REU Supplement

NER: Field-aligned Nanotube Suspensions for the Active Control of Heat Transfer in Nanosystems (NSF ECS #0404181)

Project Description

Miniaturization of computer chips has led an increasing demand for better thermal management techniques. The reduced size of microprocessors requires a more efficient way of removing heat from hot-spots. Recently, nanofluids consisting of liquid suspensions of nanoscale particles or tubes have shown considerable promise as enhanced heat-transfer fluids for thermal-management applications. For a volume fraction of 1 %, nanofluids containing carbon nanotubes have been reported to have 2.5 times greater thermal conductivity compared to the fluid without nanotubes. This very controversial finding must be explored to a greater extent. Carbon nanotubes are also unique in that their thermal conductivity is possibly orientation dependant. This property leads us to believe that aligning the nanotubes in the suspension will further increase the thermal conductivity of the nano-fluid. Moreover, such an increase in thermal conductivity would be actively controllably, since the orientation of the nanotubes can be controlled by an external electric field. The goal is thus to develop a nanofluid having actively controllable thermal conductivity, so that heat transfer can be selectively enhanced, when and where needed. In our laboratory, we have demonstrated that external AC fields can align single-walled carbon nanotubes in liquid suspensions. Furthermore, we can non-intrusively detect the orientation of the nanotubes using optical diagnostics which depend on the alignment-induced polarization effects on a laser beam transmitted through the fluid sample.

This project extends and complements the ongoing research by introducing a new measurement technique for thermal conductivity. In particular, the undergraduate student will:

1) Construct a transient hot wire apparatus to measure the thermal conductivity of fluid samples.
2) Measure and compare the thermal conductivity for randomly dispersed and electric-field aligned nanotube solutions.

Currently, measurements of nanofluid thermal conductivity are being made in our laboratory by a parallel-plate method. As an independent measurement technique, the transient-hot-wire method will provide additional data for comparison and help confirm the parallel-plate measurements. Moreover, the hot-wire apparatus has the potential to be a faster, easier-to-use method for determining the conductivity of small samples than the parallel-plate technique. The work proposed under the REU Supplement will ideally complement ongoing research supported under the main grant.

Justification

Form and Nature of Student Involvement:
The student will have the opportunity to conduct independent research on a portion of the overall project under the supervision of the PI and graduate students. He will design and construct the transient-hot-wire apparatus, collect data, and help in analyzing the results. He will also meet regularly with the PI to discuss progress, and will particular in the bi-weekly group meetings. Upon successful completion of the project, the student will coauthor papers and conference presentations. The student will be expected to travel to the American Physical Society, Division of Fluid Dynamics, Annual Meeting to present results from his research.

Experience of PI in Undergraduate Research:
The PI has had successful experience with undergraduate research in his laboratory. With support from Rutgers University under an Undergraduate Research Fellowship, an undergraduate student developed optical diagnostics for detecting nanotube orientation in the Summer of 2004. Based upon successful completion of the project, the student co-authored an abstract presented at the American Physical Society, Division of Fluid Dynamics, Annual Meeting (Shan, J. W., Brown. M., & Lin, C. 2004 Carbon nanotubes in liquid suspension: Electric-field-induced alignment and optical anisotropy. *Bull. Am. Phys. Soc. 49, Proc. of APS/DFD Ann. Mtg., Seattle, WA, Nov. 21-23*). It is expected that the student supported by the REU Supplement will also co-author papers and conference presentations as a result of the research.

The PI also is currently mentoring two undergraduate women under **Project SUPER**, an enrichment program for undergraduate women that provides undergraduate research experiences in the sciences, math, and engineering. The students are gaining hand-on experience in the PI's laboratory, and are being encouraged to continue their studies in science and engineering. The Alfred P. Sloan Foundation provided the initial funds for this program which is now supported by Rutgers University.

Personnel Justification:
Mr. Benjamin Reinecke is an undergraduate pursuing on a dual major in Mechanical Engineering and Chemical Engineering. He has experience with the synthesis of mesoporous silica particles in a batch reactor, surfactants, scanning electron microscopy, and rapid prototyping. Mr. Reinecke was recruited for this project because of his unique background and abilities in both Mechanical & Chemical Engineering. His previous experience will be of immediate use to the preparation and characterization of carbon-nanotube suspensions in various liquids. The PI will further train Mr. Reinecke in the theory and application of thermal measurements, and expose him to variety of fluid/flow diagnostic techniques. Through this research opportunity, Mr. Reinecke will be encouraged to continue his academic/career development with graduate studies in science and engineering. Mr. Reinecke is a US citizen.