Magnonic Crystals

A bottom up fabrication approach utilizing supramolecular and polymer chemistry

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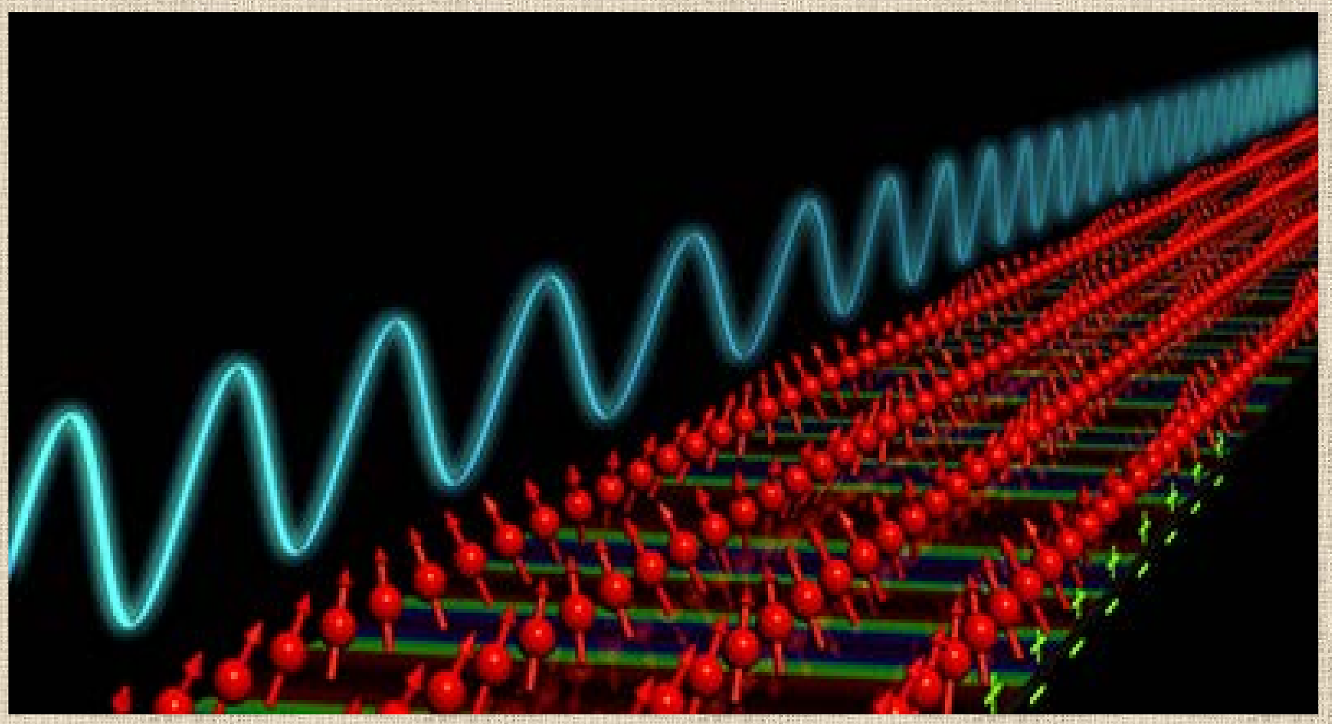
Introduction: Electrons for current conduction vs. wave propagation

Electronics has become one of the most utilized and relied on technologies for both home and industrial use, exploiting the properties of electrons and their ability to flow through conducting materials. However, electrons can also be used to conduct magnetic waves, known as magnons or spin-waves. Magnons are able to produce detectable signals well suited for electrical devices, such as logic gates or virtual storage. Spin-waves require no movement of the electron, only "precession", thus they have been shown to drastically reduce heating, while travelling at higher speeds than a flow of electrons.[1]

