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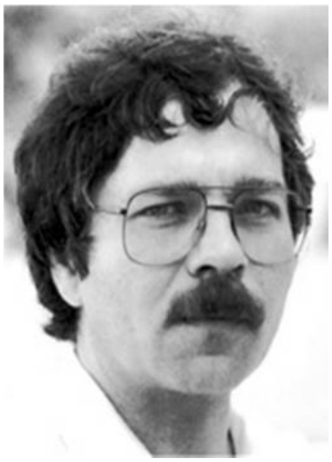
Nobel Prize in Physics 1987



J. Georg Bednorz **K. Alexander Müller**

The Nobel Prize in Physics 1987 was awarded jointly to J. Georg Bednorz and K. Alexander Müller *"for their important break-through in the discovery of superconductivity in ceramic materials"*

Information about winners:

Dr **Johannes Georg Bednorz** and Professor Dr **Karl Alexander Müller**,

IBM Zurich Research Laboratory, Switzerland,

RESEARCH INFORMATION:

This year's Nobel Prize in Physics has been awarded to **Dr Georg Bednorz** and **Professor Dr K. Alex Müller**, both researchers at the IBM Zurich Research Laboratory, for their discovery of new superconducting materials.

Superconductivity, one of the most spectacular phenomena of physics, has been known since 1911. Superconductivity arises when a superconducting material is cooled to a fairly low critical temperature. Suddenly, an electric current can then flow with no resistance whatso ever. Simultaneously, there occurs what is termed the Meissner effect. This means that a magnetic field cannot, or can only partly, penetrate the material. Hitherto, all superconducting materials have needed cooling to such low temperatures that only helium, with a boiling point of -269°C, has been practicable as a coolant. It has been the dream of many researchers to find material that remains superconducting at higher temperatures but, in spite of small advances, nothing had happened since 1973, when an alloy was produced that became superconducting at -250°C.

Last year, 1986, Bednorz and Müller reported finding superconductivity in an oxide material at a temperature 12°C higher than previously known. This was the introduction to an explosive development in which hundreds of laboratories the world over commenced work on similar material. Better superconductors have already been produced.

What Bednorz and Müller did was to abandon the "conventional" materials - alloys of different composition. Since 1983 they have concentrated on oxides which, apart from containing oxygen, include copper and one or more of the rare earth metals. The new idea was that the copper atoms in a material of this kind could be made to transport electrons, which interact more strongly with the surrounding crystal than they do in normal electrical conductors. To obtain a chemically stable material the two researchers added barium to crystals or lanthanum-copper-oxide to produce a ceramic material that became the first successful "hightemperature" superconductor.

Bednorz and Müller stand out clearly as the discoverers of this specific superconductivity. They have inspired other researchers to synthesise substances that are superconducting at temperatures more than four times higher (reckoned from absolute zero at -273°C) than the earlier ones. The development is being followed with intense interest by workers in electrotechnology and microelectronics, and by physicists who envisage exciting new applications in measurement technology.

Background Information

Superconductivity has a long history. It was discovered as far back as 1911 by the Dutch physicist Heike Kamerlingh-Onnes, who received the Nobel Prize in 1913. The associated Meissner effect was observed for the first time in 1933. Despite numerous experiments and theoretical attempts over the following years to explain how superconductivity arises, it was not until 1957 that the Americans John Bardeen , Leon

Cooper and Robert Schrieffer were able to formulate a consistent theory, the BCS theory, for which a Nobel Prize was awarded in 1972. This theory is based on the idea that the electrons form so-called Cooper pairs which subsequently perform a strongly coordinated motion within the conductor. Energy is required to break up the Cooper pairs and make the material return to its normal conducting state. The more strongly the Cooper pairs are linked, the higher the temperature at which this break-up occurs.

In the 1960's, another development in superconductivity was initiated, by the Englishman Brian Josephson (who received the Nobel Prize in 1973). This development concerned currents across points of contact between superconducting and normally conducting materials, and was to teach physicists a great deal about quantum mechanical tunnelling (hew particles can move "through" barriers) and about interference (how matter waves interact). These contact points have become important tools in high-class precision determination of magnetic fields and voltage differences.

