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Nanoisland magnetic films: Technology and possible applications

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Now there has been a significant interest in the technology of obtaining and studying magnetic nanoisland films. This is due both to the enormous applied potential of these objects. We used the RF-sputtering method to obtain nanoisland films of magnetic materials such as FeNi, Co, Ni, etc. In this report we will present the results of our work on obtaining magnetic nanoisland films and some applied aspects of these structures. Since the deposition rate is a stable value at constant technological parameters, we deposit thin films whose effective thickness was determined by the time of deposition. There is a critical thickness d*(percolation threshold) below which the films are nanoisland, and films with effective thickness d>d* become continuous. To determine the d* value, we have grown several series of FeNi films with effective thicknesses from 0.5 to 3.0 nm with thickness steps Δ~0.07 nm. The standard polished ceramic plates (sitall), crystalline silicon, silicon nitride, glass, as well as thin Al_2O_3 layers deposited on silicon were used as substrates. Figure 1 shows an image of some island FeNi films. To determine d*, the dependences of the permittivity ε(ω) and conductivity σ on the thickness were studied. It was found that Re ε(ω) and δ=[σ (T=300 K) - σ(T=77 K) simultaneously change sign at d~1.6-1.8 nm, which indicates the presence of a percolation transition at d*~1.6-1.8 nm. Thus, FeNi films with an effective thickness d<1.6 nm are island. We have shown that photoconductivity in the range 500-1500 nm, anomalous conductivity in weak electric fields, giant dielectric constant, and other unusual properties are observed in nanoisland films of FeNi and other metals. We proposed to use nanoisland FeNi films in which the effect of anomalous conductivity is observed as labels that can serve as a protection for various documents and securities and other products. Nanoisland films can also be used to create sensors of superweak magnetic fields at room temperature. For this, we fabricated multilayer island structures such as $[FeNi/Co]_N$ in figure 2. With the help of X-ray studies it was shown that in such systems the island layers do not mix and they really are periodic structures. It was found that these structures are capable of detecting (changing their resistance) magnetic fields $H<10^{-11}$ T. This is a great result and we hope to improve it.

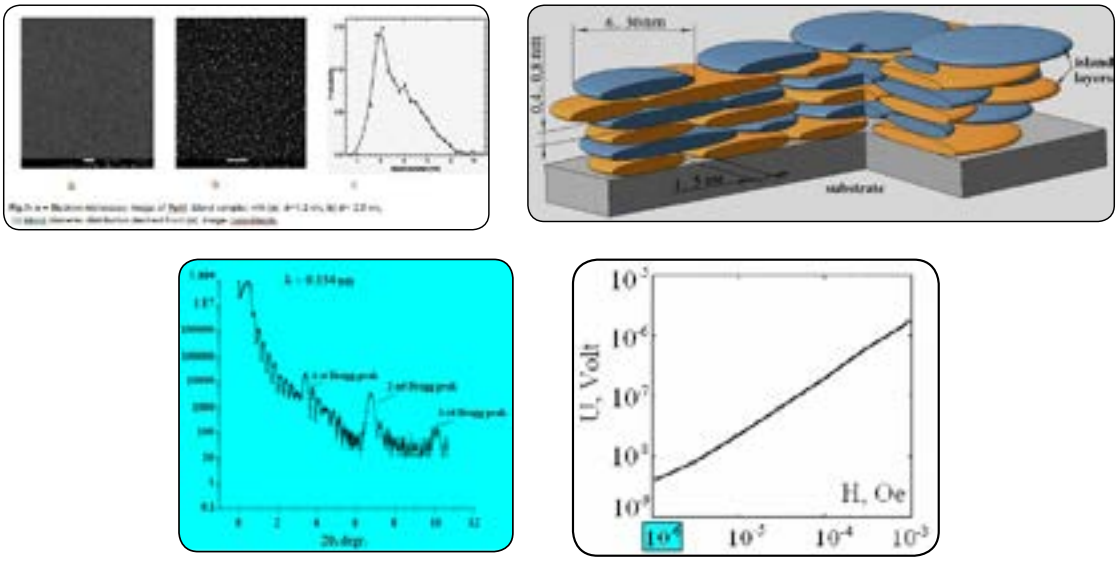

Figure 2: Multilayer structure (FeNi-Co)N

Figure 3: Angular dependence of the X-ray reflection I from the multilayer island structure [ZnTe(1.5 nm)–Ti(0.9) nm]10.

Figure 4: The dependence of the voltage U on the structure (FeNi-Co)20 on the magnetic field H.

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 and Sherstnev I A (2015) Low-frequency giant effective permittivity of island metal films. Physics of the Solid State 57(10):2099–2105.
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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