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Crystallization at Droplet Interfaces for the Fabrication of Geometrically Programmed Synthetic Magnetosomes

Matthew Gromowsky
University of Nebraska-Lincoln, mgromowsky@huskers.unl.edu

Michael Stoller
University of Nebraska-Lincoln, stoller04@gmail.com

Maddee Rauhauser
University of Nebraska-Lincoln, maddeer402@gmail.com

Marcus Judah
University of Nebraska-Lincoln, mleejudah@gmail.com

Abhiteja Konda
University of Nebraska-Lincoln, abhiteja@huskers.unl.edu

See next page for additional authors

Authors

Matthew Gromowsky, Michael Stoller, Maddee Rauhauser, Marcus Judah, Abhiteja Konda, Christopher Jurich, and Stephen Morin

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Matthew Gromowsky,[1] Michael Stoller,[1] Maddee Rauhauser,[1] Marcus Judah,[1] Abhiteja Konda,[1] Christopher Jurich,[1] Stephen Morin[1,2]

[1]Department of Chemistry, University of Nebraska - Lincoln, Lincoln, NE 68588

[2]Nebraska Center for Materials and Nanoscience, Lincoln, NE 68588

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Introduction

- Biomineralization provides, through the precise growth of inorganic materials, functional capabilities (e.g., structural rigidity or orientation sensing) vital to the host organisms.[1]
- Mimicking the **complex products observed** in **biomineralization**, including **the magnetosomes of magnetotactic bacteria**, is challenging using synthetic systems, but such mimicry would provide routes toward useful materials with applications in areas such as **drug delivery** and **microfluidics.**
- A variety of inorganic materials were able to be **formed on the boundary** between aqueous droplets, including **Synthetic Magnetosomes** (SMs).

Approach

- **Hexadecane oil** was mixed with **asolectin,** a lipid found in soybeans, to form the continuous phase
- Two aqueous phases were prepared, one containing NH_4OH, and the other containing $FeCl_3$ and $FeCl_2$.
- Droplets of both aqueous phases were placed in the continuous phase, where a **lipid monolayer** would **form surrounding the droplets**.
- When placed in contact, a **droplet interface lipid bilayer** (DIB) **formed at the contact site**, allowing small, uncharge**d particles** such as ammonia and water to **pass through to the other droplet.**[2]

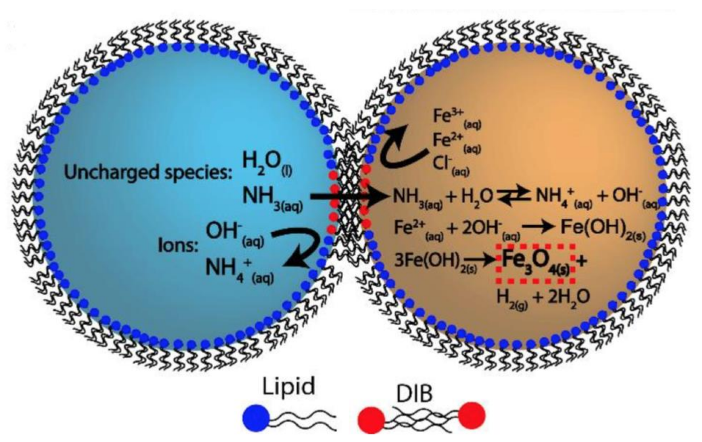

Figure 1. This represents the environment found when an iron (II,III) chloride droplet comes into contact with an ammonium hydroxide droplet. It also shows the chemistry needed for the production of magnetite.

Formation of Synthetic Magnetosomes

- Ammonia selectively diffuses across the DIB.
- As $Fe^{2+/3+}$ concentration varies, different growth behaviors are observed with **boundary-confined growth occurring** at a **75 mMol concentration.**
- Electron diffraction ring pattern indicates magnetite was formed.
- **Magnetite growth** on droplets could be **patterned, selectively,** with different contact sites.

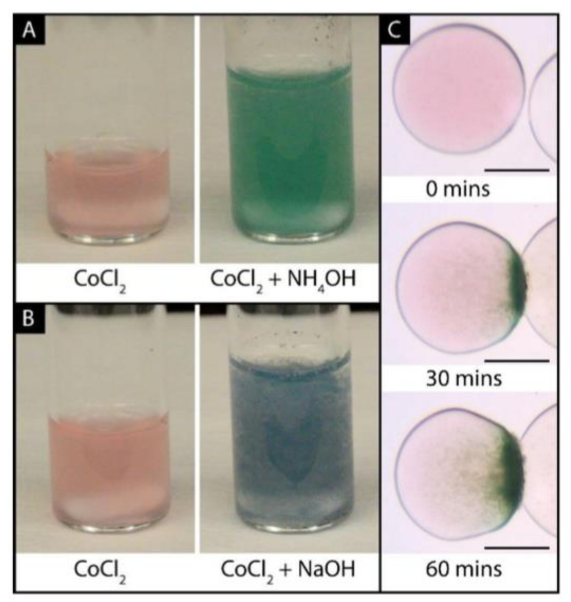

Figure 2. A cobalt control was used to ensure that ammonia was crossing from one droplet to the other. The green color seen in A indicates ammonia transport occurred in the trial shown in C.

