On-chip deposition for local control of nanomagnets

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Logo of FSU,

paste from other posters

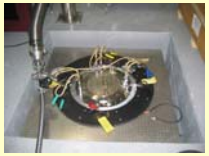
ABSTRACT

Nanoscale science deals with the study of phenomena at a very small scale - 10^{-7} m (100 nm) to 10^{-9} m (1 nm) - where properties of matter differ significantly from those at larger scales. It is a science interdisciplinary in nature, involving: physics, chemistry, biology, engineering, materials science, and computer science. Nano-sized particles exhibit different properties than larger particles of the same substance. When discussing nanoscopic scale you are viewing a measurement scale at which you cannot discuss properties of material/phenomenon without having to discuss the behavior of their individual atoms.

When studying phenomena at this scale we learn more about the nature of matter, develop new theories, discover new questions and answers in many areas, including health care, energy, and technology. Nanoscopic scale also helps us figure out how to make new products and technologies that can improve people's lives.

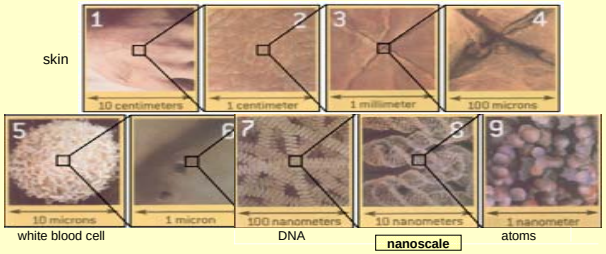
For this area of research our interest focuses on quantum effects at nanoscopic scale. The key focus will be on quantum computation and will involve studying spin dynamics in the case of magnetic molecules distributed in solid state samples. Temperatures as low as 10mK are suitable to explore the lowest energy levels of such quantum system. To this purpose, the sample has to be anchored to the mixing chamber of a dilution refrigerator. Control over the energy levels will be achieved by combining high frequency electromagnetic fields (f<50GHz) with a DC vector magnetic field.

The Group: Quantum Spin Dynamics and Nanotechnologies is focusing on quantum computation, involving studies of spin dynamics in 2 possible cases: magnetic molecules and superconducting flux qubits (quantum bits). The research techniques involve ultra low temperatures, high magnetic fields and high frequency equipments.



MACRO TO NANO

- Consider a human hand



Source: http://www.materialsworld.net/nclt/docs/Introduction%20to%20Nano%201-18-05.pdf

Fig. 1 From macro to nano

NANODEVICES

Nanodevices are tailored to perform certain functions not achievable in usual devices. Their functionality and properties cannot be addressed without discussing the behavior of individual atoms and quantum phenomena.

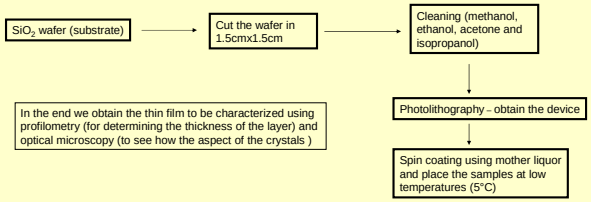
A SQUID is a Superconducting Quantum Interference Device. This special device is made of low temperature superconductors requiring cooling with liquid helium to 4K. They are used to measure extremely small magnetic fields. This is important to our research because crystals are deposited on the SQUID to measure their magnetic moment.

The Main Purpose of the Project:

- Our final goal is to deposit a small amount of molecules in a certain region of the squid. This will allow for magnetic measurements of the total magnetic moment at low temperatures.
- to determine the thickness of a thin film of K_3NbO_8 and K_3CrO_4 (realized in the Dept of Chemistry, group of Prof. N. Dalal) on the SQUID.
- to find the optimal parameters (time and speed) for spin coating in order to obtain a uniform thin layer.

Design process

Crystals appear to be the material most conducive to view properties at the nanoscopic scale due to their uniform structure. The crystals we formed came from the mother liquor solution of K_3NbO_8 (the chemical name for solution from which crystals sediment). Using spin coating, we were able to deposit K_3NbO_8 on top of a device. In order for the crystal to grow it is critical that after the deposition, the samples should stay at 5°C.



Clean room activities

1. Designing the nanodevice using photolithography (the process of transferring geometric shapes on a mask to the surface of a silicon wafer. The steps involved in the photolithographic process are wafer cleaning, barrier layer formation, photoresist application, hard baking, mask alignment, exposure with UV light and development, and soft baking).
2. The K_3NbO_8 was then taken from the Chemistry Dept to the clean room at the Center for Materials Research and Technology (MARTECH). It was here that we used a spin coater machine to spin the liquid onto the 15mm x 15mm device.

Fig. 2 Picture of clean room from inside

Fig. 3 Mother Liquor with crystals inside

Fig. 4 Spin coating machine

Fig. 5 Liquid on top of our device

SPINCOATING

Spin-coating is a procedure used to apply uniform thin films to flat substrates. An excess amount of solvent is placed on the substrate, which is then rotated at high speed in order to spread the fluid. The machine used is called a spin-coater. Rotation continues while the fluid spins off the edges of the substrate, until the desired thickness of the film is achieved. The higher the speed the thinner the film.

Example of nanodevice showing a SQUID fabricated at Martech by electron beam lithopgraphy

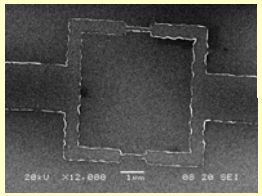


Fig. 6 Scanning Electro Micrograph of a SQUID (about 5x5μm²)

Experimental Data

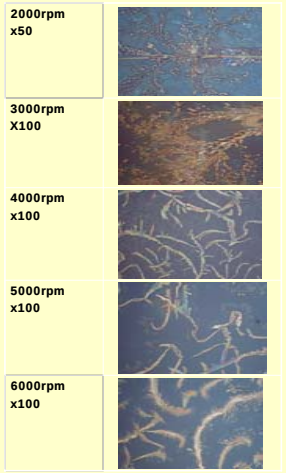
Experimental observations:

1. The crystalline structure is dendritic (like the ice crystals);

2. As we increase the spinning speed, crystals are more ordered

Optical Microscopy:

- determine the shape of the crystal
- measure the crystals dimension (magnification is 100 times)



Profilometry

- determine the thickness of the layer
- determine the height of the crystals

Fig. 6 Profilometer at MARTECH

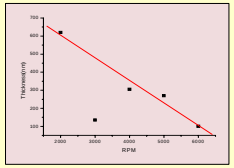


Fig. 7 Thickness dependence vs. spin coating speed

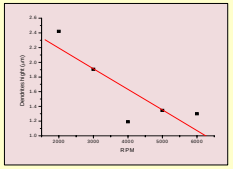


Fig. 8 Dendrites height vs. spin coating speed

Further research activity:

- The group plans to do another structural investigation: X-ray diffraction 1) to make a qualitative analysis used in determining the crystallographic phases which are present in the thin film 2) to get information about the texture, orientation of the crystallographic planes 3) more accurate measurement of the unit cell parameters (crystallites parameters)
- Finding the best solvent for the photo-resist lift-off
- Do the magnetic measurements for the molecules, situated on the SQUID, at low temperatures

Conclusions:

Using profilometry we were able to determine the best parameters for the spin-coating. From our data we can see that increasing the speed we get more homogeneous thin films, the height of the crystals decreases which gives us the certitude that smaller crystals can be grown on our device (the SQUID). The most important aspect is to obtain crystals which are even smaller (nanometer - sized) than the ones we synthesized until now, for measuring the spins coming from a couple of crystal cells.

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