Neutrons in solid state physics

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Almost all of the major changes in our society, the revolutions in transport and manufacturing, the development of computing and the internet, and the steady increase in everyday life quality, have their origin is understanding and exploiting the physics and chemistry of materials. The principal goal of modern materials science is to understand the properties of matter on the atomic scale, and to use this knowledge to optimize the properties or to develop new materials.

The development of the nuclear reactors first and the accelerator-based spallation neutron sources subsequently allowed beams of neutrons for materials research to become routinely available. Two important steps are required to apply the neutron beam for studies in the area of the solid state physics. First of all, it is crucial to moderate high-energy neutrons created by the neutron source and to reduce their velocity by five orders of magnitude from the speed of light to the speed of sound. The second necessary step would be a monochromatization of the neutron beam by proper selection of the neutrons velocity (time-of-flight method) or the neutrons wavelength (by the use of Bragg diffraction).

All interactions of slow neutrons with matter are week and generally each neutron scatters only once within the sample volume. The neutron mass gives to the thermal neutron a de Broglie wavelength comparable to interatomic distances in crystals, allowing an interference effect, used to determine both the nuclear structure and the magnetic ones. An even more important consequence of the mass is the energy of thermal neutrons (10 - 80 meV), particularly suited to study both nuclear and magnetic thermal excitations. It should be highlighted that the neutron scattering is a unique experimental technique in magnetism since the interaction with the electronic magnetic moment is of the same order of magnitude as the interaction with atomic nuclei. Neutrons are sensitive to the electronic magnetic moment or fluctuations amplitude perpendicular to the momentum transfer. Moreover, an application of polarized neutron beams allows one to separate the nuclear and the magnetic scattering and gives an access to more detailed picture of the investigated sample.

Two particular examples of neutron scattering studies will be briefly described and discussed. The first one concerns the crystal lattice dynamics in the PbTe – a typical representative of an efficient thermoelectric semiconductor family. The comparison of the selected data obtained with the use of the spallation source [1] and the steady source (reactor) will be discussed. The second example will demonstrate a sensibility of a polarized neutron reflectivity method to explore the details of both the nuclear and magnetic in-depth profile of multilayer composed of ultrathin Pt and Co layers [2].

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