Compounds with Higher Superconducting Transition Temperatures: a Search with Still Undefined Rules

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Abstract - Since the discovery of superconductivity in 1911, the search for new superconducting materials with higher transition temperatures has been the source of constant motivation, and the number of reported compounds (estimated to several thousands) is still growing. However, all new superconducting materials have so far been discovered by surprise. In spite of the strong progress in the understanding of the physical properties of the most interesting compounds, the search for new compounds is driven by intuition rather than by valid rules.

The first materials studied by Kamerlingh Onnes are today characterized as being of type I. The discovery of the eutectic material $Pb_{0.65}Bi_{0.35}$ in 1931, showing superconductivity even in presence of magnetic fields marked the beginning of a new era: the following decades were marked by a large number of new superconducting compounds and by a series of theoretical models, an important milestone being reached by the BCS theory (1957). The Abrikosov model, published in the same year, created the basis for describing the behavior of type II superconductors carrying high critical currents in a magnetic field. The development of superconducting materials for high field applications started 1961 with the fabrication of Nb_3Sn wires and the construction of the first high field solenoid.

In this talk, a broad overview of the superconducting materials discovered during the last 100 years will be given, showing that various “rules of thumb” (e.g., the well-known Matthias rule of valence electrons per atom, 1964) for the occurrence of high T_c values are, if ever, only valid for restricted material classes. A historical overview will be given for several “conventional” compounds (which conform to the BCS theory), as the phases crystallizing in cubic structures (A15, A2), or in noncubic structures (Laves phases, Chevrel phases and many others), generally characterized as Low T_c compounds. The compound MgB_2 may be considered as an extreme example of this category of materials. In the last 25 years, the research for new superconductors became more and more complex: novel types of superconducting compounds with high transition temperatures and exotic properties have been found, generally called “unconventional”, which challenge our theoretical understanding of superconductivity.

In addition, these novel superconducting systems (e.g., Bi- and Y- based oxides, pnictides) consist of 3, 4 or even 5 different elements, their complex phase diagrams constituting an additional challenge.

Keywords - Type-I and Type-II superconductors, BCS theory, Matthias rule, critical temperature, critical currents and critical fields, flux pinning, LTS; HTS; MgB_2

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