Present Views and Future Prospects of Superconductivity Science and Technology

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Since first being discovered in 1911, superconductivity has been regarded and classified as one of the most puzzling and fascinating phenomena in low temperature physics. However, the critical temperature (T_c) of superconductivity in any known materials remained below 23 K for a very long time. A famous 1957 paper by Bardeen, Cooper and Schrieffer (BCS) successfully explained the superconductivity mechanism but predicted a theoretical T_c limit of only below 30 K.

In 1986, Bednorz and Mülller in Switzerland suggested the possible existence of superconductivity with T_c as high as 30 K in a cuprate (copper oxide), La-Ba-Cu-O. Its reproducibility was immediately confirmed by S. Uchida et al.(Tokyo) and was reported in the first page of the Letters section of Vol. 26 of **JJAP**, (*Jpn. J. Appl. Phys*., **26** L1, (1987)). Encouraged by this report, superconductivity with an incredibly high T_c level of over 90 K was found in Y-Ba-Cu-O in the USA within a few weeks. Early the following year, H. Maeda et al.(Tsukuba) reached the milestone of T_c of over 110 K for the first time in Bi-Sr-Ca-Cu-O compounds (*JJAP*, **27** L209, (1988)).

It should be emphasized that these historically important papers were both published in **JJAP**, and that they triggered the worldwide "HTSC" fever. This was certainly one of the great technical breakthroughs in the history of both fundamental and applied physics .

Since then, **JSAP** (the Japan Society of Applied Physics) has made numerous and significant contributions to the field. The Superconductivity Division was officially established in 1990 and since then its nearly 350 members have continued to do important work on various activities. These include planning general symposia and specific-subject-oriented research meetings, publishing "Superconductivity News", and writing and editing reviews and research articles in the monthly-issued (in Japanese) "Oyo Buturi" journal .

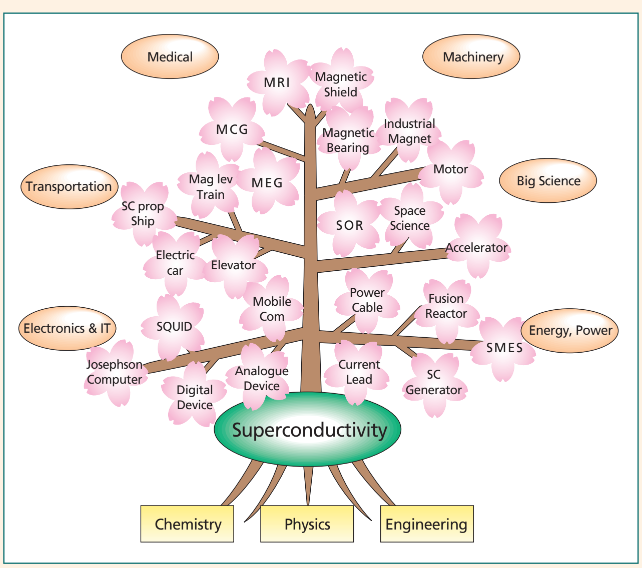

Fig.1 Application Tree of Superconductivity

The main and final goal of our division is the application of superconductivity in various scientific and technological fields in the very near future. Figure 1 illustrates expected practical future technologies in the form of an "Application Tree". They cover a vast range of areas, including the electronics, transportation, medicine, machinery, and energy-power fields. Some applications are presently in wide use based on low T_c superconductors, e.g., strong magnets for magnetic resonance imaging (MRI), industrial material processing, laboratory research and big accelerators. On the other hand, HTSC-based current leads, microwave devices, SQUID, etc. are now also available in commercial devices. The practical application of HTSC materials is extremely attractive since it makes the use of very low-cost liquid nitrogen possible as a coolant.

Many types of cryo-coolers are also now available down to 4.2K in medium-scale applications. For small-scale thin-film devices such as microwave application, electronic cooling devices may be used in future down to 77 K. These coolers can be operated without any liquid coolants such as helium or nitrogen.

The above-mentioned scope does not exclude our efforts in understanding fundamental physical aspects. In HTSC materials, there are many superconductivity mechanism details that still remain unclear, in contrast to the phonon-mediated scenario in the original BCS. The pairing symmetry of Cooper pairs, probably d-wave in HTSC, and the extremely short coherence length (~ 1 nm), poses big hurdles in the designing and practical fabrication of both electronic and power devices. As a brief example, electrical power cables or magnetic coils of lengths much longer than 1km must be continuously fabricated, while their microstrucures such as grain boundary thickness and flux-pinning centers have to be controlled with nm-scale precision. Within the context of multi-component and complicated structural materials, this poses a big challenge in the field of nm-scale chemistry.

Figure 1 illustrates how basic roots such as physics, chemistry and engineering need to be applied to superconductivity applications. The superconductivity being a truly multi- and trans-disciplinary field, we foresee other big breakthroughs in the very near future with continuous help from various science and technology communities.

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