Herrick Laboratories PURDUE UNIVERSITY

2016 Purdue Conferences
Compressor Engineering
Refrigeration and Air Conditioning
High Performance Buildings

Use of Nanoparticles In Refrigeration Systems: A Literature Review Paper

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Center for High Performance Buildings at Purdue

Presentation Overview

- Historical Developments
- Nanofluids vs Normal Suspensions
- Nanoparticles & Production Techniques
- Nanoparticle Selection
- Nanofluid Preparation
- Nanofluids for Refrigeration & Benefits
- Limitations of Nanofluids
- Literature Review
- Limitations of Literature Review & Literature
- Future Directions & Publication Checklist
- Conclusion

Historical Development

Thermal Conductivity (K)

$K_{(Metal\ \&\ Metal\ Oxides)} > K_{(Liquids)}$

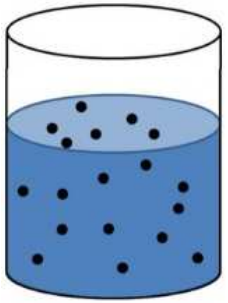
For Heat Transfer Improvement

Maxwell :(1873)	Choi :(1995)	(2016)
Normal Suspensions	Nanofluids	Many paper are published every year
(Metal particles + Liquid)	(Nano particles + Liquid)	
‘mm ’ size particles	‘nm’ size particles	

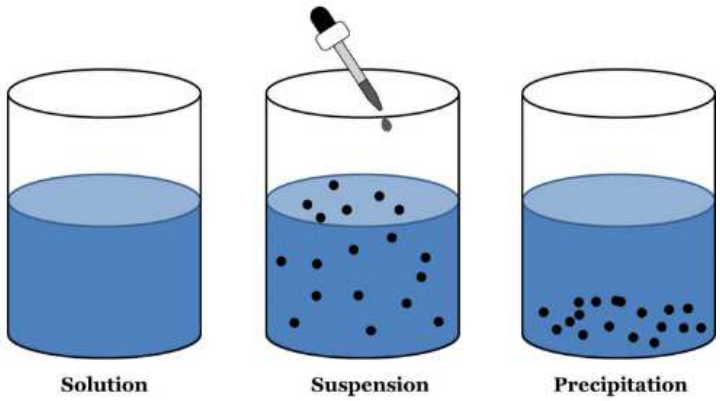
Nanofluids Vs Normal Suspensions

Nanofluids have

- Higher heat transfer rates
- Better dispersion stability
- Reduced particle clogging
- Reduced pumping power