Superconductivity has also been employed in technology. Coils of superconducting materials are found in large magnets in accelerator laboratories and other research institutions. Pilot systems have also been developed for other applications such as electrical generators and energy storage arrangements. There are also inventions based on the fact that objects can "float" on magnetic "cushions", for example in wheel bearings. Yet other applications are envisaged in electronics, and concern switches and memory elements.

However, the technical applications have so far been greatly limited, in many cases to the drawing-board, since the available superconducting materials have required cooling co such low temperatures that, in practice, only liquid helium has been accessible as a coolant. The handling of liquid helium, with a boiling point of -269°C, is complicated and expensive.

Finding materials which remain superconducting at higher temperatures has therefore, over the past 75 years, been a dream which many researchers have tried to fulfill. The critical temperature level has slowly been raised, but nothing had happened since 1973 when an alloy with a transition temperature of 23°C above absolute zero was produced.

In April 1986 measurements were reported by Georg Bednorz and Alex Müller on an oxide where the transition to superconductivity set in at a temperature of 12°C above the highest then known. Later in the same year, the two researchers purified the material, and the magnetic properties associated with a genuine superconducting state were also demonstrated.

This was the start of an avalanche. Hundreds of laboratories all over the world were soon at work with materials similar to those of Bednorz and Müller. Transition temperatures more than 90°C above absolute zero were reached during the first few months of 1987 in the United States, China, Japan and Europe, and it seems that this development has not yet come to an end. Devices based on such "high-temperature superconductors" can be cooled with liquid nitrogen, which is a considerably cheaper, more efficient and easily-handled coolant than liquid helium.

Bednorz' and Müller's new approach was to abandon the "conventional" semiconducting alloys, for instance of niobium-germanium or niobium-tin type, and to direct their search among metal oxides. It was known that some of these oxides may conduct electricity, but their conductivity is normally very limited.

At first sight, therefore, it seems astonishing that such materials can ever pass to a superconducting state when cooled. Yet it was with various oxide materials (which in addition to oxygen contain copper or nickel and some of the rare earth elements) that Bednorz and Müller had worked since 1983.

When they at last broke through all existing limits for superconducting materials, it was as a result of systematic work, deep insight and experience of structural problems in the physics and chemistry of the solid state (plus, one may assume, the intuition characteristic of the true scientist). Besides this, they had had the audacity to concentrate on new paths in their research. Their reasoning was that the copper or nickel atoms in the materials they used could be made to transfer electrons, which interact more strongly with the surrounding crystal (and consequently also with the oscillations set up by the atoms in the crystal) than is the case in normal conductors. This strong interaction is, according to current theory, one of the conditions for the pairing of electrons and the maintenance of the strongly coordinated motion which they require in the superconducting state. To obtain a chemically stable material and at the same time increase the normal conductivity Bednorz and Müller added barium to crystals of lanthanum-copper-oxide to obtain the approximate composition $La_{1.85}Ba_{0.15}CuO_4$, which turned out to be the first successful high-temperature superconductor.

Bednorz and Müller stand out clearly as the discoverers of this specific superconductivity. They have inspired-a great number of other scientists to work with related materials. As already mentioned, this has resulted in the synthesis of substances which are superconducting at temperatures more than four times higher (above absolute zero) than before. The details of how superconductivity arises in the new materials are still unknown. Intensive work is being carried out using the full arsenal of measuring methods within solid-state physics to uncover the essential mechanisms behind this phenomenon. One main question is whether the descriptions of superconductivity employed so far (i.e. the Bardeen-Cooper-Schrieffer theory) are sufficient, or whether new concepts will be needed. Perhaps it will be necessary to reconsider certain aspects of the motion and interaction of electrons in solid substances.

It is too early to predict how extensive the technical applications will be, but it is quite evident that the development is being followed with keen interest by representatives of electrical power technology, by microelectronics researchers and by physicists who envisage new applications in measurement technology.

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http://www.nobelprize.org/nobel_prizes/physics/laureates/1987/press.html