Kostic's Group Nanofluids Research Activities and Future Plans

More at: www.kostic.niu.edu/DRnanofluids (Argonne's Faculty Research Participation Program in Summer 2004 & 2005)

Future Objectives: Development of hybrid, Drag-Reduction nanofluids and other complex nanofluids with polymer additives (dubbed POLY-nanofluids and DR-nanofluids) and investigation of their structural, diffusion, thermo-physical, flow and heat transfer characteristics, for diverse applications, including: (1) enhanced energy/heat transfer, (2) flow friction reduction and tribology; (3) water treatment and purification; (4) environmental control and cleanup; (5) pharmaceutics and bioengineering; and (6) development of novel fluid/thermal and environmental/bioengineering sensors, devices and systems. The trend in further development of nano-materials is to make them multifunctional and controllable by external means or by local environment thus essentially turning them into useful nano-devices.

Thermal conductivity studies have been the focus of nanofluid research so far, but ultimately, their flow and heat transfer characteristics in real, practical applications will determine their usefulness as advanced heat-transfer fluids. Many critical phenomena have not yet been investigated, and related underlying physical phenomena are not yet fully understood [1, 2].

Grants/Funding:

- DOE/RR: Rail-Road Energy Efficiency (Engine & Tribology), 2008-Present
- NSF (Thermal Transport & Thermal Processing) research grant, 2007-2008

Developed/Acquired Apparatus/Equipment:

- Flow and heat Transfer apparatus for nanofluids (n-FHT Apparatus) [See Illustration and Appendix A below]
- Transient Hot-Wire Thermal Conductivity (HWTC) apparatus [3]
- Steady-state, Parallel-Plate Thermal-Conductivity (PPTC) apparatus [4]
- Cone-and-plate digital viscometer; Analytic digital balance, Ultrasonic mixer
- Malvern Zetasizer Nano-ZS (ZEN3600) for the measurement of size, molecular weight and zeta potential of dispersed particles and molecules in solution

Theses in progress:

- Craig Netemeyer, "Exploring Flow and Heat Transfer Characteristics of New Hybrid Polymer-Nanofluids," M.S. Thesis. Department of Mechanical Engineering, In progress, 2010.

Thesis completed:

- Casey Walleck, "Development of Steady-state, Thermal-Conductivity Apparatus for POLY-Nanofluids and Comparative Measurements with Transient HWTC Apparatus", M.S. Thesis. Department of Mechanical Engineering, Completed in October 2009.
- Kalyan Chaitanya Simham, "Development of Computerized Transient Hot-Wire Thermal Conductivity (HWTC) Apparatus for Nanofluids," M.S. Thesis. Department of Mechanical Engineering, Completed in June 2008.
- Vijay Kumar Sankaramadhi, "Development of Advanced Metal Cutting Nanofluids," M.S. Thesis. Department of Mechanical Engineering, Completed in December 12, 2006

Patents:

1. Kostic *et al*. (DOE*/Argonne's collaborators), ONE-STEP METHOD FOR THE PRODUCTION OF NANOFLUIDS, US* Patent Number: US 7,718,033 B1.
2. Kostic *et al*. (DOE*/Argonne's collaborators), ONE-STEP METHOD FOR THE PRODUCTION OF NANOFLUIDS*, U.S. Patent-Divisional Application No.12/729,494 filed by U.S. Department of Energy (Brian John Lally/Katherine Baldwin, Patent Attorney) on 3/23/2010. Additional Claims to the above. Approved in January 2010 - Issuance in process.

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[1] Kostic, M., "*Critical Issues and Application Potentials in Nanofluids Research,*" ASME-MN2006 Multifunctional Nanocomposites 2006 International Conference Proceedings, September 20-22, 2006, Honolulu, Hawaii, ASME Proceedings, New York, 2006.

[2] Kostic, M., *Effective Thermal Conductivity Errors by Assuming Unidirectional Temperature and Heat Flux Distribution Within Heterogeneous Mixtures (Nanofluids),* Proceedings of the 5th WSEAS International Conference on HEAT and MASS TRANSFER (HMT'08), Acapulco, Mexico, January 25-27, 2008. In THEORETICAL and EXPERIMENTAL ASPECTS of HEAT and MASS TRANSFER (Editors: J. Krope, S. H. Sohrab, F.-K. Benra), ISBN: 978-960-6766-31-2; ISSN: 1790-2769, p.44-49, WSEAS Press. 2008.

[3] Kostic, M. and Simham, K.C., *Computerized, Transient Hot-Wire Thermal Conductivity Apparatus for Nanofluids,* Proceedings of the 6th WSEAS International Conference on HEAT and MASS TRANSFER (HMT'09), Ningbo, China, January 10-12, 2009. In RECENT ADVANCES in HEAT and MASS TRANSFER (Editor: Lifeng Xi), ISBN: 978-960-474-039-0; ISSN: 1790-5095, p. 71-78, WSEAS Press. 2009. (**Best HMT09 Conference Paper**)

[4] Kostic, M. and Walleck, C.J., *Design of a Steady-State, Parallel-Plate Thermal Conductivity Apparatus for Nanofluids and Comparative Measurements with Transient HWTC Apparatus*, 2010 ASME International Mechanical Engineering Congress & Exposition, November 12-18, 2010, Vancouver, British Columbia, Canada, ASME, New York, 2010.

