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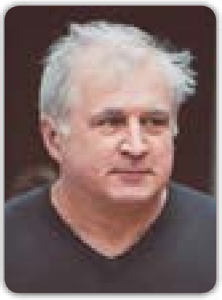

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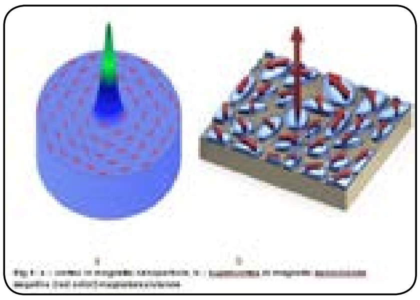
Unusual properties of multilayer nanoisland magnetic systems: Supervortices, flat spin springs and optical nonreciprocity

The paper presents the results of studies of original nanostructures - multilayer systems from magnetic nanoislands of the $(FeNi/Co)_N$ type. Earlier in the metal nanoislands, we found photoconductivity in a wide spectral range (0.4-1.5 μm), anomalous conductivity, etc. It was also found that those systems can detect at room temperature superweak magnetic fields H of less than 10^{-11}T. The physical reasons for this high sensitivity are not fully understood, but it is clear that they are due to the unusual physical properties of island systems. Metal nanoisland layers with a given effective thickness were grown by RF sputtering. For metal films, a percolation threshold was found - d* (for FeNi and Co films d*~1.8 nm). Films for d<d* were island, and d>d* - continuous. Nanoisland were flat pancakes of rounded shape with lateral dimensions of 3-30 nm, and their effective thickness varied from 0.4 to 7.0 nm. Magnetization processes were investigated at room temperature by the magneto-optical Kerr effect (MOKE). In the structures $(FeNi/Co)_N$ (N varied from 10 to 40), unidirectional magnetic anisotropy was observed, not associated with the well-known exchange anisotropy (the hysteresis loops did not have an exchange shift). It was suggested that the detected unidirectional anisotropy is associated with the appearance in the structures of an unusual supervortical magnetization. In this case the vortex is not concentrated in separate nanoislands, but is distributed over a certain set of them. Micromagnetic modeling confirmed the possibility of the existence of a supervortical magnetization in the island structure. An indirect confirmation of the existence of such unusual supervortical magnetization was the results of a study of the magnetization of the nanoislands layers on a SQUID magnetometer. The presence of a supervortical magnetization leads the island structures to be chiral and leads to the appearance of an anomalous optical nonreciprocity. In this report we discuss the possible causes of the appearance of optical nonreciprocity. However, the high sensitivity of island structures to superweak magnetic fields, apparently, is not related to supervortex magnetization. For this reason magnetization processes and magnetoresistance in special structures - bilayers $[(FeNi/Co)\text{-}Al_2O_3]_N$ were investigated. A region with specific magnetization in FeNi nanoislands in a weak magnetic field is appeared. In those regions of FeNi islands the rotation of the magnetization vector is occurred. Those regions we call a flat (two dimensions) spin springs. When the current flows through this region, additional scattering of the electron spins takes place and an additional negative magnetoresistance occurs. We believe that these spin springs can cause high sensitivity of island structures to weak magnetic fields.



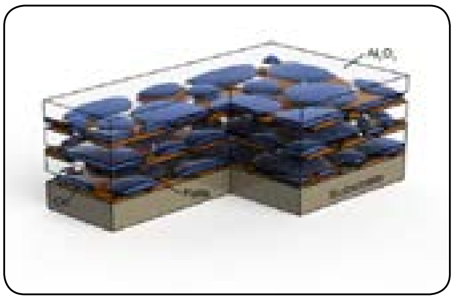
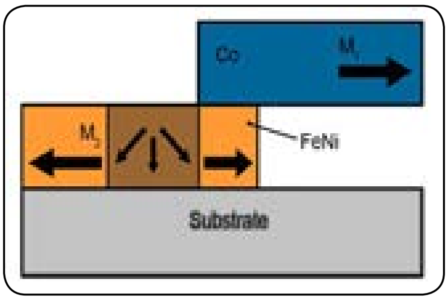


Figure 2: Multilayer structure [(FeNi/Co)-Al2O3]N.



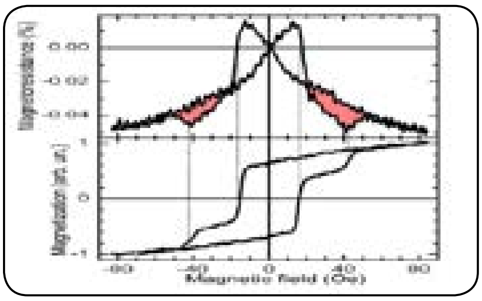


Figure 3: Bilayer FeNi/Co with flat spin spring.

Figure 4: Additional negative (red calor) magnetoresistance and hysteresis loop of a bilayer multilayer structure.

Recent Publications

1. Boltaev A P, Pudonin F A, Sherstnev I A and Egorov D A (2017) Detection of the metal-insulator transition in disordered systems of magnetic nanoislands. Journal of Experimental and Theoretical Physics 125(3):465-468.
2. Boltaev A P, N A Penin, A O Pogosov and Pudonin F A (2003) Detection of photoconductivity in hyperfine metal films in the visible and infrared spectral regions. Journal of Experimental and Theoretical Physics 96(5):940-944.
3. Boltaev A P and Pudonin F A (2006) Effect of weak electric fields on the conduction in thin metal films. Journal of Experimental and Theoretical Physics 103(3):436-440.
4. Boltaev A P, Pudonin F A, Sherstnev I A et al. (2017) Flat magnetic exchange springs as mechanism for additional magnetoresistance in magnetic nanoisland arrays. Journal of Magnetism and Magnetic Materials 428:132-135.
5. Boltaev A P, Pudonin F A and Sherstnev I A (2011) Specific features of the magnetoresistance in multilayer systems of magnetic nanoislands in weak magnetic fields. Physics of the Solid State 53(5):950.

Biography

Fedor Pudonin is the Head of Laboratory in P.N.Lebedev Physical Institute Russian Academy of Science, Russia. He is the chief researcher in the Laboratory of Heterogeneous Systems Physics.

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