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Preparation and SPM study of Mn_{12} on Au surface.

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Single-molecule magnets (SMM's) have attracted much interest for their noble magnetic properties [1,2] and potential application to nano-scale magnetic storage devices and quantum devices [3,4]. SMMs are superparamagnets composed of large numbers of identical magnetic molecules, which interact very weakly with each other, and are subject to a strong uniaxial anisotropy. In a crystal of SMMs, molecules are arranged in a lattice with uniform orientations, and the measured magnetic properties of a crystal of SMMs reflect the magnetic properties of a single molecule. The relaxation of magnetization in SMMs becomes very slow below the blocking temperature due to the strong uniaxial anisotropy and large spin of the molecule. As a result, SMMs exhibit a magnetic hysteresis and behave like a classical magnet with a magnetic moment as large as 20 μ_B. Therefore, SMMs can be used, in principle, as a nanoscale storage device. In addition, SMMs have shown fascinating quantum phenomena, such as quantum tunneling of magnetization [5,6] and quantum phase interference [7,8].

Realizing proposed applications of SMM's requires an understanding of the fundamental properties of individual molecules, and It is essential to devise a method for probing and manipulating individual molecules. One promising strategy is to deposit SMMs on a suitable substrate and use scanning probe microscopy for addressing individual molecules. Recently, there have been reports on the preparation of films of SMMs [9-13]. To this end we have synthesized $Mn_{12}O_{12}(O_2CC_4H_3S)_{16}(H_2O)_4$ and $Mn_{12}O_{12}(O_2CC_6H_5SCH_3)_{16}(H_2O)_4$ compounds, which are the functionalized derivatives of the well-known $Mn_{12}O_{12}(O_2CCH_3)_{16}(H_2O)_4$ (noted as Mn_{12}-Ac), investigated the structural and magnetic properties, and deposited a film of molecules to study the surface morphology of the film and the elastic properties of the molecules.

Molecules were prepared by reaction of 3-thiophenecarboxylic or 4-methylthiobenzoic acid with Mn12-Ac in methylene chloride followed by the repeated azeotropic distillation with either toluene or methylene chloride to remove the acetic acid. Molecular structure of the compound was characterized by a single crystal x-ray diffraction and it was found that $Mn_{12}O_{12}$ core structure is almost the same as that of Mn_{12}-Ac except for a different arrangement of four water molecules. Magnetic properties of the compound were investigated by measuring both dc and ac magnetic susceptibilities as functions of temperature and magnetic field, and the spin (S=10), blocking temperature (T_B=3.2K), and the magnetic anisotropy constant (D=0.61K) of the molecule were determined.

A film of the molecules was chemically deposited on an atomically flat gold surface. Surface morphology of the film and the elastic properties of the molecules were investigated using a tapping mode atomic force microscopy. Molecules were found to be arranged randomly with an abnormal height distribution due to weak inter-molecular interaction and the anisotropic shape and bonding probability of the molecule. We found that $Mn_{12}O_{12}(O_2CC_6H_5SCH_3)_{16}(H_2O)_4$ molecules adhere to Au surface much faster than $Mn_{12}O_{12}(O_2CC_4H_3S)_{16}(H_2O)_4$ molecules. From the amplitude-distance curves measured on top of the molecules we found that the mechanical stiffness of the molecule adsorbed on gold surface is about 0.2 N/m.

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