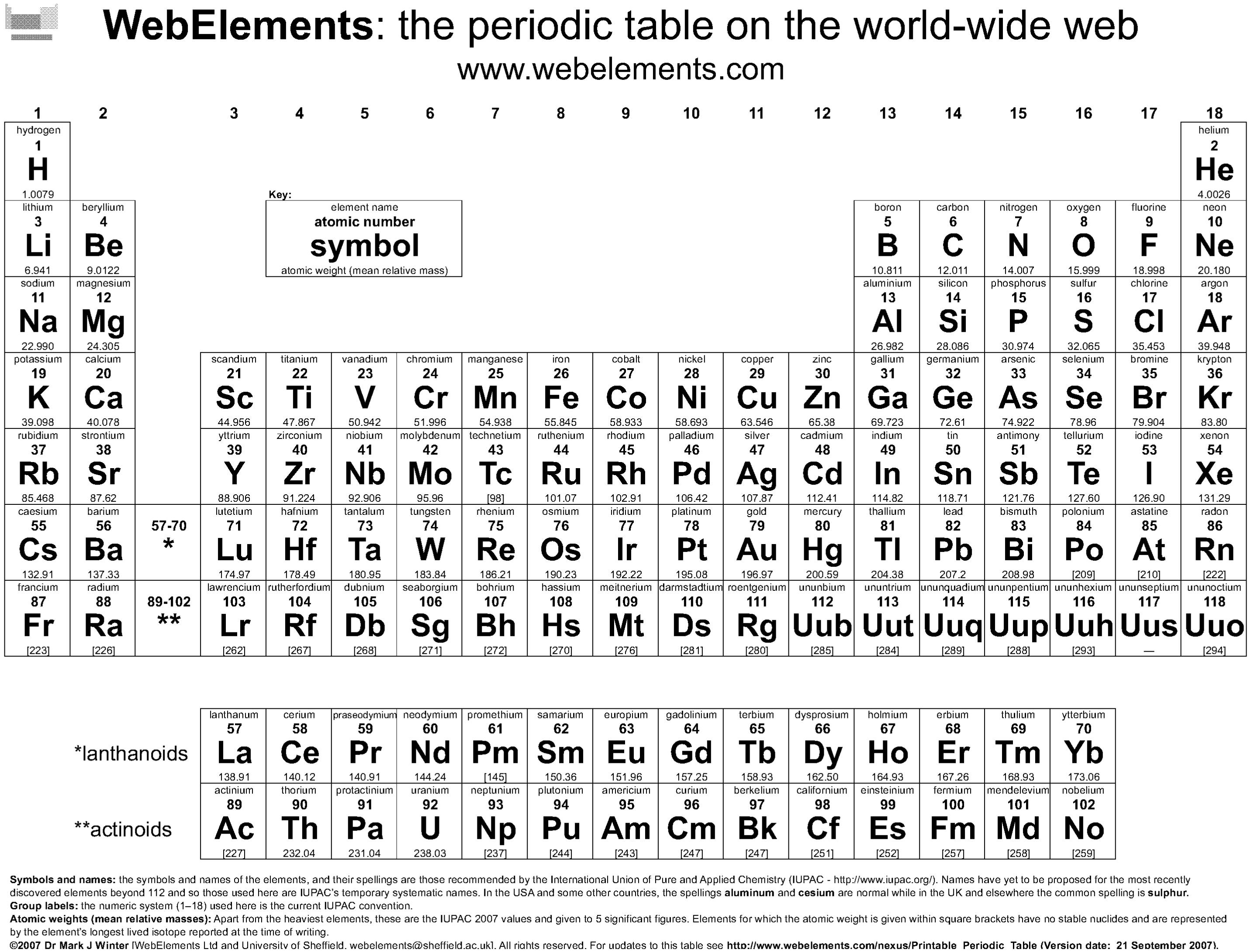
A comprehensive scientific article on special oxides: Table of contents

Table of contents (continued) (page numbering refers to the submitted version of the article)

On the following pages 65 and 66:

- The periodic table of the chemical elements
- Global Scaling: A representation of the so-called Fundamental Fractal

The periodic table of the chemical elements



WebElements: the periodic table on the world-wide web
www.webelements.com

Key:
element name
atomic number
symbol
atomic weight (mean relative mass)