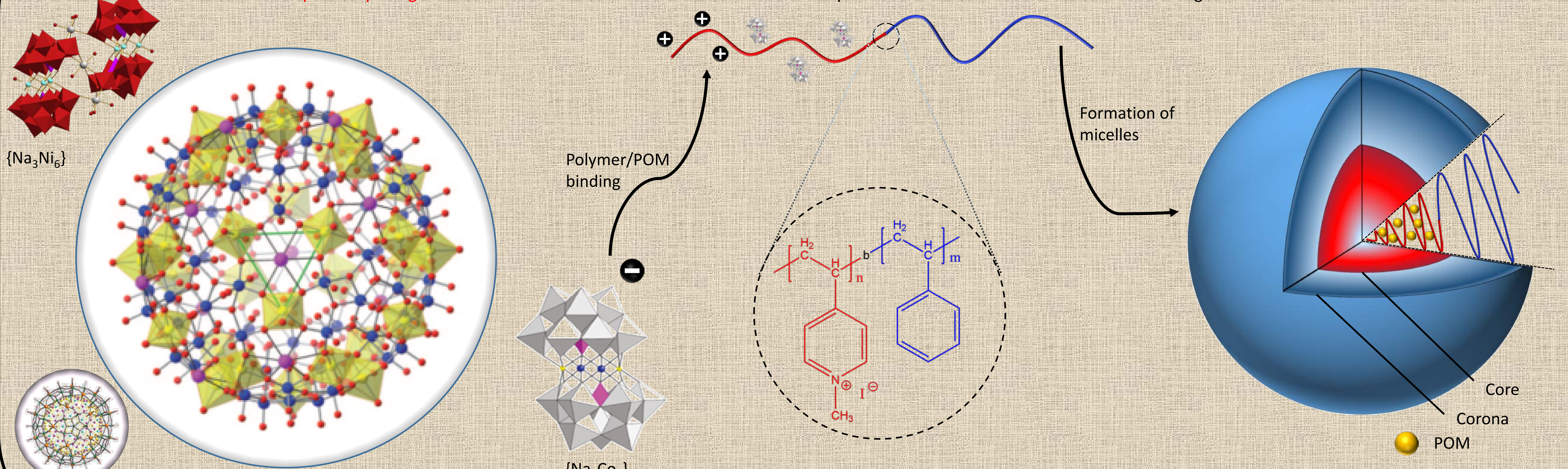


Background: The building blocks for magnonic crystals

Magnonic crystals are structures capable of guiding spin-waves, and are comprised of electron spin aligned materials.[2] There are multiple ways to fabricate magnonic crystals and wave-guides, including lithographic techniques, though these are often limited by size and stability.[3] One method explored in this project is a bottom up approach. Polyoxometalates (POM's) have been chosen to influence the magnetic properties on a substrate, and will be encapsulated into micelles with a block copolymers (BCP). Following the fabrication of POM encapsulated micelles, they will be assembled onto a ferromagnetic substrate, permalloy, and tested for their ability to manipulate spin-waves.

Mechanism of Fabrication

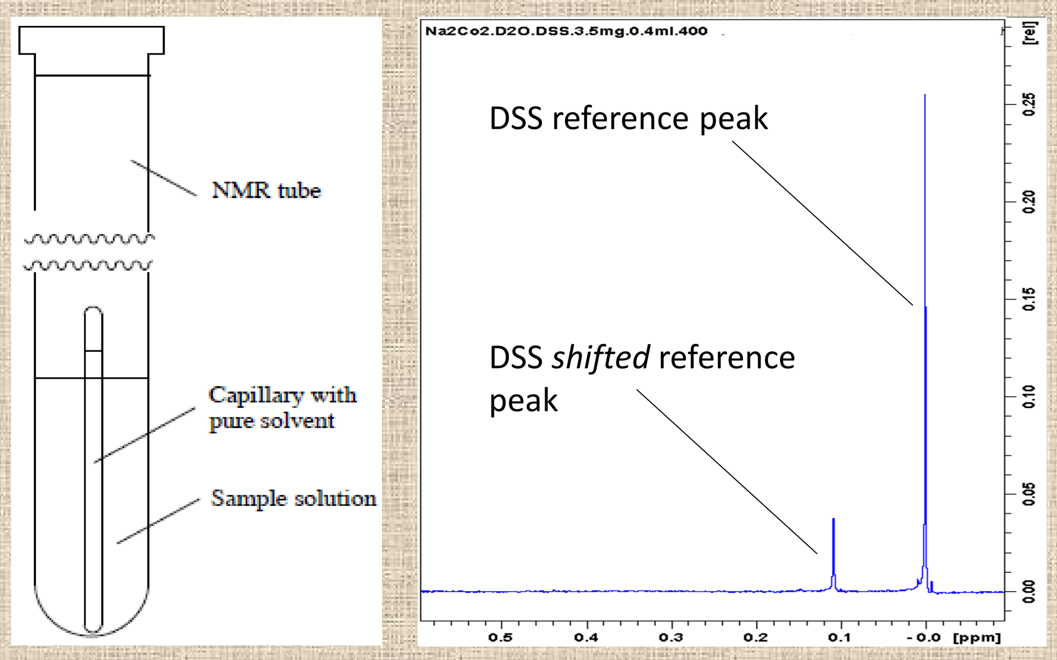
POM's are highly anionic, meaning they have an affinity for positively charged species. They come in a variety of discrete shapes, sizes, and chemical composition. Most importantly however, they are magnetically diverse. BCP's are well-known for forming uniform structures of various morphologies including lamellar films, gyroids, micelles and vesicles. Using these properties, a block copolymer with one positively charged block and one neutral block has been selected to encapsulate POMs in the cores of micelles for ordering on a substrate.



