Chemical Engineering & Materials Science
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The effect of the alcohol, iron salt species on the shape, homogeneity and magnetic properties of silica nanorods

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Abstract

A polymer's macroscopic properties can be manipulated and enhanced using nanoparticles.[1] Shear, magnetic and electric fields can further increase this enhancement to improve the polymer's tensile strength, thermal and electrical conductivity, as well as color and optical activity.[1] The use of thermo-responsive polymers with nanorods allows the researcher to control and manipulate these macroscopic properties and introduce complex flow and optical properties. This serves as a basis for flexible electronics which have grown in popularity and relevance in recent years.

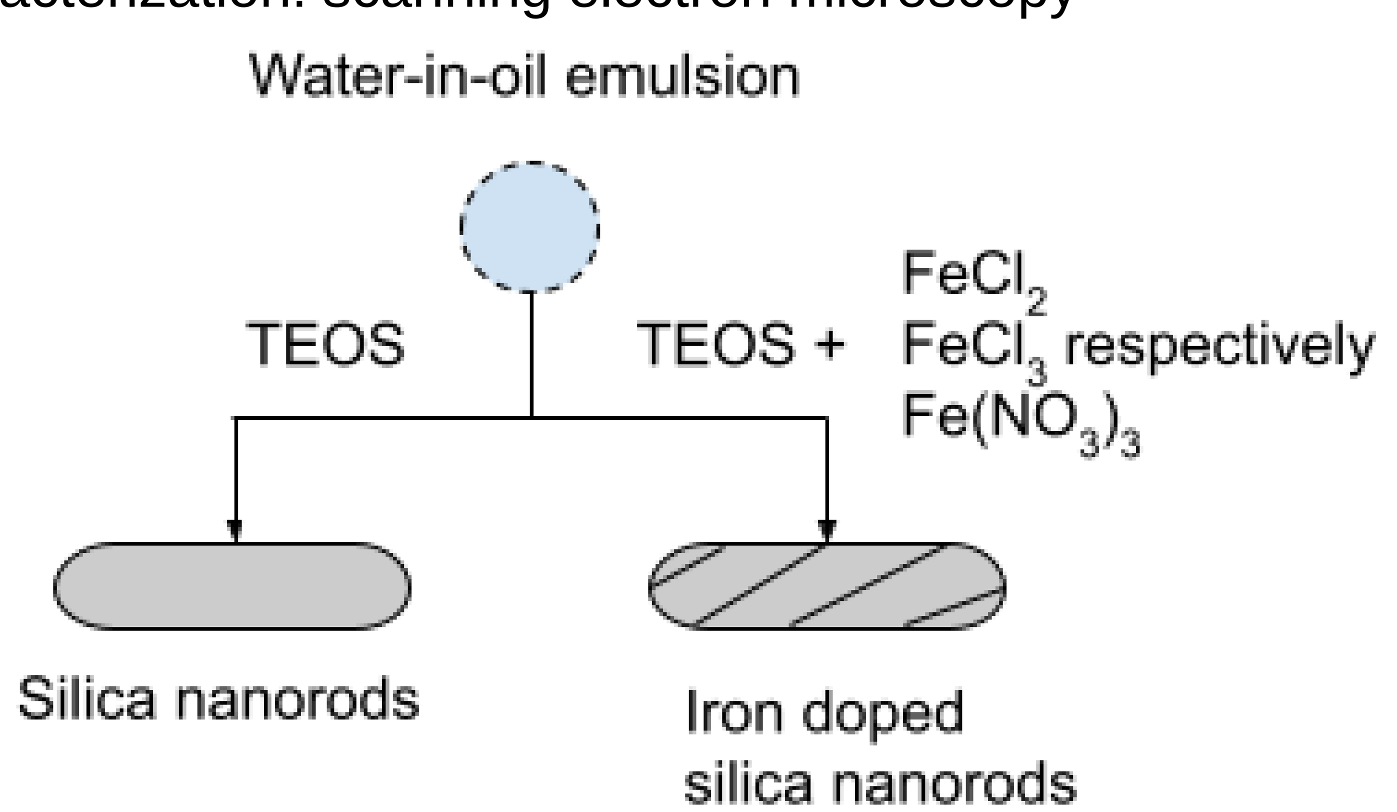
Motivation

Purpose: synthesize silica nanorods with various aspect ratios, determine how shape, concentration and iron content of the nanorods can be controlled

