New Quantum Molecular Spintronics and How to Increase Hysteresis Temperature in Single-Molecule Magnets

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Spintronics, based on the freedoms of the charge, spin, and orbital of the electron, is a key technology in the 21st century. Magnetic random access memory (MRAM), which uses giant magnetoresistance (GMR) or tunneling magnetoresistance (TMR), have several advantages over conventional systems, such as nonvolatile information storage, high operation speeds on the order of nanoseconds, high storage densities, and low power consumption. Although bulk or classical magnets composed of transition metal ions are normally used, in our study, we use single-molecule magnets (SMMs). SMMs undergo slow magnetic relaxation due to the double-well potential, defined as \(|D|S^2\), and quantum tunneling, making them excellent materials for quantum computers and high density memory storage devices. However, the hysteresis temperatures for SMMs are still very low. Thus, application of SMMs is difficult. In my presentation, I will discuss methods for increasing the hysteresis temperatures of SMMs.

In general, to increase hysteresis temperatures, we must suppress quantum tunneling and increase \(|D|S^2\) for d-metal SMMs and the energy gaps between the ground and the first excited states for f-metal SMMs. For this purpose, we have used derivatives of double-decker bis-phthalocyaninato-Tb(III) SMMs (TbPc2). However, the magnetization of the original TbPc2 has a hysteresis temperature of 1.8 K, and frequency dependence of the AC magnetic susceptibility is observed at 50 K. This is due to quantum tunneling in the ground state. In order to suppress quantum tunneling, we have incorporated an exchange bias via intermolecular interactions among TbPc2 molecules.

First, we have synthesized the clamshell type dinuclear [TbPc2]2 bridged with the dibenzyl-ethox moieties. The hysteresis temperature is 25 K. Then, we synthesized a fused dinuclear complex, [TbPc2]2, where two TbPc2 moieties are connected with benzyl group on one of the Pc ligands. In the crystals, one TbPc2 and one of a neighboring [TbPc2]2 weakly interact. Thus, the hysteresis temperature increased to 27 K. Next, we synthesized the liquid crystals of TbPc2 derivatives by introducing the long alkyl chains. A hysteresis temperature of 31 K was observed.

Discotic Liquid Crystal SMM

![Discotic Liquid Crystal SMM](image)