Molecular Nanomagnets

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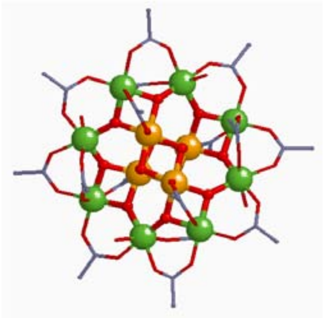
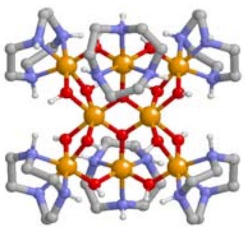
Molecular Nanomagnets

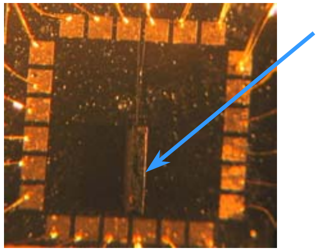
Molecular nanomagnets have large spins that are magnetically bistable in a crystal at low temperatures. They exhibit fascinating quantum mechanical behavior on a macroscopic scale, and hold great promise for important applications such as high density storage of data, and possibly as qubits for quantum computation. Two prototypical examples are shown below. (*Solid State Commun.*, **127**, 131139, 2003.)



Mn_{12}-acetate; S=10



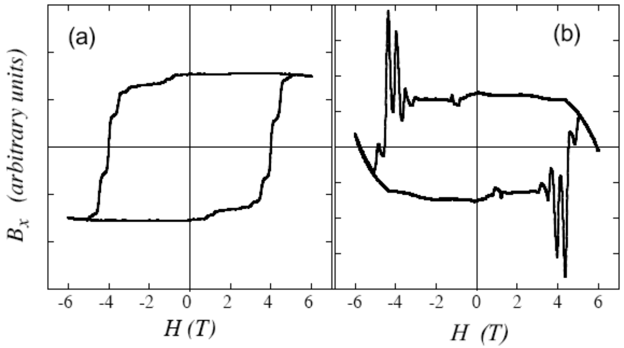
Fe_8; S=10



A crystal of Mn_{12}-ac was mounted on an array of 10 x 10 μm^2 Hall sensors which were used to measure the local magnetization of the sample.

Experiments

We are currently studying the properties of the prototypical molecular magnet, Mn_{12}-Acetate using spectroscopic probes, and very small Hall bars that measure the magnetization on a local length scale of microns. The figure below shows the magnetization measured at the end (left curve), and near the middle (right curve) of a sample.



Computing power/speed and the density of memory elements for storing and manipulating information have been steadily increasing, while the size of the component memory "bits" have been decreasing very rapidly. We are descending into a world dominated by quantum mechanical phenomena.

Considerable effort is currently being devoted to methods for storing information at molecular length scales. In order to continue our steep trajectory to better, smaller and faster computers, we must learn to understand and manipulate physics and chemistry at the molecular level. Moreover, quantum computation, a new and entirely different computing paradigm based on quantum phenomena, is being widely explored, both mathematically and experimentally. Rather than having two possible "classical" values, 0 or 1, the quantum mechanical elements of quantum computers, called "qubits", represent a far broader set of possibilities, enabling much greater computing power.

A number of potential candidates for high-density information storage and quantum computation are under investigation, among them molecular nanomagnets, sometimes referred to as "single molecule magnets". We are studying Mn_{12}-Acetate, a prototypical member of this class of materials. It consists of a very large number of identical clusters of 12 manganese atoms that form magnetic molecules regularly arranged in an organic crystal; each molecule is a little magnet that is equivalent to 20 times the magnetism of a single electron.

A summary of our recent work can be found in Solid State Communications, Vol. 127, p. 131139. The focus of our current research is on spectroscopic measurements at low temperatures at the synchrotron light source at Brookhaven, and measurements at City College of New York of the local magnetization at low temperatures on a length scale of microns using very small Hall bars.

Single Molecule Magnets

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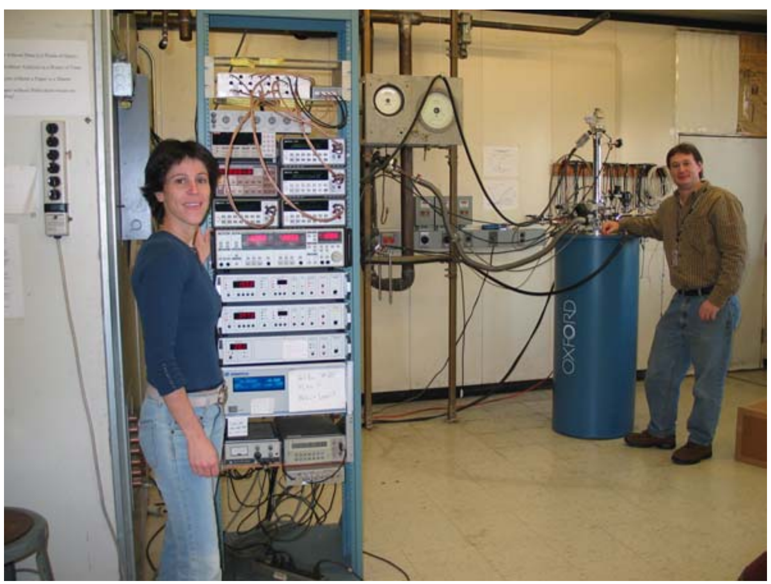
Education

One research associate (Kevin Mertes, now at Amherst), two graduate students (Yoko Suzuki, and Nurit Avraham visiting from the Weizmann Institute in Rehovot, Israel) and several undergraduate students (David Graybill, Kurt James, Ricardo Gonzalez) have participated in this project. The picture below shows Nurit Avraham (left) and Kevin Mertes (right).



Societal Impact

Computing power/speed and the density of memory elements for storing and manipulating information have been increasing rapidly. The size of memory “bits” is decreasing and we are rapidly descending into a world where quantum mechanics dominates the behavior. Considerable effort is currently being devoted to storing information at molecular length scales. In order to continue our steep trajectory to better, smaller and faster computers, we must learn to understand and manipulate physics and chemistry at the molecular, quantum mechanical level. Moreover, quantum computation, a new and entirely different computing paradigm based on quantum phenomena, is being widely explored. Molecular nanomagnets of the type we’re studying are possible elements or “qubits” under consideration for use in quantum computers.