US007718033B1

(12) **United States Patent**
Kostic et al.

(10) **Patent No.: US 7,718,033 B1**
(45) **Date of Patent: May 18, 2010**

(54) **ONE-STEP METHOD FOR THE PRODUCTION OF NANOFLUIDS**

(75) Inventors: **Milivoje Kostic**, Chicago, IL (US); **Mihajlo Golubovic**, Chicago, IL (US); **John R. Hull**, Downers Grove, IL (US); **Stephen U. S. Choi**, Napersville, IL (US)

(73) Assignee: **The United States of America as represented by the United States Department of Energy**, Washington, DC (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 979 days.

(21) Appl. No.: **11/456,944**

(22) Filed: **Jul. 12, 2006**
(Under 37 CFR 1.47)

(51) **Int. Cl.**
B01D 1/22 (2006.01)
B01D 3/08 (2006.01)
B01D 3/10 (2006.01)
B01D 3/28 (2006.01)

(52) **U.S. Cl.** **159/49**; 159/6.3; 159/7; 159/11.2; 159/13.2; 159/44; 159/DIG. 16; 202/205; 202/238; 203/1; 203/89; 203/91; 165/58; 165/68; 165/89; 252/74; 196/112; 196/114; 208/360; 208/366; 427/81

(58) **Field of Classification Search** .... 159/6.3, 159/7, 11.2, 12, 13.2, 44, 49, DIG. 15, DIG. 16, 159/DIG. 23; 202/205, 236, 238; 203/1, 203/89, 91, 100; 252/74; 165/58, 68, 89, 165/90, 201; 568/840; 196/112, 114; 208/360, 208/366; 427/81
See application file for complete search history.

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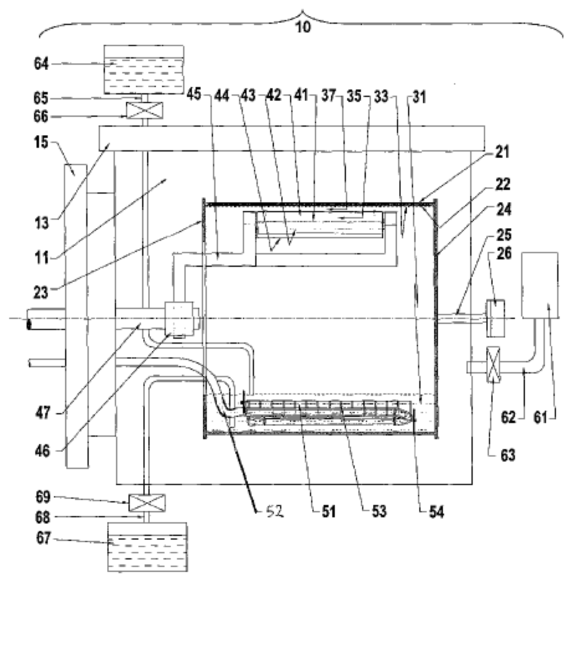
Primary Examiner—Virginia Manoharan
(74) *Attorney, Agent, or Firm*—Brian J. Lally; Mark P. Dvorscak; Paul A. Gottlieb

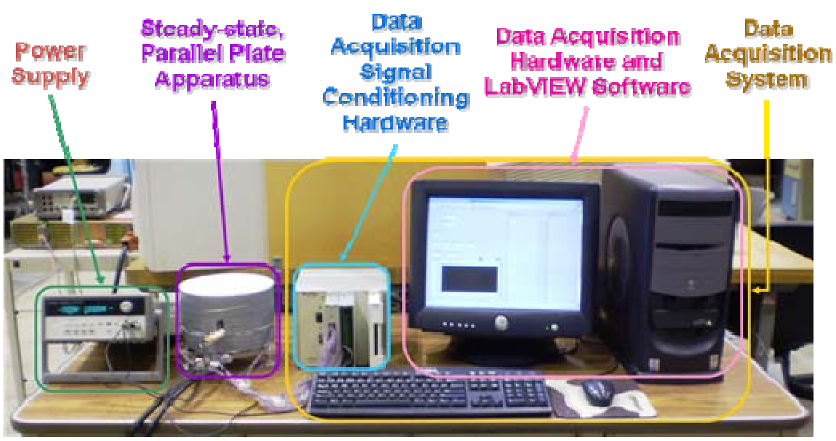
(57) **ABSTRACT**

A one step method and system for producing nanofluids by a particle-source evaporation and deposition of the evaporant into a base fluid. The base fluid such (i.e. ethylene glycol) is placed in a rotating cylindrical drum having an adjustable heater-boat-evaporator and heat exchanger-cooler apparatus. As the drum rotates, a thin liquid layer is formed on the inside surface of the drum. A heater-boat-evaporator having an evaporant material (particle-source) placed within its boat evaporator is adjustably positioned near a portion of the rotating thin liquid layer, the evaporant material being heated thereby evaporating a portion of the evaporant material, the evaporated material absorbed by the liquid film to form nanofluid.

