Thermal Management Using Diamond Nanofluids

Farzin Mashali, Ehsan Languri, Gholamreza Mirshekari

In cooperation with
International FemtoSci Inc.
Dr. Jimmy Davidson
Dr. David Kerns

1. Objectives

- Microstructural characterization of a novel fully functionalized nanodiamond (ND).
- Investigation of nanodiamond additives on thermal conductivity of deionized water (DI).
- Investigation of diamond nanofluid flowing in a closed loop that is destined for cooling of an electronic component.

2. Introduction

Due to continually increasing power of electronic components, an exploration for more efficient heat dissipating system can constitute today a rather challenging task. However, there is an entire different level of concern than just efficiency. There are many cases where transformer failure, due to overheating or related lifetime situations, has been **catastrophic**.

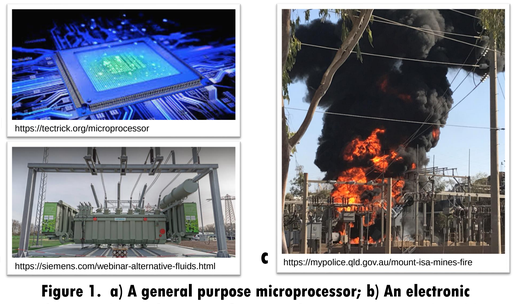


Figure 1. a) A general purpose microprocessor; b) An electronic transformer; c) Transformer explosion at the Mount Isa mine Sep. 2017.

Nanofluids Solution:

Nanofluids are engineered suspensions of nanoparticles in a base fluid, whose thermal properties are interestingly well higher than those of base fluids.

FemtoSci nanodiamond advantages:

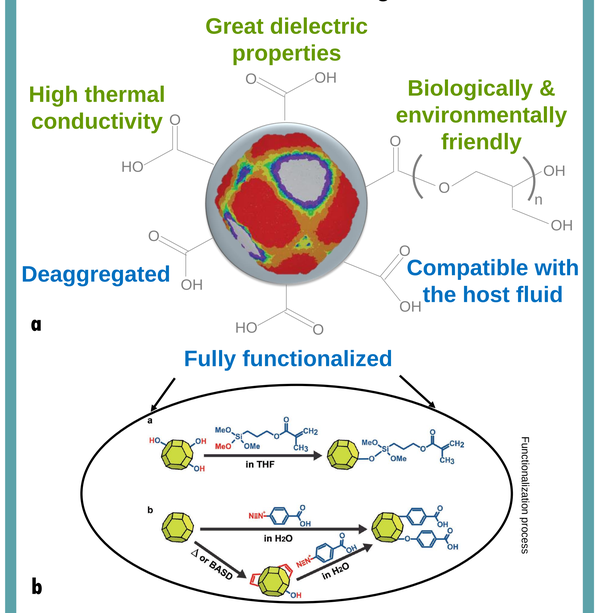


Figure 2. a) Advantages of nanodiamond in general and FemtoSci nanodiamond in particular [1], b) functionalization schematic [2].

4. Results

4.1. Microstructural Characterization

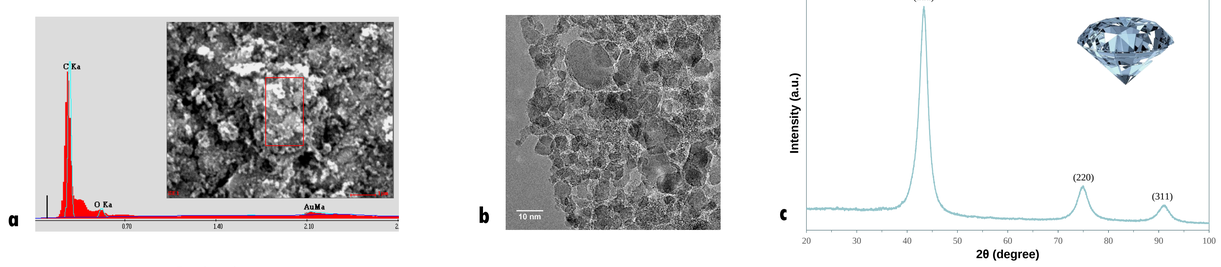


Figure 4. a) EDS analysis of elements in the ND sample; b) TEM image from the nanodiamond sample showing the spherical particles (~ 5nm); c) XRD pattern of nanodiamond sample which is matched with diamond diffractions.

