Magnetization-mediated superconducting diode effect

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The superconducting diode effect (SDE), in which superconducting current flows in one direction and Ohmic current in the other direction, is expected to be observed in non-centrosymmetric superconductors. Intrinsic SDEs originating from band structure were experimentally pointed out in polar superconductors such as Nb/V/Ta superlattices [1]. On the other hand, extrinsic SDEs have also been discovered in superconductors with asymmetric patterning of artificial pinning centers or in superconductor/ferromagnet hybrid devices [2-4]. However, most existing SDEs required an external magnetic field, which limits their practical application. With the progress of research, it has been reported that normal-superconducting switching is possible at zero magnetic fields in materials such as van der Waals heterostructures [5], non-centrosymmetric multilayers [6], and trilayer graphene with small twist angles [7]. In particular, asymmetric multilayers or superlattices are simple ways of breaking space-inversion symmetry and are interesting as they are suitable for implementing microfabrication techniques. In addition, they have a high degree of freedom in the number of layers, stacking order, and constituent elements.

Recently, we have succeeded in controlling the polarity of SDEs in [Nb/V/Co/V/Ta] multilayer devices at zero magnetic fields [6]. However, further improvement of the zero-field SDEs and clarification of their microscopic origins are significant issues to be addressed.

We fabricated Fe-inserted superconducting superlattices to enhance non-reciprocal critical current at zero magnetic fields by combining [Nb/V/Ta] superlattices and Fe, which has a larger magnetic moment than Co. As a result, we successfully observed the magnetic hysteresis of non-reciprocal critical current similar to the behavior of the magnetization curve of Fe without complicated control of the magnetic state. We also realized the magnetization control of zero-field SDEs. This result suggests the existence of exchange interactions on Cooper pairs from the ferromagnetic layers.

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