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Polarized neutron reflectometry for investigation of low-dimensional 2D magnetic & superconducting periodic and quasiperiodic heterostructures

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Low-dimensional magnetic and superconducting heterostructures, due to the presence of a large number of interesting phenomena, are currently being actively studied. One of the effective methods for studying magnetism is polarized neutron reflectometry, which makes it possible to obtain isotopic and magnetic depth profiles with nanometer resolution. Low-temperature studies of proximity effects in superconducting-ferromagnetic systems [1] and rare-earth films with nontrivial magnetic ordering [2] were carried out using the REMUR reflectometer of the IBR-2 reactor (Dubna).

Proximity effects at the interface between two media are currently being actively studied. Of particular interest are layered low-dimensional structures with superconducting (S) and ferromagnetic (F) properties, in which the interaction of two antagonistic order parameters is realized. Promising systems for studying proximity effects are S/F heterostructures made of niobium and rare earth (RE) metals [3]. As example for the layered heterostructure Al2O3//Nb(40 nm)/[Dy(6 nm)/Ho(6 nm)]34/Nb(10 nm) it was found that at a temperature below the superconducting transition, the magnetic state of the helimagnet was affected by superconductivity, namely the fan-shaped magnetic state the ordering was rearranged into helimagnetic ordering [4].

The described periodic layered systems are artificial layered crystals. When neutrons are reflected from a periodic layered structure, Bragg peaks are observed. Layered artificial quasicrystals are also of particular interest. It is possible to create artificial layered systems with quasicrystallinity in the direction perpendicular to the plane of the structure. The possibility of creating layered quasicrystals from alternating superconducting and ferromagnetic layers is considered. These model systems are simple to manufacture and research, but will make it possible to study non-trivial phenomena, such as fractal superconductivity and long-range magnetic order in a quasiperiodic system, as well as their coexistence. The creation of Fibonacci structures using magnets with helical magnetic order is of particular interest.

[1] Yu.V. Nikitenko et al. // Physics of Particles and Nuclei, v. 53, No. 6, pp. 1089-1125 (2022).
[2] D.I. Devyaterikov et al. // Journal of Surface Investigation, v. 16, № 5, pp. 839-842 (2022).
[3] Khaydukov Yu.N. et al. // Phys. Rev. B, vol. 99, pp. 140503(R) (2019).
[4] Zhaketov V.D. et al. // Physics of the Solid State, Vol. 65, No. 7 (2023).

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