Block Co-polymer
Poly(styrene-block-N-4, methyl vinylpyridine methyl iodide)

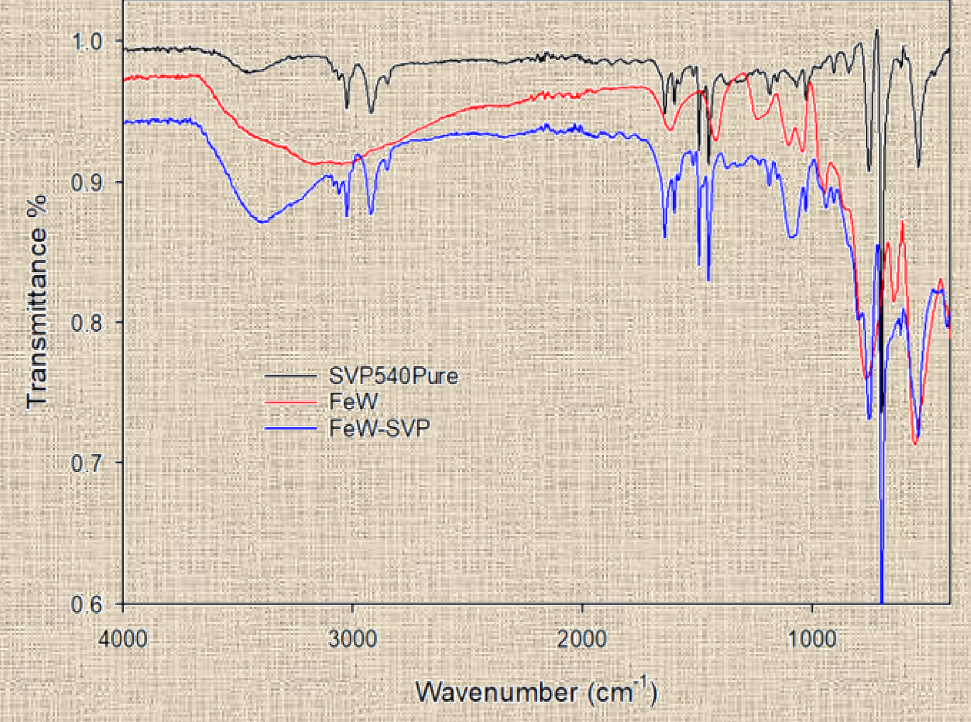
POM encapsulation by a BCP in the core of a micelle