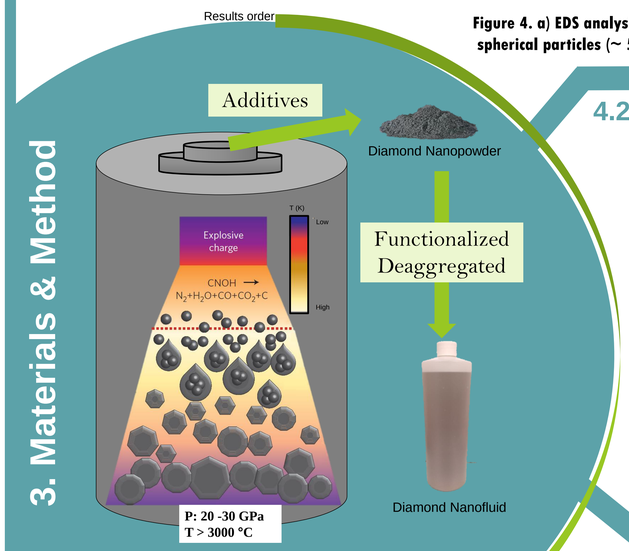


Figure 3. The process of diamond nanopowder and diamond nanofluid production [3].

4.2. Thermal Conductivity

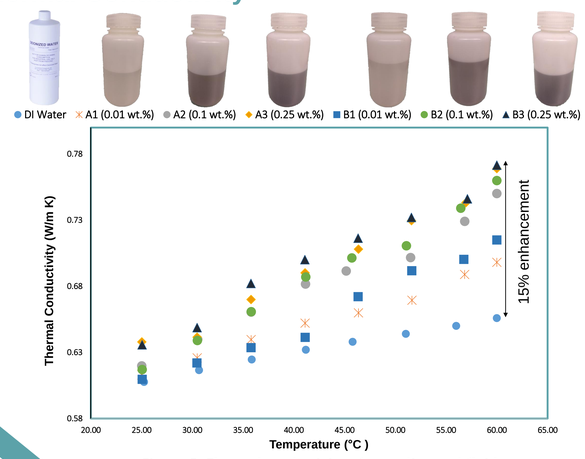


Figure 5. Thermal conductivity of nanodiamond fluid samples in different concentrations and temperatures.

4.3. Heat Transfer Loop

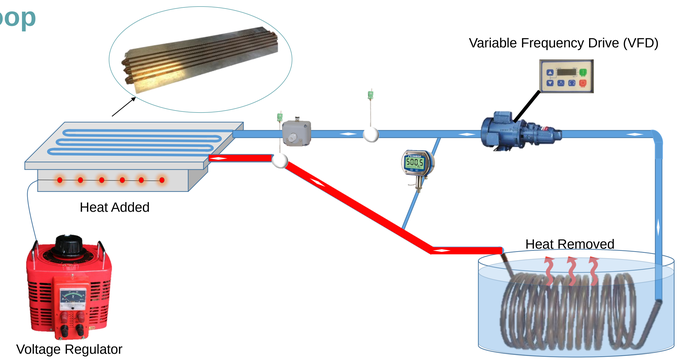


Figure 6. Heat transfer loop schematic, the cold plate is the test section which destines for the heat dissipation electronic component.

