Magnetic Structure of Iron Oxide Nanoparticles Using PSANS

David Bordelon, Liwei Huang, Roberto Olayo-Valles, Catherine Rastovski, Jennifer Shih, Roland Stone
Background

- Iron Oxide Magnetic Nanoparticles (IOMNPs) can be heated via alternating magnetic field in an induction coil.

\[ V(\text{AC}) \]

- Heat applied to cancer cells can have a substantial therapeutic effect.
- Heat may sensitize cancer to radiation therapy and/or chemotherapeutic agents.
Heat Generation is measured for various nanoparticles as the SAR (specific absorption rate) measured in W/g(Fe).

For clinical application high heat output is desirable.

Particle heat output curves vary depending on the particle properties and magnetic field strength.

What particle properties influence the heat generation?
Iron Oxide Nanoparticle

- Iron Oxide Core
- Physisorbed Dextran Shell, (MW = 40,000) shell, (branched polysaccharide)
- Aqueous solution
- Polydispersity (DLS) of ~30%
Motivation

- Use SANS to look at nm shell structures
- Good contrast between H$_2$O and Fe$_3$O$_4$ (-0.52e -6 vs. 6.91e -6 A$^{-2}$)
- D$_2$O is a good contrast match to core—lets us see the shell (6.32e -6 vs. 6.91e -6 A$^{-2}$)
- Contrast matching the core yielded a different structure at high Q.
- Nuclear scattering was reduced by contrast matching.
- To determine if the scattering is from the magnetic core or the dextran, PSANS measurements are necessary.
Experimental Design

Things to consider
- Decay of $^3$He
- Polarization corrections

Measurements
Background corrections
- Open Beam
- Empty Sample Holder
- Blocked beam

Scattering of Sample
- $\uparrow\uparrow, \downarrow\downarrow, \uparrow\downarrow, \downarrow\uparrow$

Polarization Efficiencies
- Open beam with/without $^3$He
- Polarized beam, no sample, $\uparrow\uparrow, \downarrow\downarrow, \uparrow\downarrow, \downarrow\uparrow$
- Polarized beam with beam block

Polarization Efficiencies
- $P_{^3\text{He}} = 0.974$, at start time
- $P_{SM} = 0.865$
- $P_F = 0.910$
PSANS 2D Intensity Data

\[ N^2 + M_y^2 - 2NM_Y \]

\[ N^2 \]

\[ M_X^2 + M_Z^2 \]

\[ M_Z^2 \]

\[ N^2 + M_y^2 + 2NM_Y \]

\[ N^2 \]

\[ M_X^2 + M_Z^2 \]

\[ M_Z^2 \]
Isotropic Magnetic Scattering
Comparison of Polarized and Unpolarized Beams
Sphere Fit

\[ R_G = \sqrt{\frac{3}{5}} R = 8.5 \text{nm} \]
Cylinder Fit

\[ L = 30.2\, \text{nm} \]
\[ R = 5.7\, \text{nm} \]

\[ R_G = \sqrt{\frac{R^2}{2} + \frac{L^2}{12}} = 9.6\, \text{nm} \]
Conclusions

- There is magnetic scattering from the core

- PSANS allows us to separate the nuclear scattering from the magnetic scattering

- The magnetization is isotropic

- There is some magnetic structure (~10 nm) smaller than the core (~50 nm)
Kathryn Krycka, Liwei Huang, David Bordelon, Jennifer Shih, Roland Stone, Catherine Rastovski, Roberto Olayo-Valles, Andrew Jackson
Special Thanks

Andrew Jackson, Kathryn Krycka,
Cindi Dennis, Cedric Gagnon, David Mildner,
and Paul Butler