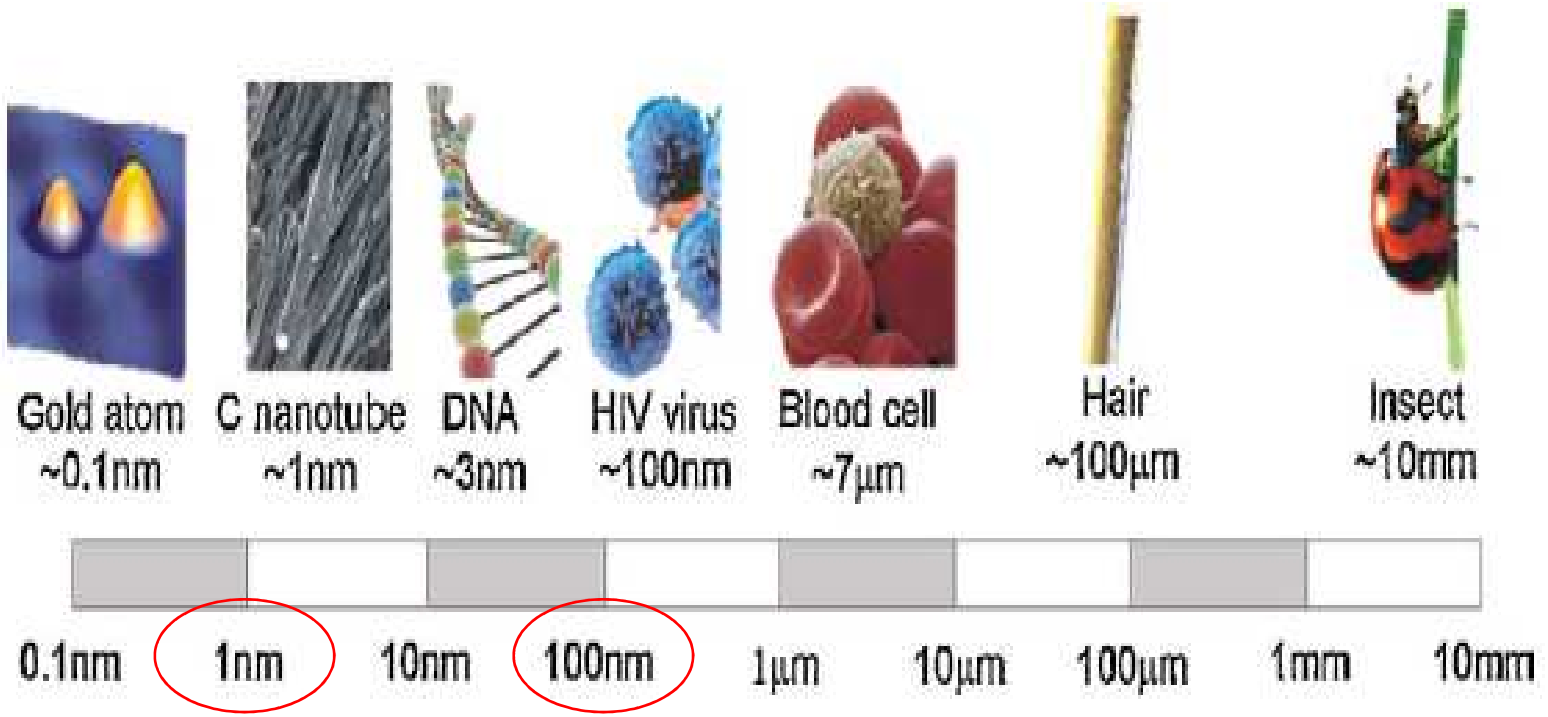
Nanofluid



Normal Suspension

Nanoparticles

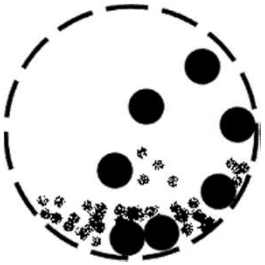
(1 nm < NP Size < 100 nm)



