Thermal conductivity and heat generation in magnetite nanofluids

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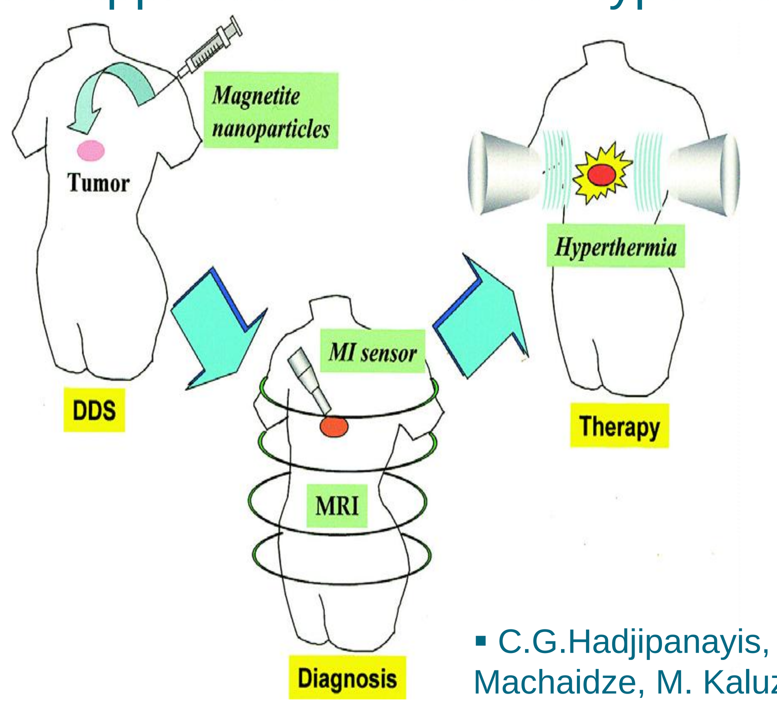
Introduction

- Nanofluids are suspensions of nanoparticles in a liquid media; they have applications in cooling or solar collectors
- Nanofluids transport properties are not fully understood
- *Magnetic* nanofluids use magnetic nanoparticles. In an alternating magnetic field (AMF) they generate heat. They have applications in cancer hyperthermia:



▪ C.G.Hadjipanayis, R. Machaidze, M. Kaluzova, et al. Cancer res. 75(2010) 6303

Objectives

- Systematic investigation of transport and heat dissipation properties of magnetic nanofluids:
  - Thermal conductivity (k)
  - Specific absorption rate (SAR) in AMF
  - Viscosity
- Understanding the effect of concentration on these properties
- k: some disagreement in the literature between experimental data and prediction
- SAR: limited data exist on concentration effect

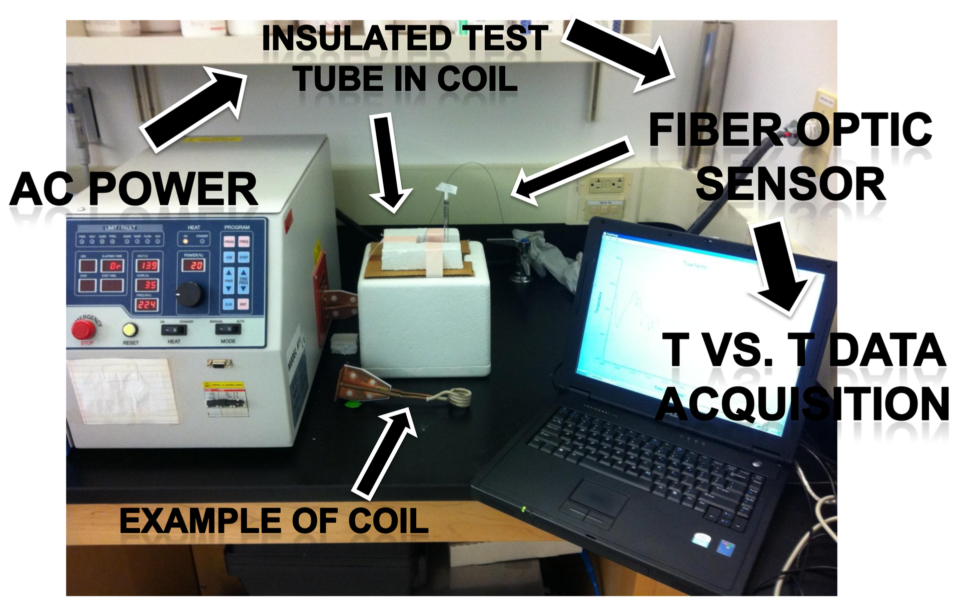
Methods

Coil setup for measuring specific absorption rate:

1. AC magnetic field produced with constant current around test fluid
2. Temperature of fluid recorded as function of time
3. Specific absorption rate calculated from equation

$$SAR = \frac{c_{lq}m_{lq} + c_{np}m_{np}}{m_{np}}\left(\frac{\Delta T}{\Delta t}\right)_{\Delta t \to 0}$$

Eq. 1: c: specific heat; m: mass; (lq): carrier fluid; (np): magnetic nanoparticles; T: temperature; t: time



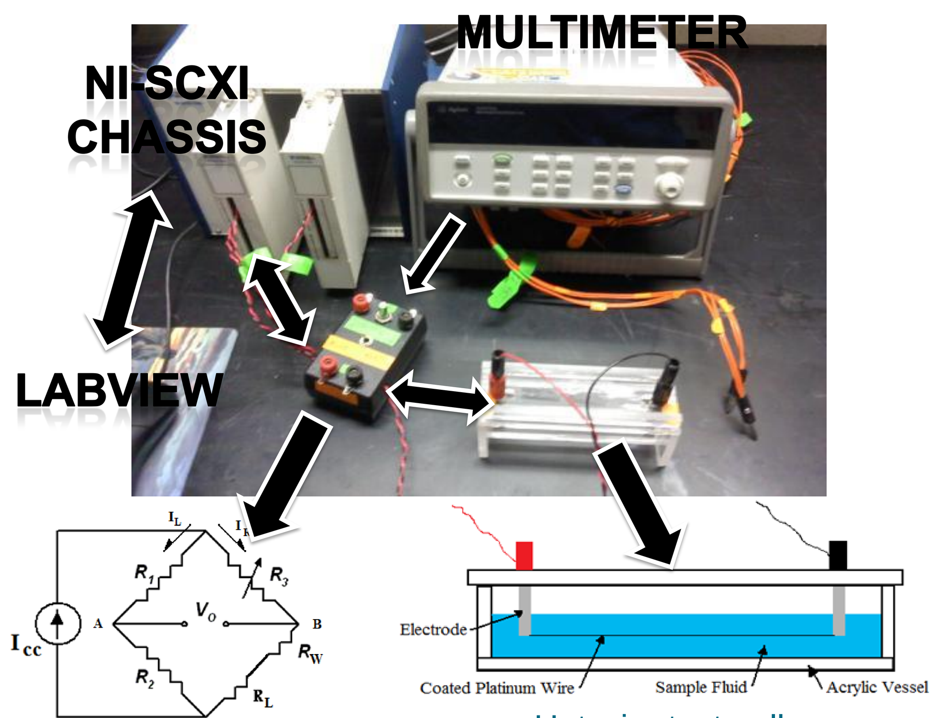
Experimental apparatus

Transient hot wire method to measure thermal conductivity:

1. Voltage is passed through a wire at constant current
2. Change in resistance of wire determines its change in temperature based on TCR
3. Change in temperature of wire depends on fluid thermal conductivity

$$k = \frac{Q}{4\pi L} \Big/ \frac{d\Delta\bar{T}}{d\ln t}$$

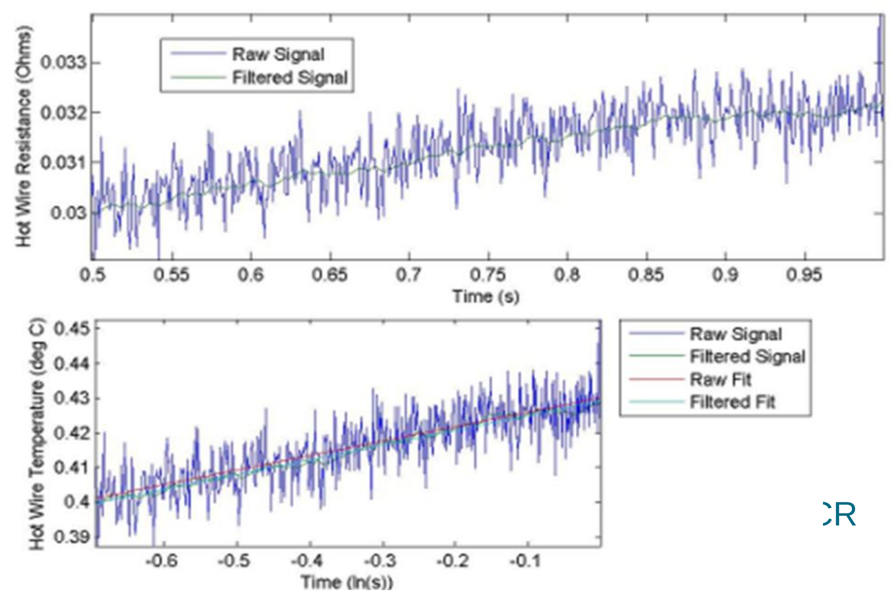
Eq 2: Q: total power consumed by the wire; L: is the length of the wire; Last term: determined from plot of T vs. ln(t)