NMR – Evans Method



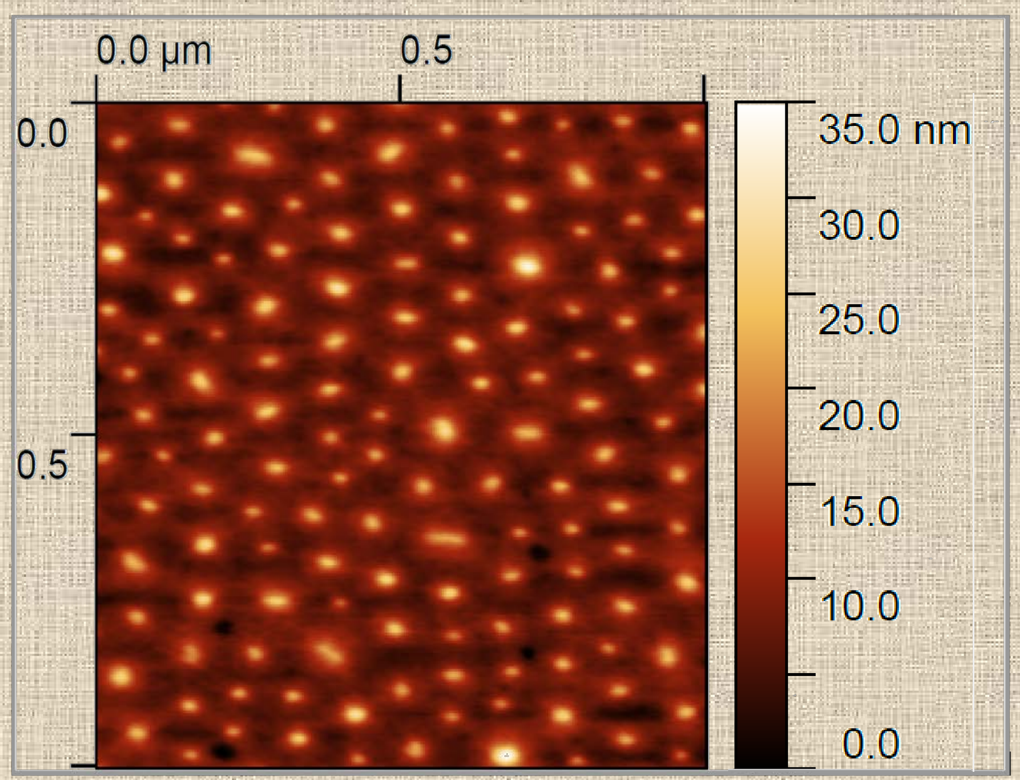
The magnetic properties of POM's are diverse, and can be explored with an NMR based technique. An NMR tube is filled with a reference solution containing a reference compound (DSS). A smaller tube is then inserted, containing the same solution, but also containing POMs. A spectrum is taken of the combined system, the DSS reference peak as well as a shifted reference peak is obtained. The difference in chemical shift is used to calculate the effective magnetism of the POM.

IR – BCP/POM Binding



Infrared spectroscopy is a simple yet invaluable technique utilized in this project. Above are the IR spectra taken of powdered samples of the BCP (SVP540Pure), the pure POM (FeW), and the combined powder after ion exchange has occurred (FeW-SVP). It can be seen that the combined BCP/POM powder generates a combined IR spectra of the two pure compounds, suggesting that the POMs have been incorporated into the BCP chains.

AFM – Micelle Arrays



Atomic force microscopy is an imaging technique that primarily provides surface topography of a material. Equipped with scanning probe cantilever, it is possible to produce images with atomic resolution. This image shows an ordered array of micelles spin-coated onto a silicon wafer after the outlined formation of composite micelles above. From this image the degree of ordering and size of the micelles can be observed.

Conclusion

The fabrication of POMs and their magnetic characterization with the Evans method has been successful in evaluating how well they respond to an external magnetic field, and give an idea on how they may be used in the fabrication of magnonic crystals. Combining POMs with BCPs has been shown promise in successful binding with IR, followed by the relatively ordered arrays of micelles.

Future Work

As this project is still early in development there is still much testing and characterization to be done. Techniques like transmission electron microscopy, energy dispersive X-ray spectroscopy, and magnetic force microscopy will provide insight as to how ordered the POMs are in the micelles. Whereas techniques including SQUID, electron paramagnetic resonance, and ferromagnetic resonance will provide the details as to how these systems will respond as magnetic waveguides.

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