Length scale & some related examples

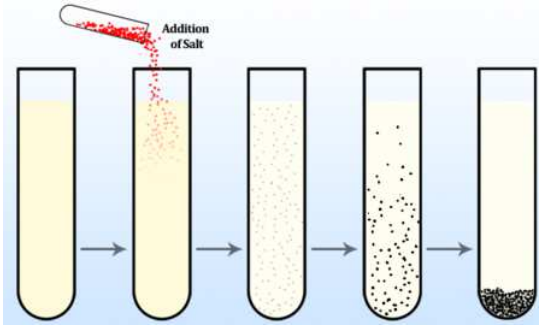
Nanoparticles Production Techniques

- Mechanical attrition



- Pyrolysis

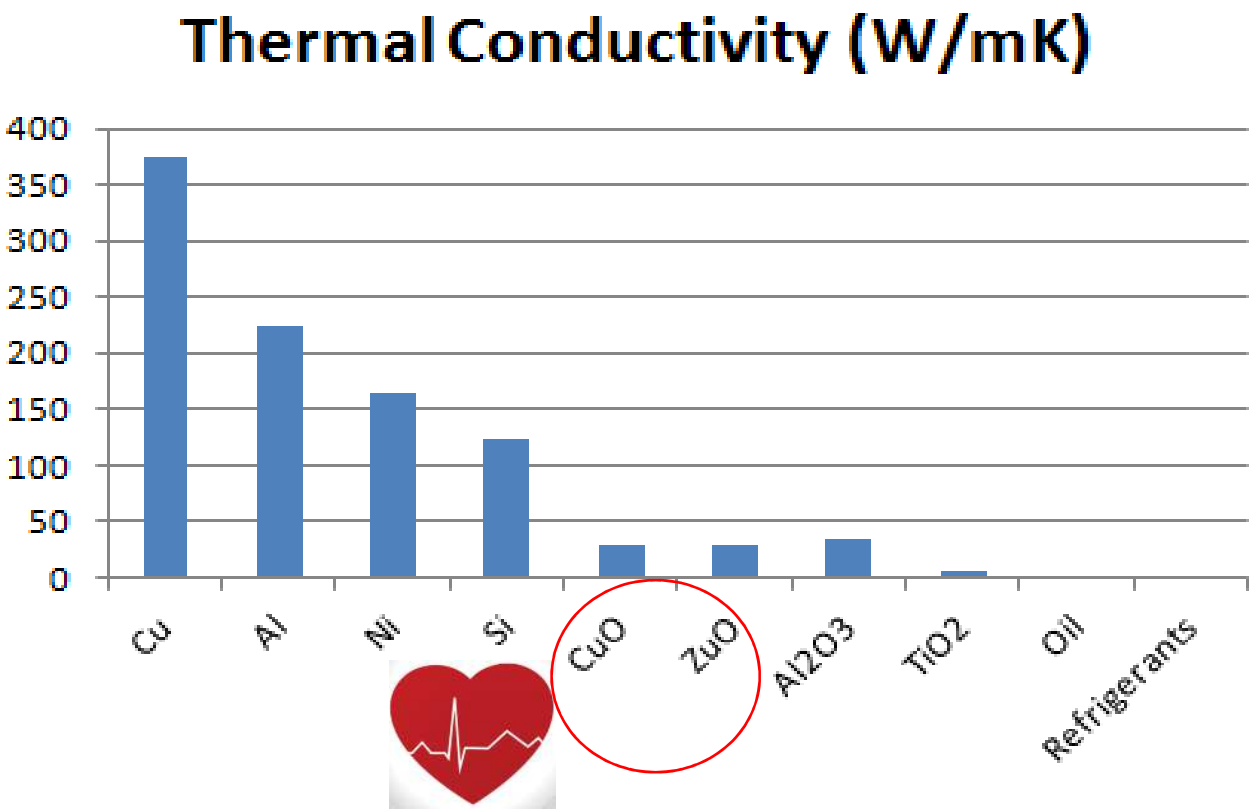
- Gas condensation
- Chemical precipitation