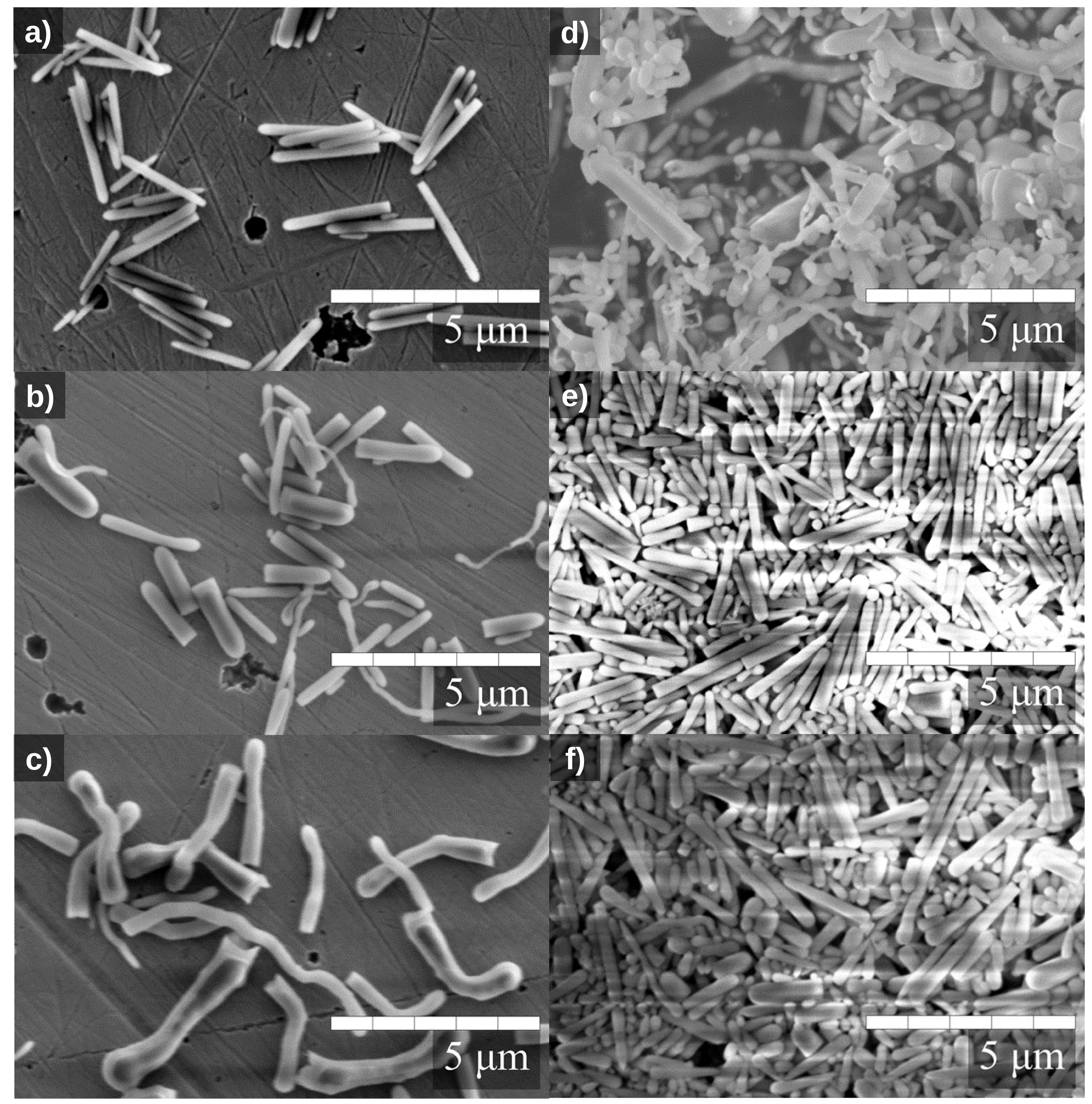
- Benefits of silica nanorods:
  - Anisotropic shape
  - Inert to many materials
  - Silica abundant
  - Controlled shape, size
  - Influence sample prop's
  - Common in literature
  - Cheap to synthesize

Nanoparticle synthesis

- Stöber process: tetraethyl orthosilicate (TEOS) is crosslinked in a water-in-oil emulsion into finely tunable sizes and shapes.[2]
- Synthesis of iron doped nanorods: inclusion of iron salts where small amounts of iron are doped and can cause the nanorods to react to magnetic fields. [3]
- Characterization: scanning electron microscopy

