DOWNLOAD PDF THE PHYSICS OF COMPOSITE SUPERCONDUCTORS

Chapter 1 : A.L. Rakhmanov (Author of The Physics of Composite Superconductors)

Composite superconductors offer the solution to a wide range of problems, the principal of which are: thermomagnetic instability, instability of the superconducting state with respect to strong pulsed perturbations, heat release under varying external conditions, and inadequate strength and plasticity.

There are many criteria by which superconductors are classified. The most common are: These points are called vortices. Furthermore, in multicomponent superconductors it is possible to have combination of the two behaviours. In that case the superconductor is of Type By theory of operation[edit] It is conventional if it can be explained by the BCS theory or its derivatives, or unconventional , otherwise. Superconductor material classes include chemical elements e. Elementary properties of superconductors[edit] This section needs additional citations for verification. Please help improve this article by adding citations to reliable sources. Unsourced material may be challenged and removed. April Learn how and when to remove this template message Most of the physical properties of superconductors vary from material to material, such as the heat capacity and the critical temperature, critical field, and critical current density at which superconductivity is destroyed. On the other hand, there is a class of properties that are independent of the underlying material. For instance, all superconductors have exactly zero resistivity to low applied currents when there is no magnetic field present or if the applied field does not exceed a critical value. The existence of these "universal" properties implies that superconductivity is a thermodynamic phase , and thus possesses certain distinguishing properties which are largely independent of microscopic details. Both the massive and slim cables are rated for 12, A. The simplest method to measure the electrical resistance of a sample of some material is to place it in an electrical circuit in series with a current source I and measure the resulting voltage V across the sample. If the voltage is zero, this means that the resistance is zero. Superconductors are also able to maintain a current with no applied voltage whatsoever, a property exploited in superconducting electromagnets such as those found in MRI machines. Experiments have demonstrated that currents in superconducting coils can persist for years without any measurable degradation. Experimental evidence points to a current lifetime of at least , years. Theoretical estimates for the lifetime of a persistent current can exceed the estimated lifetime of the universe , depending on the wire geometry and the temperature. In a normal conductor, an electric current may be visualized as a fluid of electrons moving across a heavy ionic lattice. The electrons are constantly colliding with the ions in the lattice, and during each collision some of the energy carried by the current is absorbed by the lattice and converted into heat , which is essentially the vibrational kinetic energy of the lattice ions. As a result, the energy carried by the current is constantly being dissipated. This is the phenomenon of electrical resistance and Joule heating. The situation is different in a superconductor. In a conventional superconductor, the electronic fluid cannot be resolved into individual electrons. Instead, it consists of bound pairs of electrons known as Cooper pairs. This pairing is caused by an attractive force between electrons from the exchange of phonons. The Cooper pair fluid is thus a superfluid , meaning it can flow without energy dissipation. In a class of superconductors known as type II superconductors , including all known high-temperature superconductors , an extremely low but nonzero resistivity appears at temperatures not too far below the nominal superconducting transition when an electric current is applied in conjunction with a strong magnetic field, which may be caused by the electric current. This is due to the motion of magnetic vortices in the electronic superfluid, which dissipates some of the energy carried by the current. If the current is sufficiently small, the vortices are stationary, and the resistivity vanishes. The