High temperature superconductivity

Lecture course for Ph.D. students by Dr. Alexander A. Kordyuk

Scope

This course gives a broad introduction to the phenomenon of superconductivity, starting from basic experimental facts and models for the conventional superconductors and then, through the discovery of high temperature superconductors, covering the modern view on their mechanism, properties and applications.

Topics (as taught in Spring 2005)

I. PHENOMENON OF SUPERCONDUCTIVITY

1. **Conventional superconductors, basic experimental facts.** Resistivity of metals and discovery of superconductivity. Perfect conductivity. Meisner effect and levitation. Type I and type II superconductors. FC and ZFC. Vortices, vortex motion and vortex pinning. *H-T* phase diagram and magnetization curves. Pining force, critical current, and critical state model. Surface barrier.
2. **Phenomenological models.** London's Equations. Pippard non-local electrodynamics. Ginzburg-Landau theory. Ginsburg-Landau parameter. Intoduction to vortex matter: vortex lattice properties: melting, reversibility line, vortex glass, Larkin-Ovchinnikov model.
3. **Microscopic theory.** Cooper pairs. Magnetic flux quantum. Isotope effect. Origin of the attractive interaction. The BCS theory. Gap equation. Fermi liquid concept. Self-energy. The Eliashberg equations. Phonon fingerprints in tunneling experiments. The critical temperature. Coulomb interaction and high coupling limit.

II. MATERIALS AND APPLICATIONS

4. **Materials, from LTSC to HTSC.** Metals and alloys. Laves phases. Chevrel phases. A15. Magnesium diboride. High-Tc cuprates.
5. **Applications.** Josephson effects. SQUIDs. Superconducting detectors and mixers. RSFQ logic. Qubits. Cables, current limiters and magnets. Motors and flywheels. Levitation and MAGLEV.

III. HTSC problem

6. **What is new.** Crystal structure of cuprates. Doping and *xT* phase diagram. Mott insulators, antiferromagnet, spin excitations, t-J model. Superconducting dome. d-wave gap. Pseudogap.
7. **Electronic structure.** Band structure and Fermi surface. Van Hove singularity. Bilayer splitting. Green's function. Spectral function and self-energy from experiment. Momentum resolving techniques. ARPES and INS. ARPES and FT STS. Transport properties and electronic structure.

Assignments

Reading

1. M. Tinkham. *Introduction to Superconductivity.* New York, NY: McGraw-Hill, 1975.
2. V. V. Schmidt. *The physics of superconductors*, Eds. P. Mueller and A. V. Ustinov, Springer, 1997.
3. P. G. de Gennes. *Superconductivity of Metals and Alloys.* Addison-Wesley, 1989.
4. V. L. Ginzburg, D. A. Kirzhnits, *High-temperature superconductivity.* Consultants Bureau, New York, 1982.
5. J. F. Annett. *Superconductivity, Superfluids and Condensates.* Oxford Univ. Press, Oxford 2004.

Video Lectures

- Video Lectures on Superconductivity http://www.msm.cam.ac.uk/ascg/lectures/, University of Cambridge
- Nobel Lecture by Vitaly L. Ginzburg http://nobelprize.org/mediaplayer/index.php?id=540
- Nobel Lecture by Alexei A. Abrikosov http://nobelprize.org/mediaplayer/index.php?id=537