Wheatstone Bridge

Hot wire test-cell

Thermal K Reading



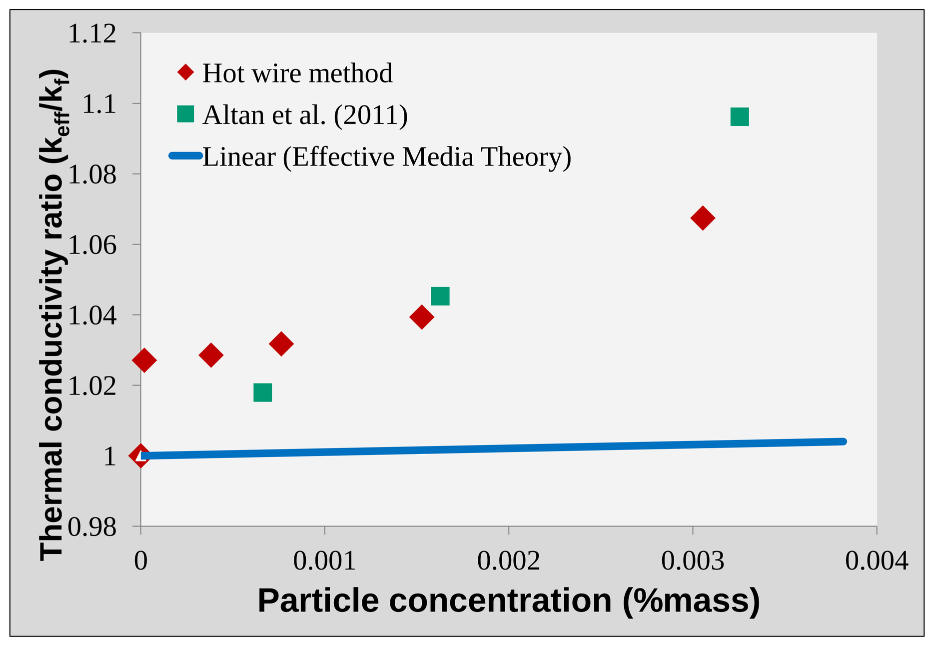
- TCR determined experimentally
- Data acquired for 1.5 s, data from 0.5 to 1 s used for calculations

Calibration:

Fluid	Exp. (W/mK)	Theor. (W/mK)	% Error
ethanol	0.167414	0.171	-2.10
methanol	0.20261	0.207	-2.12
hexane	0.119786	0.124	-3.40

Results

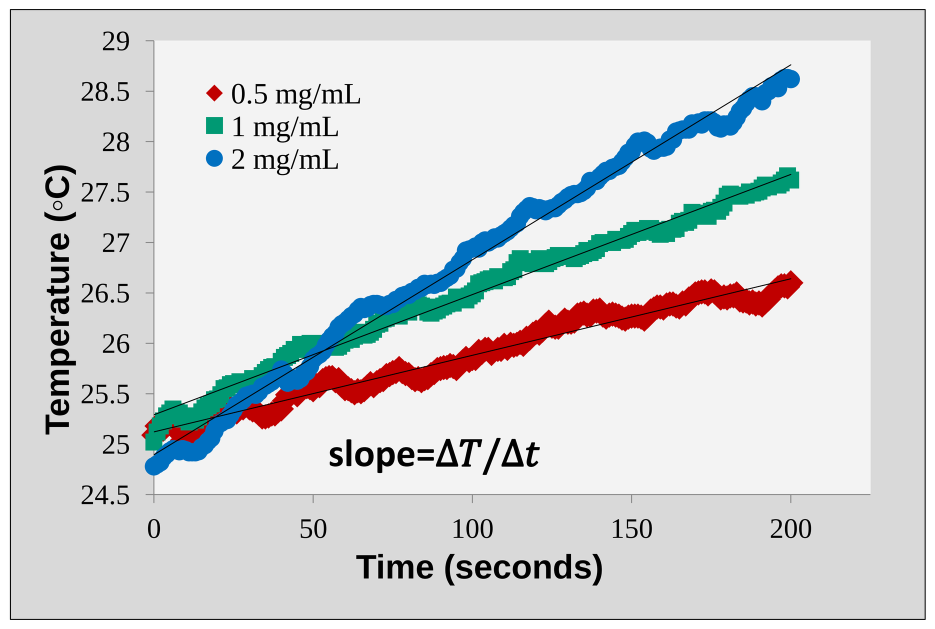
Thermal Conductivity



- Hot wire method: significant jump with the addition of a small amount nanoparticle to solvent
- Literature exp. data (using commercial instrument) suggests a linear trend , agreeing with trend of math model
- Theory does not consider agglomeration or particle movement