resistance due to this effect is tiny compared with that of non-superconducting materials, but must be taken into account in sensitive experiments. However, as the temperature decreases far enough below the nominal superconducting transition, these vortices can become frozen into a disordered but stationary phase known as a "vortex glass". Below this vortex glass transition temperature, the resistance of the material becomes truly zero. The value of this critical temperature varies from material to material. Solid mercury , for example, has a critical temperature of 4. As of , the highest critical temperature found for a conventional superconductor is K for H_2S, although high pressures of approximately 90 gigapascals were required [9]. Cuprate superconductors can have much higher critical temperatures: The explanation for these high critical temperatures remains unknown. Electron pairing due to phonon exchanges explains superconductivity in conventional superconductors, but it does not explain superconductivity in the newer superconductors that have a very high critical temperature. Similarly, at a fixed temperature below the critical temperature, superconducting materials cease to superconduct when an external magnetic field is applied which is greater than the critical magnetic field. This is because the Gibbs free energy of the superconducting phase increases quadratically with the magnetic field while the free energy of the normal phase is roughly independent of the magnetic field. If the material superconducts in the absence of a field, then the superconducting phase free energy is lower than that of the normal phase and so for some finite value of the magnetic field proportional to the square root of the difference of the free energies at zero magnetic field the two free energies will be equal and a phase transition to the normal phase will occur. More generally, a higher temperature and a stronger magnetic field lead to a smaller fraction of electrons that are superconducting and consequently to a longer London penetration depth of external magnetic fields and currents. The penetration depth becomes infinite at the phase transition. The onset of superconductivity is accompanied by abrupt changes in various physical properties, which is the hallmark of a phase transition. For example, the electronic heat capacity is proportional to the temperature in the normal non-superconducting regime. At the superconducting transition, it suffers a discontinuous jump and thereafter ceases to be linear. This exponential behavior is one of the pieces of evidence for the existence of the energy gap. The order of the superconducting phase transition was long a matter of debate. Experiments indicate that the transition is second-order, meaning there is no latent heat. However, in the presence of an external magnetic field there is latent heat, because the superconducting phase has a lower entropy below the critical temperature than the normal phase. It has been experimentally demonstrated [10] that, as a consequence, when the magnetic field is increased beyond the critical field, the resulting phase transition leads to a decrease in the temperature of the superconducting material. Calculations in the s suggested that it may actually be weakly first-order due to the effect of long-range fluctuations in the electromagnetic field. In the s it was shown theoretically with the help of a disorder field theory , in which the vortex lines of the superconductor play a major role, that the transition is of second order within the type II regime and of first order i. Meissner effect When a superconductor is placed in a weak external magnetic field H, and cooled below its transition temperature, the magnetic field is ejected. The Meissner effect is a defining characteristic of superconductivity. The Meissner effect is sometimes confused with the kind of diamagnetism one would expect in a perfect electrical conductor: In a perfect conductor, an arbitrarily large current can be induced, and the resulting magnetic field exactly cancels the applied field. The Meissner effect is distinct from thisâ€”it is the spontaneous expulsion which occurs during transition to superconductivity. Suppose we have a material in its normal state, containing a constant internal magnetic field.