23 Claims, 10 Drawing Sheets



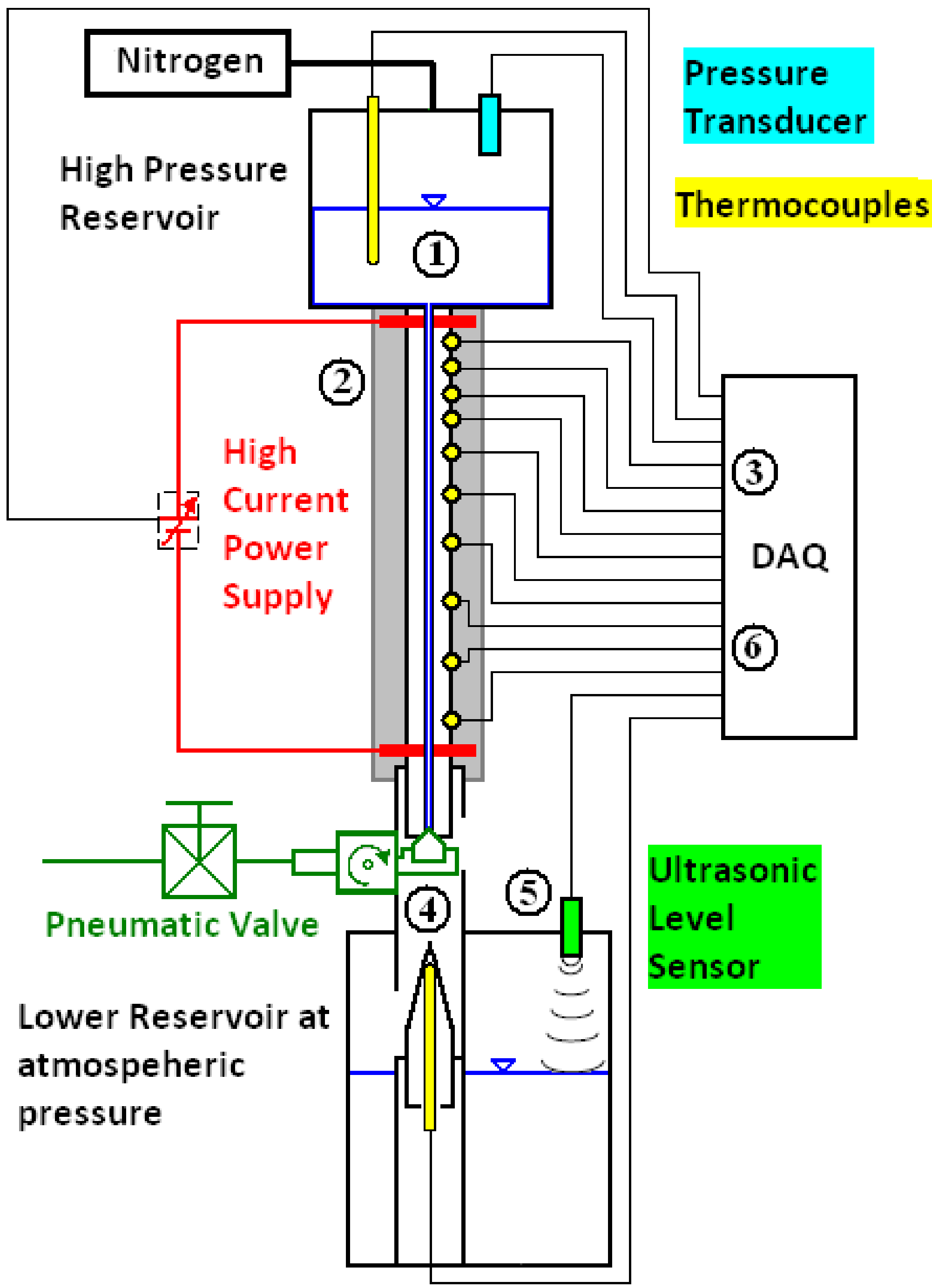
Flow and heat Transfer apparatus for nanofluids (n-FHT Apparatus)



Steady-state, Parallel-Plate Thermal-Conductivity (PPTC) apparatus [4]

Transient Hot-Wire Thermal Conductivity (HWTC) apparatus [3]

APPENDIX A – N-FHT Apparatus Schematic



1) Test fluid is pressurized with nitrogen in high-pressure reservoir
2) Fluid flows through the stainless steel capillary tube heated with high-current DC
3) Temperatures are measured along the tube as the test fluid flows through
4) The fluid exits the tube and the outlet temperature is measured along with inlet temperature and heating power
5) The flow rate is calculated using the measured change of fluid level in the low-pressure reservoir
6) Nusselt Number and friction factor is calculated using the collected data