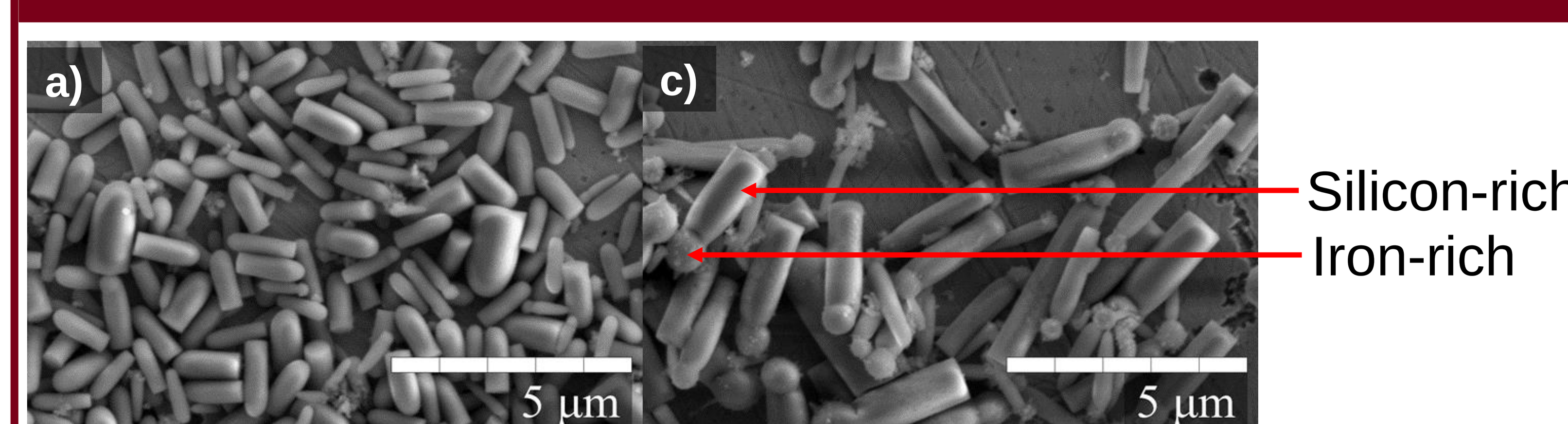


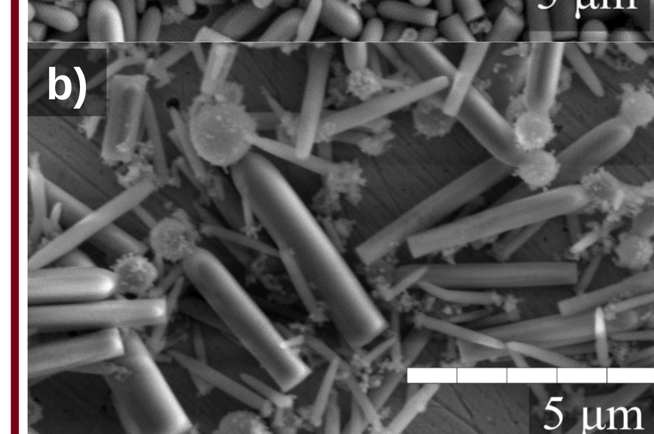
Results from varying alcohol mixtures



Scanning electron microscopy for nanorods synthesized from a) pure pentanol, and 1:4 ratio alcohol mixtures of b) ethanol to 1-pentanol, c) 1-propanol to 1-pentanol, d) 1-butanol to 1-pentanol e) 1-hexanol to 1-pentanol, f) 1-octanol to 1-pentanol

Results from iron doping

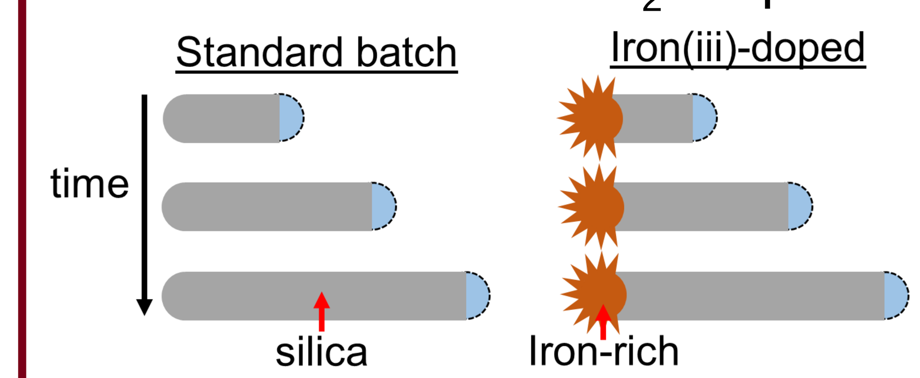




Scanning electron microscope for 1.0%-by-mass doped nanorods with a) iron (III) chloride b) iron (III) chloride and c) iron (III) nitrate

Discussion

- Nanorod homogeneity affected by alcohols
- Nanorod structure instability for short chain alcohols
  - stability increases as alcohol carbon chain increases
- Increase in diameter from nanorods made from pure ethanol
- Iron-rich portions seen on $FeCl_3$, $Fe(NO_3)_3$ nanorods
  - Enrichment seen on initiation side of nanorod
  - None seen in $FeCl_2$ -doped nanorods



(left) Iron-rich spiked area seen on curved (initiation) side of nanorod, indicating early reaction

- Silica nanorods grow from curved-end to flat end
  - Spikiness on curved end indicates early reaction of iron
- Rate of iron-deposition > rate of silicon-deposition

Future Work

- Controlled iron-species addition to control reaction rate
- Use rheology to characterize the flow properties, such as viscosity, of nanorod-polymer mixtures
- Vibrating sample magnetometry to characterize magnetic properties of the iron doped samples
- X-ray diffraction to determine crystal structure

References

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