4.4. Particle Size Distribution

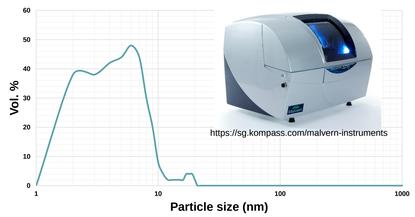


Figure 8. Nanodiamond fluid particle size distribution obtained via dynamic light scattering (DLS) analysis.

4.5. Dynamic Viscosity

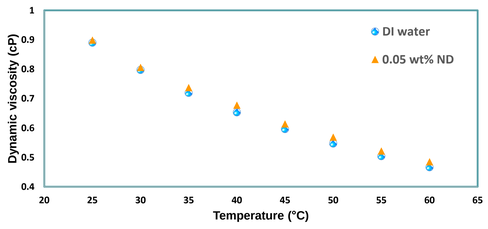


Figure 9. Dynamic viscosity of DI water and 0.05 wt% nanodiamond fluid; the maximum increase in viscosity is less than 4%.

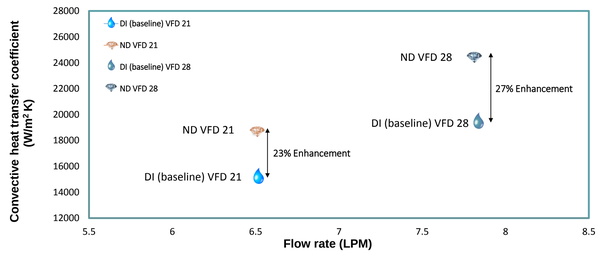
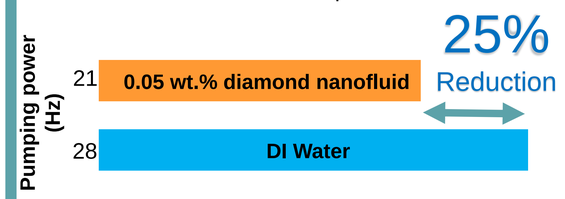


Figure 7. Heat transfer coefficient (h) for DI water and 0.05 wt.% diamond nanofluid in two flow rates.

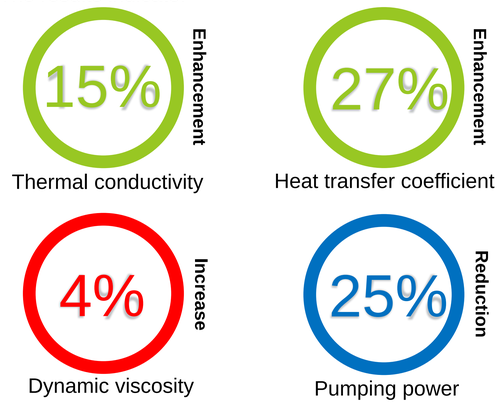
5. Discussion

The EDS, TEM and XRD results confirm that the nanodiamond nanofluids are synthesized and well purified. By adding tiny amounts of diamond nanoparticles to DI water, and with no penalty in the viscosity, significant enhancements in thermal conductivity and heat transfer coefficient are observed compared with other studies. More investigations show that with an equal heat transfer rate (6.4 kW) for water and 0.05 wt.% diamond nanofluid, 25% less pumping power have been used to flow the nanofluid in the loop.



6. Conclusions

The results indicate:



Future work:

The nanofluid will be flowing in the heat transfer loop in various flow rates and concentrations. Having more results would help us to discuss the enhancements via nanodiamonds thoroughly and compare the results with other studies.

7. References

[1] Branson, B. T., et al. (2013) Acs Nano, 7(4): 3183-3189.

[2] Barnard, A. S., (2008) J. Mater. Chem., 18(34): 4038-4041.

[3] Mochalin, V. N., et al. (2012) Nat. nanotechnol., 7(1): 11-23.

Acknowledgments

The authors would like to express their appreciation to the Center for Manufacturing Research (CMR) and Dr. ChaBum Lee for their cooperation and support.