Proposal of a new type of a Superconducting Switching Device

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Abstract

We propose a new type of superconducting switching device using Supeconducting metal-Normal metal-Superconducting metal (S-N-S) superlattice. The coherent region should be separated if the spacing of S-N-S superlattice is optimized to reveal dimensional crossover effect, where the spin exchange correlation between the superconducting layers should be maximal. The operation principle of the proposed device is modulation of Broch resonance inside of the superlattice by the gate operation.

Key words: Superconducting layered structure, Transport of Cooper Pair, Kondo effect, Broch resonance

1. Intorduction

Since the first prediction of the superconducting device by Brian David Josephson in 1962[1], the device has been known to be not only a high frequency switching device consuming extremely low energy, but also a very applicable device to many fields such as Superconducting Quantum Interference Devices (SQUIDs). However the Josephson junction as a switching device has never been practically used in spite of a lot of trials, because there are some reasons such as chaotic noise during the operation beyond the frequency of 7x10^8Hz, attenuation of signals transmitted across the tunneling barrier, delay of signals by parasitic capacitance and mechanical fragility against thermal stress. It is recognized that these problems are caused by the existence of the inserted insulator.

The oxide superconductor discovered by K.Alex Muller and J.Georg Bednorz[2] has never been introduced to switching device because of its high electric polarization. This means that these problems cannot be essentially solved by partitioning the coherent region by dielectric material with high electric polarization. We are going to discuss the way of partitioning the coherent region without dielectric materials in terms of spin exchange correlation.

2. Separation of the coherent region in the metal system

Giant Magneto-Resistance (GMR) is known to be the example of separating magnetic domain in the metal systems without any dielectric materials[3]. In the case of GMR, the separation is realized by optimizing the spin exchange correlation between ferromagnetic layers. Even in the systems of Superconducting metal-Nomal metal-Superconducting metal (S-N-S) system, it has already been reported that the layer-by-layer anti-ferromagnetically spin arrangement should be realized if the spin exchange correlation between

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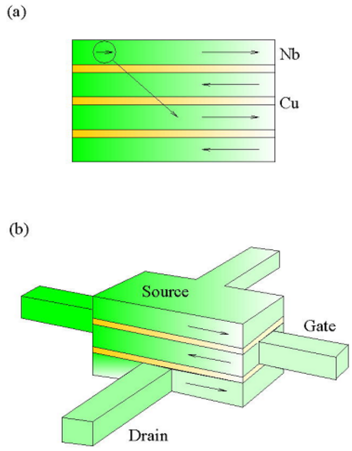

Fig. 1. Preferential transport of itinerant Cooper pair in the mesoscopic S-N-S superlattice (a). As a result of the preferential transport between superconducting layers, we can separate the coherent region in the unit cell of 4-probe switching device (b).

superconducting layers is maximal[4]. It is concluded that the coherent region could be divided by tuning superlattice spacing without any dielectric materials.

3. The proposed four-prove switching Device

Figure 1 shows the schematic diagram of a unit cell of a four-probe switching device. The transition of the electrons between the correlated layers should be preferential and the transition to the next layer should be restricted by Kondo effect[5](Figure 1a). Based on this philosophy, a unit cell of a four-probe device with a source, a gate and a drain has been proposed by one of the authors (K.Tsukui)(Figure 1b). The principle of switching operation is based on the modulation of the Bloch resonance[6],[7] and nonlinear transport due to Bloch resonance[8].

The inserted paramagnetic metal plays the same role as insulator, which can be treated as the band gap in the case of semiconductor superlattices. This “Tunneling barrier effect” has been authorized in the case of use of the paramagnetic layer with different angular momentum[9].

Consequently the proposed device should be able to be operated keeping the superconducting current by Broch resonance, therefore, the operation is independent of the frequency limit decided by the gap energy in the case of the conventional RC-type Josephson junction. The frequency of switching operation is expected up to 10^{18}Hz concerning plasmon loss energy of the normal metals (Cu; in the order of 10^{3}eV). If such high-frequency operation could be possible, electric pulses and photons could be transformed to each other.

4. Conclusion

In this paper, we proposed a new type of superconducting switching device using Superconducing metal-Normal metal-Superconducting metal (S-N-S) superlattice. This device doesn’t include any dielectric materials, which prevent conventional superconducting devices from high-frequency operation.

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