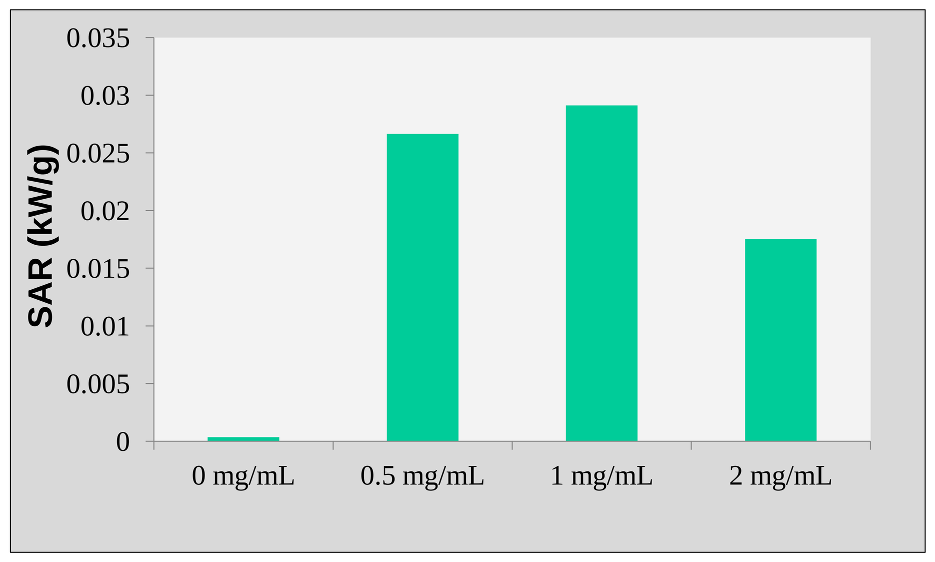
Results

Temperature Change



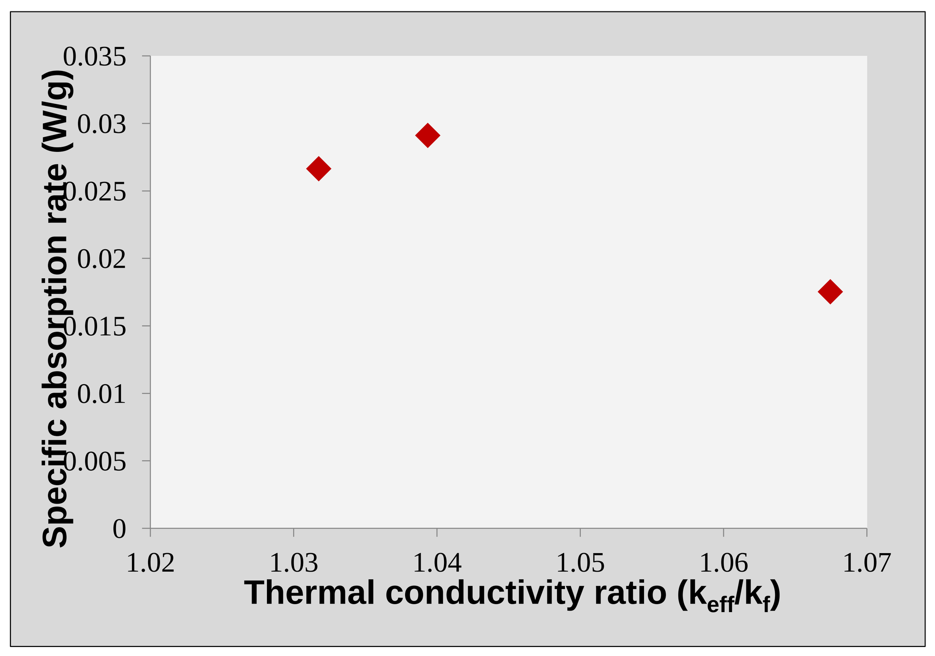
- Increase in heat generation for higher concentrations, as expected

Specific Absorption Rate



- Increase in SAR for low concentrations

Thermal Conductivity vs. Specific Absorption Rate



- At high concentrations, k increases, increasing heat losses which could result in a smaller measured SAR

Conclusions

Non-linear trend of k at low concentrations, increase in SAR with lower concentrations, and higher SAR at lower k for low concentrations

For the future: lower concentrations for k to see how trend continues, SAR tests at lower concentrations, and viscosity measurements to relate to k and SAR

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