1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
hydrogen **1** **H** 1.0079																		helium **2** **He** 4.0026
lithium **3** **Li** 6.941	beryllium **4** **Be** 9.0122												boron **5** **B** 10.811	carbon **6** **C** 12.011	nitrogen **7** **N** 14.007	oxygen **8** **O** 15.999	fluorine **9** **F** 18.998	neon **10** **Ne** 20.180
sodium **11** **Na** 22.990	magnesium **12** **Mg** 24.305												aluminium **13** **Al** 26.982	silicon **14** **Si** 28.086	phosphorus **15** **P** 30.974	sulfur **16** **S** 32.065	chlorine **17** **Cl** 35.453	argon **18** **Ar** 39.948
potassium **19** **K** 39.098	calcium **20** **Ca** 40.078		scandium **21** **Sc** 44.956	titanium **22** **Ti** 47.867	vanadium **23** **V** 50.942	chromium **24** **Cr** 51.996	manganese **25** **Mn** 54.938	iron **26** **Fe** 55.845	cobalt **27** **Co** 58.933	nickel **28** **Ni** 58.693	copper **29** **Cu** 63.546	zinc **30** **Zn** 65.38	gallium **31** **Ga** 69.723	germanium **32** **Ge** 72.61	arsenic **33** **As** 74.922	selenium **34** **Se** 78.96	bromine **35** **Br** 79.904	krypton **36** **Kr** 83.80
rubidium **37** **Rb** 85.468	strontium **38** **Sr** 87.62		yttrium **39** **Y** 88.906	zirconium **40** **Zr** 91.224	niobium **41** **Nb** 92.906	molybdenum **42** **Mo** 95.96	technetium **43** **Tc** [98]	ruthenium **44** **Ru** 101.07	rhodium **45** **Rh** 102.91	palladium **46** **Pd** 106.42	silver **47** **Ag** 107.87	cadmium **48** **Cd** 112.41	indium **49** **In** 114.82	tin **50** **Sn** 118.71	antimony **51** **Sb** 121.76	tellurium **52** **Te** 127.60	iodine **53** **I** 126.90	xenon **54** **Xe** 131.29
caesium **55** **Cs** 132.91	barium **56** **Ba** 137.33	**57-70** *****	lutetium **71** **Lu** 174.97	hafnium **72** **Hf** 178.49	tantalum **73** **Ta** 180.95	tungsten **74** **W** 183.84	rhenium **75** **Re** 186.21	osmium **76** **Os** 190.23	iridium **77** **Ir** 192.22	platinum **78** **Pt** 195.08	gold **79** **Au** 196.97	mercury **80** **Hg** 200.59	thallium **81** **Tl** 204.38	lead **82** **Pb** 207.2	bismuth **83** **Bi** 208.98	polonium **84** **Po** [209]	astatine **85** **At** [210]	radon **86** **Rn** [222]
francium **87** **Fr** [223]	radium **88** **Ra** [226]	**89-102** ******	lawrencium **103** **Lr** [262]	rutherfordium **104** **Rf** [267]	dubnium **105** **Db** [268]	seaborgium **106** **Sg** [271]	bohrium **107** **Bh** [272]	hassium **108** **Hs** [270]	meitnerium **109** **Mt** [276]	darmstadtium **110** **Ds** [281]	roentgenium **111** **Rg** [280]	ununbium **112** **Uub** [285]	ununtrium **113** **Uut** [284]	ununquadium **114** **Uuq** [289]	ununpentium **115** **Uup** [288]	ununhexium **116** **Uuh** [293]	ununseptium **117** **Uus** —	ununoctium **118** **Uuo** [294]

*lanthanoids	lanthanum **57** **La** 138.91	cerium **58** **Ce** 140.12	praseodymium **59** **Pr** 140.91	neodymium **60** **Nd** 144.24	promethium **61** **Pm** [145]	samarium **62** **Sm** 150.36	europium **63** **Eu** 151.96	gadolinium **64** **Gd** 157.25	terbium **65** **Tb** 158.93	dysprosium **66** **Dy** 162.50	holmium **67** **Ho** 164.93	erbium **68** **Er** 167.26	thulium **69** **Tm** 168.93	ytterbium **70** **Yb** 173.06
**actinoids	actinium **89** **Ac** [227]	thorium **90** **Th** 232.04	protactinium **91** **Pa** 231.04	uranium **92** **U** 238.03	neptunium **93** **Np** [237]	plutonium **94** **Pu** [244]	americium **95** **Am** [243]	curium **96** **Cm** [247]	berkelium **97** **Bk** [247]	californium **98** **Cf** [251]	einsteinium **99** **Es** [252]	fermium **100** **Fm** [257]	mendelevium **101** **Md** [258]	nobelium **102** **No** [259]

Symbols and names: the symbols and names of the elements, and their spellings are those recommended by the International Union of Pure and Applied Chemistry (IUPAC - http://www.iupac.org/). Names have yet to be proposed for the most recently discovered elements beyond 112 and so those used here are IUPAC's temporary systematic names. In the USA and some other countries, the spellings **aluminum** and **cesium** are normal while in the UK and elsewhere the common spelling is **sulphur.**
Group labels: the numeric system (1–18) used here is the current IUPAC convention.
Atomic weights (mean relative masses): Apart from the heaviest elements, these are the IUPAC 2007 values and given to 5 significant figures. Elements for which the atomic weight is given within square brackets have no stable nuclides and are represented by the element's longest lived isotope reported at the time of writing.

