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Brain like Artificial Neural Network Based on Superconducting Neurons and Synapses

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Energy efficiency and the radically reduction of the power consumption level becomes a crucial parameter constraining the advance of supercomputers. The most promising solution is design and development of the Brain-like systems with non-von Neumann architectures, first of all – the Artificial Neural Networks (ANN) based on superconducting elements. Superconducting ANN needs elaboration of two main elements – nonlinear switch, neuron [1] and linear connecting element, synapse [2]. We present results of our design and investigation of artificial neurons, based on superconducting spin valves – S/F/S Josephson Junctions with weak link F fabricated from magnetic material (Ni or alloy CuNi), and superconducting synapse based on layered hybrid structures superconductor-ferromagnet.

We obtained and analyzed results of experimental study of the proximity effect in a stack-like superconductor/ferromagnet (S/F) superlattices Nb/Co with F = Co ferromagnetic layers of different thicknesses and coercive fields, and S= Nb superconducting layers of constant thickness equal to coherence length of niobium which can serve as an artificial synapse.

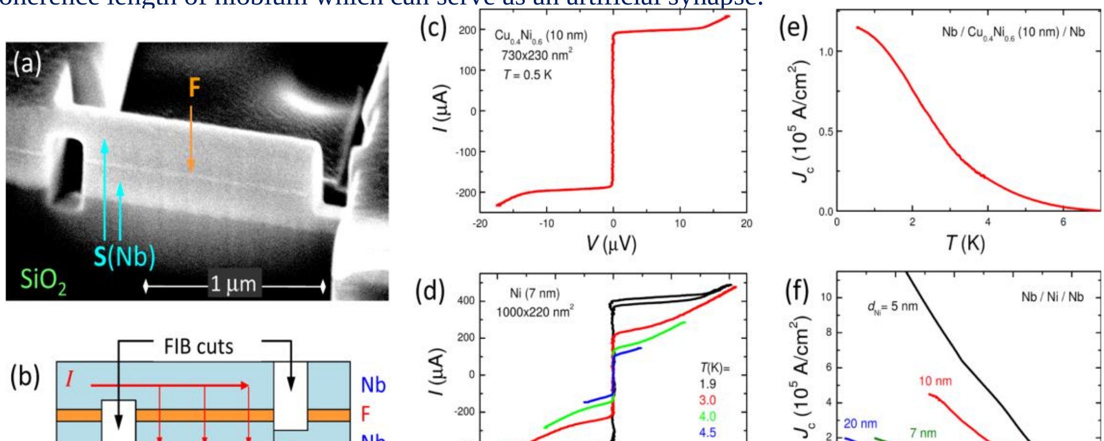

Fig.1. a) TEM image of the artificial neuron – Nb/F/Nb Josephson Junction, b) sketch of the Nb/F/N Josephson Junction with F - magnetic material (Ni, or CuNi) , c) I-V switching curve of the Nb/CuNi/Nb Josephson Junction at fixed temperature T=0,5 K, d) c) I-V switching curves of the Nb/Ni/Nb Josephson Junction at number of fixed temperatures listed in the inset, e) Temperature dependence of the critical current of Nb/CuNi/Nb Josephson Junction, f) Temperature dependence of the critical current of the set of Nb/Ni/Nb Josephson Junctions with various thickness of the Ni layer.

The superlattices Nb/Co demonstrate change of the superconducting order parameter in thin niobium films due to switching from the parallel to the antiparallel alignment of neighboring ferromagnetic layers magnetization. We argue that such superlattices can be used as tunable kinetic inductors for ANN synapses engineering. As the result of design of the ANN using that two elaborated base elements, artificial neurons and artificial synapses, allows construction of the computer with 6-7 orders of magnitude lower energy consumption in comparison with the traditional computer designed from semiconducting base elements.

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