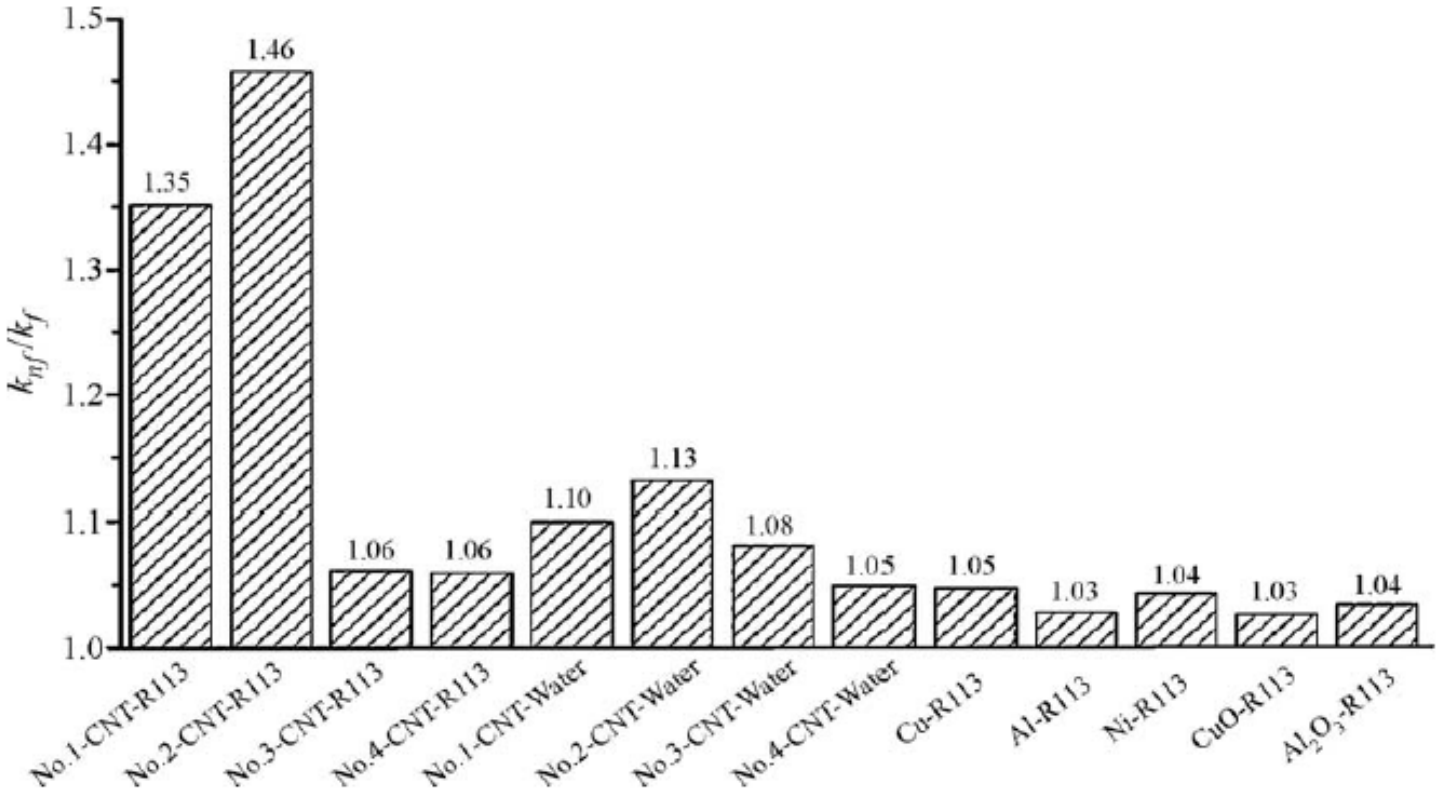
Nanoparticle Selection

Carbon Nano Tubes : $1800 < K_{CNT} < 6600$ (W/m k)

Diamond: $2200 < K_{Diamond} < 2300$ (W/m k)



Thermal Conductivity Increase



Thermal conductivity of nanofluid (K_{nf}) & Pure fluid (K_f)

Nanofluid Preparation

Preparation Methods

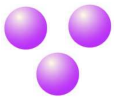
One Step Method / Two Step Method : Nanoparticle Production & Dispersion in one/two steps respectively.

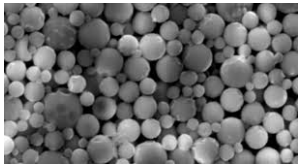
Guidelines for nanofluid preparation

- Dispersability of nanoparticles
- Stability of nanoparticles
- Chemical compatibility of nanoparticles
- Thermal stability of nanofluids.

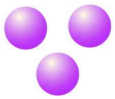
Nanofluids For Refrigeration Systems

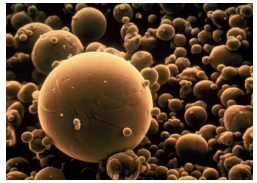
Nanoparticles + Lubricant = Nanolubricant



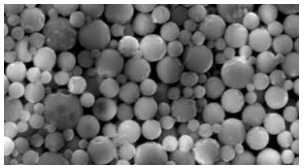


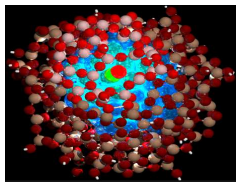
Nanoparticles + Refrigerant = Nanorefrigerant





Nanolubricant + Refrigerant = Nanolubricant _refrigerant





Nanofluid Benefits In Refrigeration

Nanolubricant

- Improved tribological characteristics (Friction & viscosity)
- Improved compressor performance

Nanorefrigerant

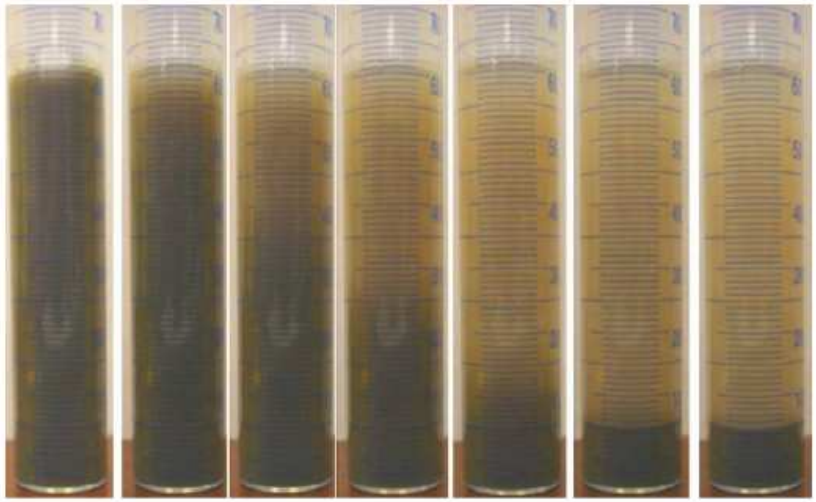
- Improved thermo-physical properties (H/T Coefficient)
- Improved refrigerating effect

