

NIU Strategic Planning Concept Paper:

Novel Polymer-Nanofluids: NIU Wet-Nanotechnology Potential

Identity:

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This is, by its nanoscale nature, a multidisciplinary project and activity to include many faculty and students, including engineering, physics, chemistry and biology, and possibly other departments.

More at: www.kostic.niu.edu/DRnanofluids

Proposal:

Development of many industrial and new technologies is limited by existing thermal management and need for high-performance cooling. Nanofluids, stable colloidal mixtures of nanoparticles (including nanofibers and functional nanocomposites) in common fluids, have a potential to meet these and many other challenges. A collaborative research with NIU's Institute for NanoScience, Engineering & Technology (InSET) and Argonne National Laboratory (ANL) to create and investigate new advanced Drag-Reduction-nanofluids (dubbed DRnanofluids) with an objective to enhance heat-transfer properties and reduce flow friction, is proposed here. Considering unique properties of drag-reduction fluids (Kostic's prior research), very promising results with nanofluids obtained in ANL, and InSET research resources, new potentials and possibly new discoveries are anticipated. In addition to thoughtful engineering research with systematic parametric investigation to develop and optimize production of nanofluids with enhanced flow and heat transfer properties, supporting research in characterizing physical structure and motion/interactions, including development of advanced photon source techniques in coherent x-ray scattering to characterize static and dynamic structural properties/interactions of nano-materials (collaboration with NIU Physics), and synthesizing and investigating chemical structure/composition and electro-chemical interactions (collaboration with NIU Chemistry) will be very useful for understanding of underlying phenomena and optimization of development/design/production of nanofluids with desired, enhanced thermo-physical properties. The improved methods will be developed to integrate drag-reducing polymer additives with metal and metal- and carbon-based composite-nanoparticles in common base fluids, and for the first time, to produce polymer-nanofluids, with not only observed heat transfer enhancement, but equally importantly, with improved flow-friction characteristics. Ultimately, thermo-physical properties and macroscopic flow and heat-transfer characteristics of the polymer-nanofluids will be investigated.

This research will lead to the development of improved and new methods for production and characterization of diverse, complex nanofluids with polymer additives. Improved theoretical understanding of complex nanofluids, and diverse processes in nanofluids will have an even broader impact. Nature is full of nanofluids, like blood, a complex biological nanofluid where different nanoparticles (at molecular level) accomplish different functions, and where nanofluid components actively respond to their local environment. Many mining and manufacturing processes involve waste products that consist of mixtures of nanoscale particles with fluids. A wide range of active self-assembly mechanisms for nanoscale structures start from a suspension of nanoparticles in fluid. Beyond the primary goal of producing enhanced flow and heat-transfer nanofluids, this research could lead to important developments in bio-medical applications, environmental control and cleanup, and directed self-assembly at the nanoscale.

The ultimate goal is to understand the underlying physical phenomena of diffusion, momentum, and energy transport in these novel nanofluids, by correlating and modeling measured nano- and macro-characteristics, thus making possible development and production-optimization of tailor-made nanofluids with significantly enhanced thermo-mechanical properties, critical for existing and emerging applications. This will be achieved by improvement of existing and development of new chemical synthesis and surface-stabilization methods for nanofluid production with functionally-stable and active nanostructure. A systematic study of the nano-scale surface chemistry, and physical structure and dynamics, will yield improved understanding of the underlying physical phenomena and thus contribute to the general understanding of the chemistry and physics of complex fluids.

Rationale:

The core of this proposal is the novel idea of combining drag-reducing polymers (Kostic's early research) with high thermal conductivity nanofluids (new research), which may revolutionize many critical and new application areas. Also, it will be "easier" for NIU to establish and compete in "newly-developing" so called "wet-nanotechnology" than in "well-developed" "dry-solid-state-nanotechnology," where the latter has a potential to enhance the former. This research may open the road for development of diverse, complex nanofluids with polymer additives (including chemical and biological nanofluids), dubbed POLY-nanofluids, with unprecedented application potential yet to be developed. I have been collaborating for several years with pioneer-researchers in Argonne National Laboratory (ANL) and have a patent-pending invention with them, and recently obtained an NSF exploratory research grant. I have formed initial collaboration and developed proposals with NIU chemistry and physics researchers (Professors Lin and Lurio) and our NSF NIRT proposal was highly recommended for funding (the highest NSF ranking) but was declined due to lack of funding at that time. NIU with InSET have the necessary expertise, which could be further enhanced by collaboration with and using additional resources in ANL, to conduct the systematic and comprehensive, interdisciplinary research in nanofluids area.

Impact:

The proposed activities will have a wide impact on all NIU strategic imperatives: (1) NIU teaching and learning environment will be strengthen and extended in critical and profitable areas; (2) new creative strategies and proposals will be developed to support scholarly and research multidisciplinary activities; (3) NIU regional and global impact will be extended; and (4) many faculty, staff, and students will increase interest in important nano-science activities, and new faculty and new students will be interested to choose and join NIU over other institutions.

Nanofluids may have unprecedented impact in many application areas, including more efficient cooling and heating in new and critical applications, environmental control and cleanup, bio-medical applications, and directed self-assembly of nanostructures. In addition, NIU multidisciplinary activities in nanofluids and wet-nanotechnology will also contribute to general nano-science education of students and general public through outreach and other education efforts.