Chapter 2 : Superconducting Magnets - Composite Technology Development, Inc.

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It also implied that the Hall conductance can be characterized in terms of a topological invariable called Chern number. Laughlin, in , realized that this was a consequence of quasiparticle interaction in the Hall states and formulated a variational method solution, named the Laughlin wavefunction. It was realized that the high temperature superconductors are examples of strongly correlated materials where the electronâ€"electron interactions play an important role. In , David Field and researchers at Aarhus University discovered spontaneous electric fields when creating prosaic films [clarification needed] of various gases. This has more recently expanded to form the research area of spontelectrics. Theoretical[edit] Theoretical condensed matter physics involves the use of theoretical models to understand properties of states of matter. These include models to study the electronic properties of solids, such as the Drude model , the Band structure and the density functional theory. Theoretical models have also been developed to study the physics of phase transitions , such as the Ginzburgâ€"Landau theory , critical exponents and the use of mathematical methods of quantum field theory and the renormalization group. Modern theoretical studies involve the use of numerical computation of electronic structure and mathematical tools to understand phenomena such as high-temperature superconductivity , topological phases , and gauge symmetries. Emergence Theoretical understanding of condensed matter physics is closely related to the notion of emergence , wherein complex assemblies of particles behave in ways dramatically different from their individual constituents. Electronic theory of solids[edit] Main article: Electronic band structure The metallic state has historically been an important building block for studying properties of solids. He was able to derive the empirical Wiedemann-Franz law and get results in close agreement with the experiments. The Hartreeâ€"Fock method accounted for exchange statistics of single particle electron wavefunctions. Only the free electron gas case can be solved exactly. The density functional theory DFT has been widely used since the s for band structure calculations of variety of solids. Symmetry breaking Some states of matter exhibit symmetry breaking, where the relevant laws of physics possess some symmetry that is broken. A common example is crystalline solids, which break continuous translational symmetry. Other examples include magnetized ferromagnets , which break rotational symmetry , and more exotic states such as the ground state of a BCS superconductor , that breaks U 1 phase rotational symmetry. For example, in crystalline solids, these correspond to phonons , which are quantized versions of lattice vibrations. Phase transition Phase transition refers to the change of phase of a system, which is brought about by change in an external parameter such as temperature. Classical phase transition occurs at finite temperature when the order of the system was destroyed. For example, when ice melts and becomes water, the ordered crystal structure is destroyed. In quantum phase transitions , the temperature is set to absolute zero, and the non-thermal control parameter, such as pressure or magnetic field, causes the phase transitions when order is destroyed by quantum fluctuations originating from the Heisenberg uncertainty principle. Here, the different quantum phases of the system refer to distinct ground states of the Hamiltonian. Understanding the behavior of quantum phase transition is important in the difficult tasks of explaining the properties of rare-earth magnetic insulators, high-temperature superconductors, and other substances. For the later, the two phases involved do not co-exist at the transition temperature, also called critical point. Near the critical point, systems undergo critical behavior, wherein several of their properties such as correlation length , specific heat , and magnetic susceptibility diverge exponentially. However, it can only roughly explain continuous phase transition for ferroelectrics and type I superconductors which involves long range microscopic interactions. For other types of systems that involves short range interactions near the critical point, a better theory is needed. Renormalization group methods successively average out the shortest wavelength fluctuations in stages while retaining their effects into the next stage. Thus, the changes of a physical system as viewed at different size scales can be investigated systematically. The methods, together with powerful computer simulation, contribute greatly to the explanation of the critical phenomena associated with continuous phase transition. Such probes include effects of electric and magnetic fields , measuring response functions , transport properties and thermometry. Image of X-ray diffraction pattern from a protein crystal. Scattering Several condensed matter experiments involve scattering of an experimental probe, such as X-ray , optical photons , neutrons , etc. The choice of scattering probe depends on the observation energy scale of interest. Visible light has energy on the scale of 1 electron volt eV and is used as a scattering probe to measure variations in material properties such as dielectric constant and refractive index. X-rays have energies of the order of 10 keV and hence are able to probe atomic length scales, and are used to measure variations in electron charge density. Coulomb and Mott scattering measurements can be made by using electron beams as scattering probes. NMR experiments can be made in magnetic fields with strengths up to 60 Tesla. Higher magnetic fields can improve the quality of NMR measurement data. The blue and white areas represent higher density. Optical lattice Ultracold atom trapping in optical lattices is an experimental tool commonly used in condensed matter physics, and in atomic, molecular, and optical physics. The method involves using optical lasers to form an interference pattern , which acts as a lattice, in which ions or atoms can be placed at very low temperatures. Cold atoms in optical lattices are used as quantum simulators, that is, they act as controllable systems that can model behavior of more complicated systems, such as frustrated magnets. Bose and Albert Einstein , wherein a large number of atoms occupy one quantum state. It is hoped that advances in nanoscience will lead to machines working on the molecular scale. Research in condensed matter physics has given rise to several device applications, such as the development of the semiconductor transistor , [3] laser technology, [51] and several phenomena studied in the context of nanotechnology. The qubits may decohere quickly before useful computation is completed. This serious problem must be solved before quantum computing may be realized. To solve this problem, several promising approaches are proposed in condensed matter physics, including Josephson junction qubits, spintronic qubits using the spin orientation of magnetic materials, or the topological non-Abelian anyons from fractional quantum Hall effect states.

Chapter 3 : Physics - Viewpoint: Pile on the metal

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Chapter 4 : R.G. Mints (Author of The Physics of Composite Superconductors)

Abstract The current status of solid and composite superconductors is reviewed. The discussion covers the electrodynamic, thermal, and mechanical processes associated with superconductivity, the problem of the stability of the superconducting state, and energy dissipation in variable fields.

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Chapter 8 : Mechanical and Electromagnetic Properties of Composite Superconductors - MagLab

Thanks to the expertise of Dr. Naseem Munshi, the field of superconducting magnets has continued to progress and advance. There are several challenges when designing these magnets, particularly when it comes to considering all of the various factors that enable successful superconductivity.

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