Nanolubricant-refrigerant

- Enhanced solubility between oil & refrigerant
- More oil returns back to the compressor

Limitations of Nanofluids

- Poor long term stability
- High pressure drop
- High pumping power
- Low specific heat
- Particle settling
- Fouling
- High production cost

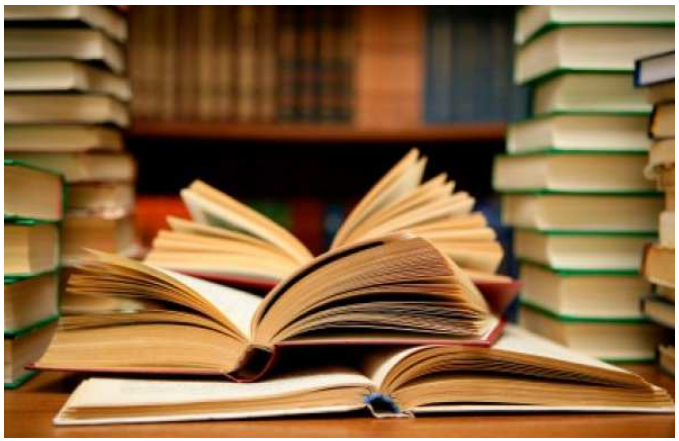


Literature Review

Section one: Basic research

Properties studied are

- Thermal conductivity
- Viscosity
- Heat transfer coefficient
- Friction factor

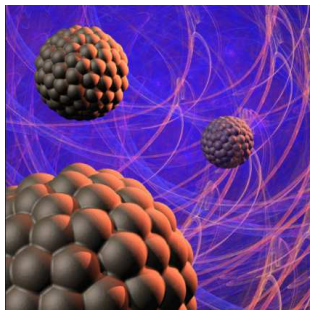


Section two: Applied research in refrigeration system

Literature Review

With use of nanoparticles most papers show

- Increase in heat transfer coefficient & thermal conductivity
- Reduction in friction factor
- Increase is viscosity & pressure drop
- Improvement in coefficient of performance



With use of nanoparticles small number of papers show

- Decrease in heat transfer coefficient

Literature Review

Comments

- Research is in its primitive stage, large research is possible
- Synchronization between basic & applied research is needed
- Publication checklist is needed to compare different results
- Mixed (Positive & Negative) results are observed.
- Most of the literature shows improvement in heat transfer & coefficient of performance with use of nanoparticles

Limitations of Literature Review

- Need to find nanofluid with continuous dispersion stability through out refrigeration system.
- Nanofluid preparation method, sonication time durations needs to be specifically mentioned in the papers.
- Nanoparticle migration studies in evaporator are limited & no such study in condenser is yet published.
- Basic properties of nanofluids like latent heat, specific heat, density, surface tension, dielectric strength, miscibility, & solubility also needs to be investigated.

Limitations of Literature

- Nanofluid containing mixture of different types of nanoparticles is not published yet.
- Industrial refrigeration systems are not yet studied.
- Screw & centrifugal compressors, shell & tube and plate type heat exchangers are not yet studied.
- Flooded evaporators are not yet studied.
- Natural refrigerants like ammonia are not yet studied.
- More focus also needs to be given on flow boiling with and without lubricants.

Future Research Directions

- Cover the limitations of literature & literature review
- Data base with number of investigations needs to be created
- Checklist while publishing research is provided to compare results between different papers
- Interdisciplinary study approach may help to develop better prediction methods useful for basic research

Checklist For Publications

- Nanoparticle/s
- Size (dry & in fluid)
- Base fluid (refrigerant/ lubricating oil/ other)
- Nanoparticle concentration (in mass/ volume basis in lubricant, refrigerant & in refrigerant-lubricant)
- Nanofluid preparation method
- Dispersion stability duration
- Are experimental tests performed with stable dispersion?
- Details (name, type, quantity) of surfactants/ dispersants
- Details of sonication time and dispersion method used
- Experimental/test conditions.

Conclusion

Opportunities	Challenges
• High heat transfer rate	• Poor long term stability
• High coefficient of performance	• High pressure drop
• Small refrigeration systems	• High pumping power
• Light refrigeration systems	• Low specific heat
• Low capital & running cost	• High production cost

For use of nanofluids in refrigeration more research is needed.

Thank You !

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