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Recent Superconductivity Research

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EDITORIAL NOTE

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Applications are being found for superconducting materials during a rapidly growing number of technological areas, and therefore the look for novel superconductors remains a serious scientific task. However, the steady increase within the complexity of candidate materials presents an enormous challenge to researchers. Especially, conventional experimental methods aren't compatible to an efficient look for candidates during a compositional space growing exponentially with the amount of elements; neither do they allow a fast extraction of reliable multidimensional phase diagrams delineating the physical parameters that control superconductivity. New research paradigms which will boost the speed and therefore the efficiency of research into superconducting materials are urgently needed. High-throughput methods for the rapid screening and optimization of materials have aided the acceleration of research in bioinformatics and therefore the pharmaceutical industry, yet remain rare in quantum materials research. During this paper we briefly review the history of high-throughput research then specialize in some recent applications of this paradigm in superconductivity research. We consider the role these methods can play altogether stages of materials development, including high-throughput computation, synthesis, characterization, and therefore the emerging field of machine learning for materials. The high-throughput paradigm will undoubtedly become an important tool in superconductivity research within the near future.

The field of superconductivity began with the invention by H. Kamerlingh-Onnes in 1911 that mercury wire at 4.2 K had zero electric resistance. Zero resistance implied transmission of current at any distance with no losses, the assembly of huge magnetic fields, because a superconducting loop could carry current indefinitely-storage of energy. These applications weren't realized because, as was quickly discovered, the superconductors reverted to normal conductors at a comparatively low current density, called the critical current density or during a relatively low magnetic flux, called the critical field, Hc. In 1916, Silsbee, at the National Bureau of Standards, hypothesized that the critical current for a superconducting wire was adequate to that current which gave the critical field at the surface of the wire. The rationale for this behaviour wasn't made clear until the invention of the Meissner effect in 1933.

Until 1986, the very best critical temperature obtained for any superconductor was only 23.2 K. This meant that superconductors had to be cooled by liquid helium-an expensive and sometimes unreliable process. Consequently, many potential applications weren't commercially viable. Additionally, most scientists had come to take superconductivity as a mature field with little possibility for any significant increase in critical temperatures. All this suddenly changed with the invention by K. A. Bednorz and J. G. Müller of high-temperature superconductivity.

Many applications for high-temperature superconductivity depend upon understanding and improving the critical current. To the present end, YBCO macrobridge (bridge dimensions are much greater than the coherence length) was fabricated to know not only Jc, but intra-film Josephson effects. Extremely noisy sections of the V-I curve were observed, always well below Tc. This behaviour could have ramifications for potential low-noise applications of high-Tc superconductors. The noise depends on temperature, bias current, and therefore the magnetic flux. A really rapid change of switching rate with very small fields and little changes in bias current was observed, which suggests that the noise could also be thanks to the motion of vortices in and out of pinning sites.

The ability of a superconductor to levitate a magnet above its surface is documented, and for high-Tc superconductors it's often demonstrated. Recently, it's been realized that specially processed samples of a high-Tc superconductor are often levitated below a magnet. This unusual sort of levitation involves “attraction” of the superconductor by a magnet instead of the Meissner effect “repulsion” seen for a levitated magnet. A crucial application for this effect would be in magnetic bearings.