Image as well as more detailed information:
www.webelements.com

Global Scaling: A representation of the so-called Fundamental Fractal on the level n_0 and n_1

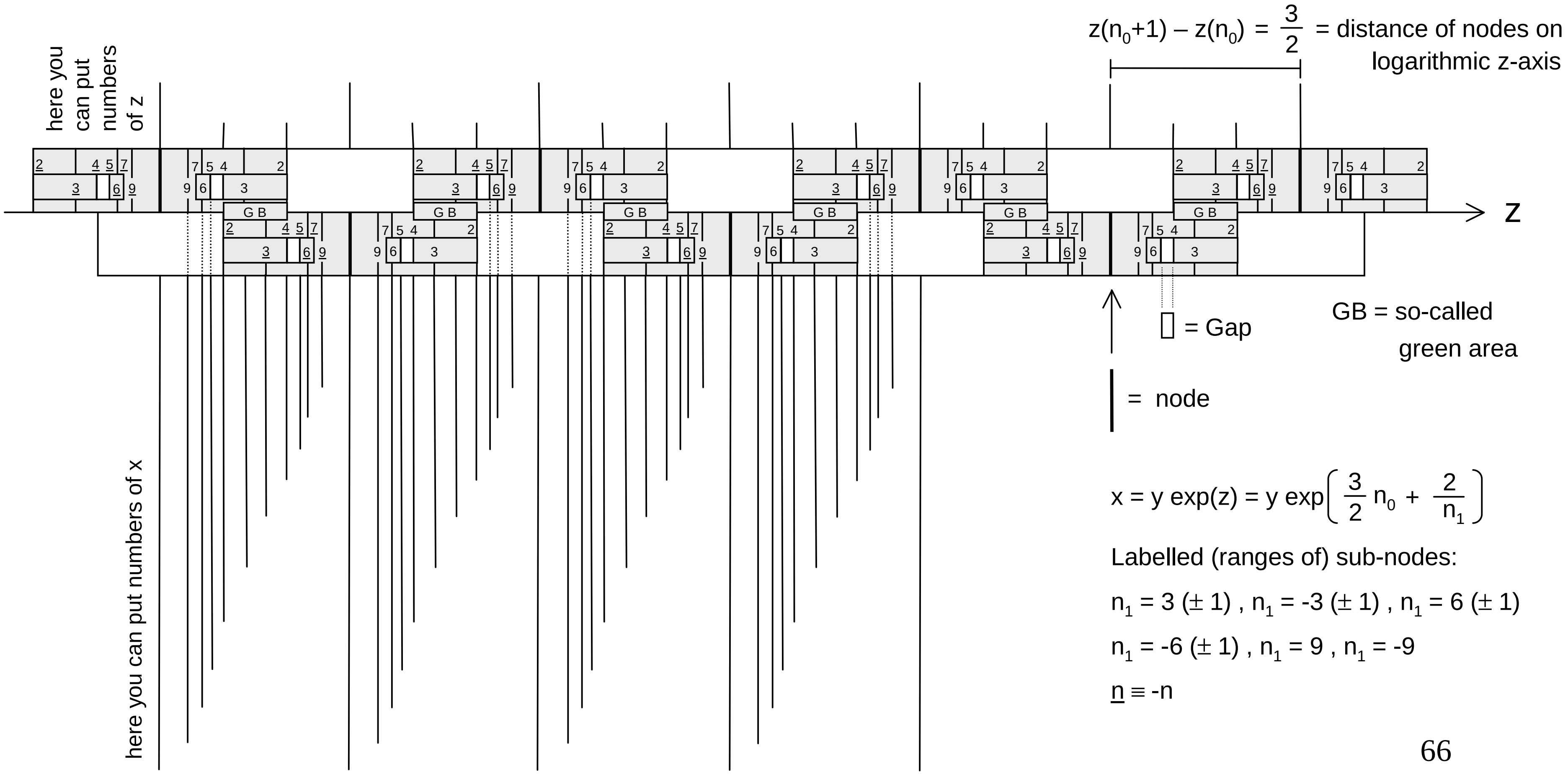
$$z = \ln \frac{x}{y} = \frac{3}{2} n_0 + \cfrac{2}{n_1 + \cfrac{2}{n_2 + \ddots}}$$

$n_0 = \pm k$ $n_1 = \pm 3j$ $k, j = 0, 1, 2, 3 \ldots$

so-called nodes: n_0 , $z(n_0)$, $x(n_0)$
so-called sub-nodes: n_1 , $z(n_1)$, $x(n_1)$

x = physical quantity or number (ratio or set) under consideration y = calibration unit of the considered physical scale such as length [m]

For further information see pages 17 – 26 and an introduction into Global Scaling, the so-called Global Scaling Theory Compendium, which can be downloaded from www.global-scaling-institute.de



$z(n_0+1) - z(n_0) = \frac{3}{2}$ = distance of nodes on logarithmic z-axis

▯ = Gap

GB = so-called green area

| = node

$$x = y \exp(z) = y \exp\left(\frac{3}{2} n_0 + \frac{2}{n_1}\right)$$

Labelled (ranges of) sub-nodes:

$n_1 = 3\ (\pm 1)$, $n_1 = -3\ (\pm 1)$, $n_1 = 6\ (\pm 1)$

$n_1 = -6\ (\pm 1)$, $n_1 = 9$, $n_1 = -9$

$\underline{n} \equiv -n$