Meissner effect essay example

Law, Evidence

Meissner effect is one of the remarkable properties of superconductors. Most superconductors are metals and metal alloys. However, some non-metals also exhibit superconductive properties hence they are regarded as superconductors. A superconductor refers to a material that can transfer electric current with zero resistance. This implies that when electric current is passed through a superconductor at a temperature below the critical temperature value (Tc), no energy is lost in any form: sound, heat, or light. It is important to point out that superconductivity of a material can only be observed at temperature below the critical temperature (Tc). Critical temperature values vary from one material to another.

Examples of materials that form superconductors include; mercury (Hg), niobium, tin (Sn), lead(Pb), yttrium-Barium-copper oxide, lanthanum(La), tantalum(Ta), zinc(Zn), osmium(Os), chromium(Cr), molybdenum(Mo), and uranium(U). Superconductors are classified into two groups: type 1 and type 2. Type 1 category mainly consists of metals and metalloids. The metalloids in this category are mainly those that can conduct electricity at room temperature. Type 1 superconductors have lower critical temperature (Tc) than type 2. They require the lowest temperature in order to become superconductive. Another important feature of materials in this category is that their transition to a superconducting state is sharp. Examples of type 1 superconductors are lead, lanthanum, and mercury.

Type 2 superconductors on the other hand mainly comprise of compounds of metals and metal alloys. This category of superconductors differs from type 1 category on two main aspects: they exhibit gradual transition to superconductive state and bear higher critical temperatures than their type

1 counterparts. Examples of type 2 superconductors include; Tl7Sn2Ba2SiCu10O2, Tl6Ba4SiCu9O18+, and Tl5Ba4SiCu8O16+. Perovskites, which are the most recently-discovered superconductors are also categorised as type 2 superconductors.

Meissner effect was discovered by a German physicist called Walther Meissner and Robert Ochsenfeld in 1933 (Hofmann, 123). The duo carried out an experiment that lead to this discovery using tin and lead samples. The samples were cooled below their critical temperatures in applied magnetic field. Then the magnetic field distribution outside the samples was measured and used to detect that all the magnetic fields inside the samples were cancelled out. This was determined indirectly based on the law of conservation of magnetic flux by the conductor: increase in interior magnetic field leads to an increase in the exterior magnetic field. This exclusion of magnetic field from the interior of a superconductor at a temperature below the critical temperature is referred to as meissner effect (Hofmann, 124). Meissner effect occurs when a material undergoes transition from normal to superconductive state. In this case, if the material is placed in a weak magnetic field, electric currents are set up near its surface. These currents in turn produce magnetic fields which cancel the magnetic field applied in the bulk of the material (Narikiyo, 96). The magnetic fields inside the material therefore become zero. Meissner effect simply states that a super conductor exhibits perfect diamagnetism when in superconducting state. In meissner state, the magnetic susceptibility is equal to -1. The susceptibility of -1 implies that materials are strongly barred from magnetic fields.

Both perfect conductors and superconductors exhibit meissner effect.

However, there is distinction in conditions under which meissner effect can be observed between the two materials. For a perfect conductor, perfect diamagnetism is influenced by the magnetic field of the material before cooling to a state of zero resistance and electrical resistivity of the material after cooling. On the other hand, a superconductor excludes all the magnetic fields from its bulk after transition to superconductive state regardless of its magnetic field prior to the transition into the superconducting state. This implies that meissner effect can also be observed in superconductors when cooled below critical temperature first before being put in external magnetic field. However, this is not the case with perfect conductors. For instance, when a perfect conductor is put in a magnetic field and then cooled to a temperature so that its resistivity becomes zero, perfect diamagnetism does not occur (Li, 230). However, if the material is cooled to zero resistance state first and then put in a magnetic field, perfect diamagnetism is observed. The diagram below illustrates this phenomenon.

T = Tc T ˂ Tc

Cooling magnetic field

R ≠0 R = 0

Cooling

Figure 1: magnetic behaviour of a perfect conductor. The diagram is obtained from Hofman’s Solid state physics: An introduction.

In the case of a superconductor, when a material is cooled to below critical temperature and then placed in a magnetic field, all the applied magnetic fields are excluded from the interior of the material: meissner effect is observed. Similar observation is made when a superconductor is put in a magnetic field and then cooled to superconducting state.

T = Tc T ˂ Tc

Cooling Magnetic field

R ≠0 R = 0

Cooling

T˃ TC

Figure 2: magnetic behaviour of a superconductor. The diagram is obtained from Hofman’s Solid state physics: An introduction.

The meinsser effect in superconductivity can be explained by BCS theory. The theory suggests that cooper pairs of electrons are responsible for the meissner effect in superconductive materials. The theory also states that electrons found in perfect conductors group in a manner slightly different form how electrons in materials that have superconductive properties pair up. This partly explains the distinction in conditions under which both superconductors and perfect conductors show perfect diamagnetism. London equations can also be used to explain Meissner effect. According to London’s second equation, the curl of the current density is directly proportional to the magnetic field.

Superconductors also exhibit antigravity effect. Some of the materials that can be used for antigravity effect include barium, mercury, neodymium, bismuth, aluminium, titanium, copper, lead, and cobalt. Antigravity effect is the effect caused by rotating magnetic fields in which the region around the material causing the effect is free from the force of gravity. This phenomenon is currently being explored for development of new technology in space exploration (Millis, Marc, and Eric, 154). However, few studies have been conducted to determine the mechanism with which this phenomenon takes place. It has however been suggested that during rotation of a magnetic field, electrons move from the centre of the magnetic material towards the periphery of the material.

Works cited

Hayes, Judy. Meissner Effect, Penetration Depth, and Residual Magnetism in Superconductors. Pasadena: Jet Propulsion Laboratory, California Institute of Technology, 1959. Print.

Hofmann, Philip. Solid State Physics: An Introduction. Weinheim: Wiley-VCH, 2008. Print. Top of Form

Li, Mai S. Paramagnetic Meissner Effect and Related Dynamical Phenomena. Amsterdam [u. a.: Elsevier, 2003. Print.

Millis, Marc G, and Eric W. Davis. Frontiers of Propulsion Science. Reston, Va: American Institute of Aeronautics and Astronautics, 2009. Internet resource.

Narikiyo, Osamu, and H Fukuyama. Proximity Induced Meissner Effect in Dirty Normal Metals. Tokyo, Japan: Institute for Solid State Physics, University of Tokyo, 1989. Print.