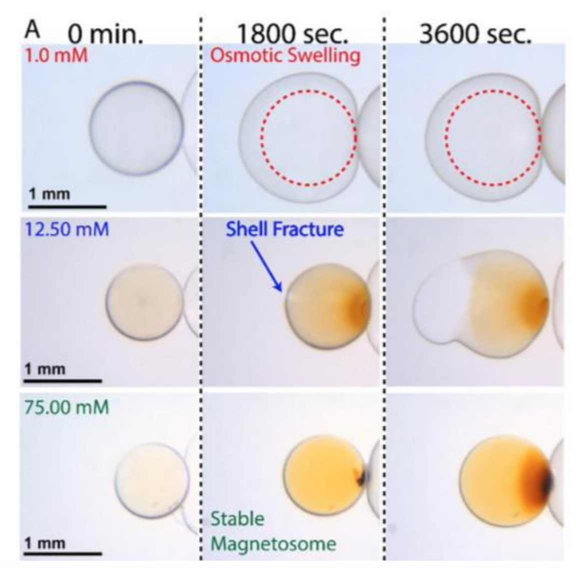

Figure 3. A matrix showing the effect of different concentrations of $Fe^{2+/3+}$ in contact with NH_4OH.

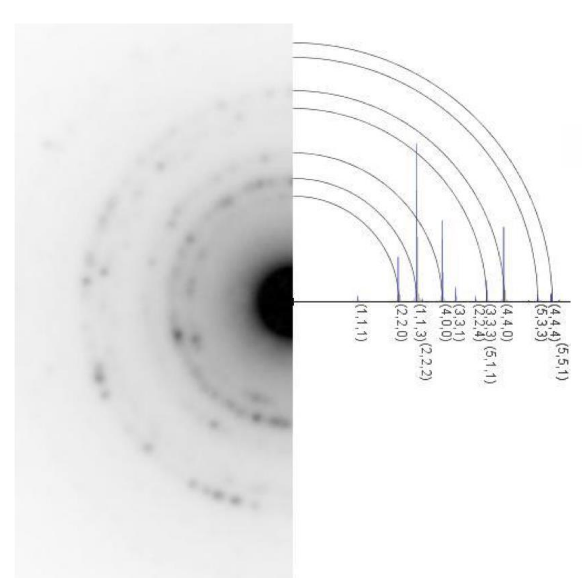

Figure 4. The left image is the electron diffraction ring pattern of magnetite particles collected from one of the droplet experiments. The right is the simulated electron ring of magnetite.

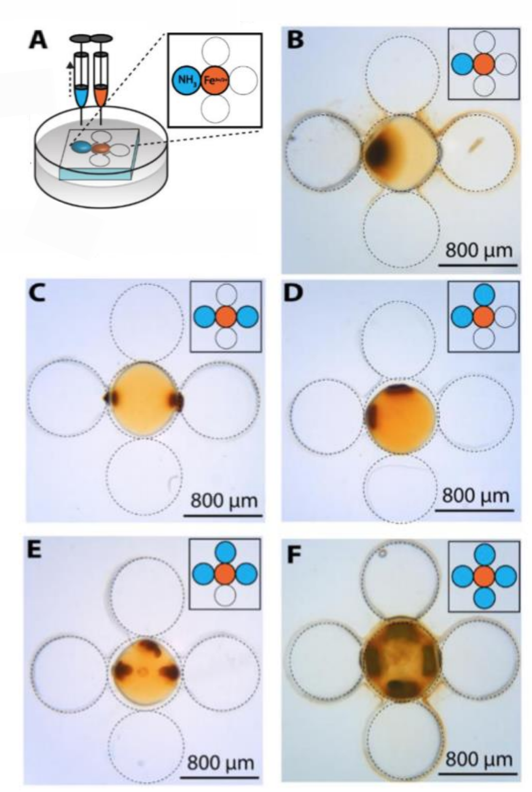

Figure 5. 75 mMolar iron droplets are able to be patterned in contact with 50/200 NH_4OH

Magnetic Properties

- SMs can be **manipulated** by a **magnetic field.**
- SM **polarization** and **growth patterns** can be **programmed using external magnetic fields**.
- **SMs** synthesized outside of a magnetic field **aligned** at a rate **indicating magnetic polarization**.

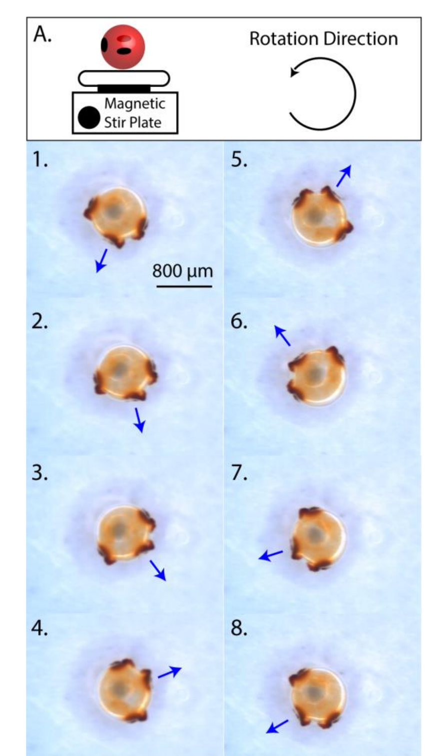

Figure 6. A SM being rotated on a stir plate.

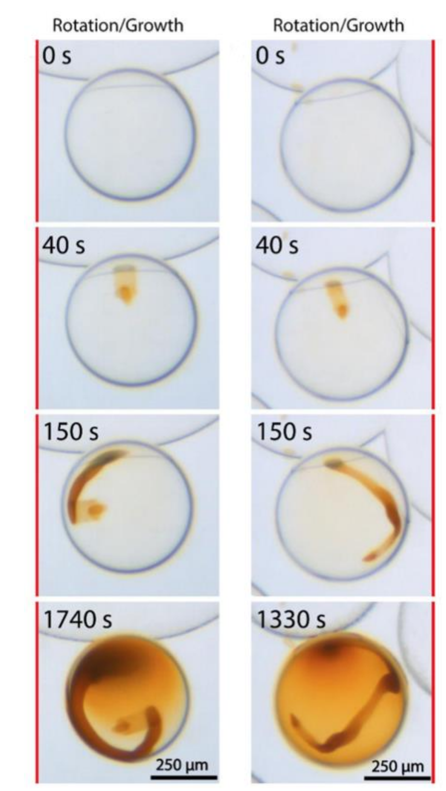

Figure 7. SM growth manipulated by a magnetic field.

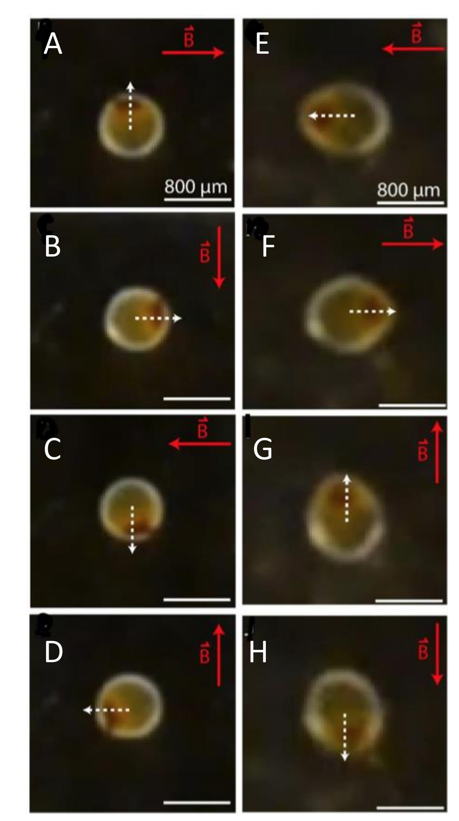

Figure 8. A-E show the orientation of rotating SMs synthesized without magnetic field. E-H show the orientation of rotating programmed SMs grown in magnetic field.

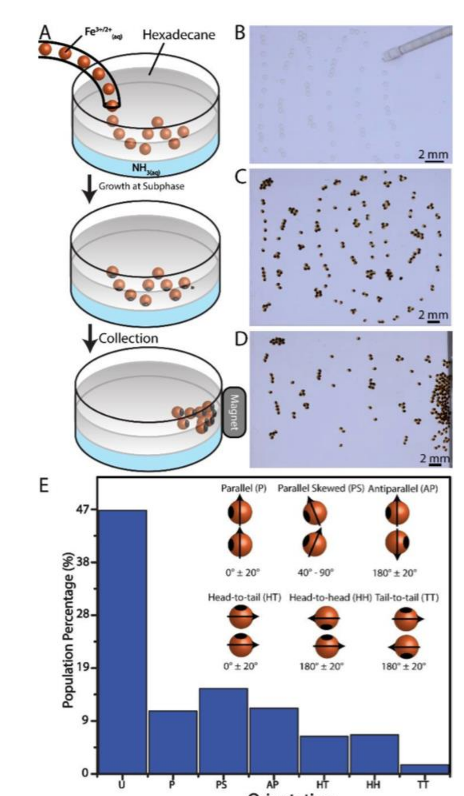

Figure 9. A shows a method of mass producing SMs. B, C, D show random dispersal of droplets. E indicates the orientation is non-random and indicate magnetic polarization.

Conclusions/Future Directions

- We were able to **produce programmable magnetite** in **aqueous droplets**.[3]
- The **synthetic magnetosomes** are **naturally polarized** in a direction perpendicular to the point of growth.
- Due to the magnetic properties, a variety of applications exist.
- We will continue investigating mineral systems with similar properties, such as magnesium salts

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