

Shrikaant Kulkarni
Susanta Das *Editors*

Ionic Liquids, Nanofluids and Nanotechnology

Innovations, Applications and
Sustainability



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Lecture Notes in Nanoscale Science and Technology (LNNST) aims to report latest developments in nanoscale science and technology research and teaching – quickly, informally and at a high level. Through publication, LNNST commits to serve the open communication of scientific and technological advances in the creation and use of objects at the nanometer scale, crossing the boundaries of physics, materials science, biology, chemistry, and engineering. Certainly, while historically the mysteries in each of the sciences have been very different, they have all required a relentless step-by-step pursuit to uncover the answer to a challenging scientific question, but recently many of the answers have brought questions that lie at the boundaries between the life sciences and the physical sciences and between what is fundamental and what is application. This is no accident since recent research in the physical and life sciences have each independently cut a path to the edge of their disciplines. As both paths intersect one may ask if transport of material in a cell is biology or is it physics? This intersection of curiosity makes us realize that nanoscience and technology crosses many if not all disciplines. It is this market that the proposed series of lecture notes targets.

Shrikaant Kulkarni • Susanta Das
Editors

Ionic Liquids, Nanofluids and Nanotechnology

Innovations, Applications and Sustainability

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From Antiquity to Innovation: Biomedical Applications of Ionic Liquids, Nanofluids, and Nanoparticles

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Ionic Liquids in Nanofluids: Design and Applications



Farhat Aisha Ansari and Amita Somya

Abbreviations

[C2mim][Ac]	1-Ethyl-3-methylimidazolium acetate
[C2mim][C(CN) ₃]	1-Ethyl-3-methylimidazolium tricyanomethanide
[C2mim][C ₂ SO ₄]	1-Ethyl-3-methylimidazolium ethylsulfate
[C2mim][CH ₃ SO ₃]	1-Ethyl-3-methylimidazolium methanesulfonate
[C2mim][Dca]	1-Ethyl-3-methylimidazolium dicyanamide
[C2mim][SCN]	1-Ethyl-3-methylimidazolium thiocyanate
[C4mim][BF ₄]	1-Butyl-3-methylimidazolium tetrafluoroborate
[C4mim][C(CN) ₃]	1-Butyl-3-methylimidazolium
[C4mim][CF ₃ SO ₃]	1-Butyl-3-methylimidazolium Trifluoromethanesulfonate
[C4mim][Dca]	1-Butyl-3-methylimidazolium dicyanamide
[C4mim][NTf ₂]	1-Butyl-3-methylimidazolium bis (trifluoromethylsulfonyl)imide
[C4mim][PF ₆]	1-Butyl-3-methylimidazolium hexafluorophosphate
[C4mim][SCN]	1-Butyl-3-methylimidazolium thiocyanate
[C4mmim][NTf ₂]	1-Butyl-2,3-dimethylimidazolium bis (trifluoromethylsulfonyl)imide
[C6mim][BF ₄]	1-Hexyl-3-methyl imidazolium tetrafluoroborate
[C6mim][NTf ₂]	1-Hexyl-3-methylimidazolium bis (trifluoromethylsulfonyl)imide

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[C6mim][PF6]	1-Hexyl-3-methylimidazolium hexafluorophosphate
[C8mim][NTf2]	1-Methyl-3-octylimidazolium bis (trifluoromethylsulfonyl)imide

1 Introduction: Ionic Liquid-Based Nanofluids

Ionic liquids (ILs) constitute a distinctive and adaptable category of chemicals formed exclusively from ions. Ionic liquids (ILs) have garnered substantial scientific and industrial attention related to their exceptional physicochemical characteristics, including low vapour pressure, enhanced heat and chemical resistivity, and the ability to respond to certain conditions through the choice of diverse positive and negative ion combinations. Ionic fluids are a novel category of fluids consisting only of ions, exhibiting melting temperature less than 100 °C [1]. In recent years, the formation of normal temperature ionic fluids has garnered significance from scientists, industry professionals owing to comparatively lesser melting points (<30 °C). Compared to typical molecular liquids, the density of ionic liquids exhibits a modest drop, predominantly in a linear fashion, with rising temperature. Scientists studied how an elevation in temperature from 15 °C to 37 °C results in a reduction of the molecular density of [BMIM][NTf2] from 1446 to 1375.7 kg/m³ (4.86%) [1, 2]. The thickness of ionic liquids (ILs) generally exceeds that of traditional thermal transfer fluids, for example, ethylene glycol.

Nevertheless, similar to other fluids, the thickness of ILs decreases significantly (non-linearly) with rising temperature as reported by research [3]. The decrease in fluidity of ionised fluids is especially essential for thermal applications at higher temperatures, since it can substantially decrease the required pumping power. Ionic liquids (ILs) are fluids at normal temperature, consisting of ionic mixtures. It has attracted attention as heat exchange liquids because of their superior thermophysical characteristics [4]. These features encompass a low pressure gradient and fluctuation, significant heat capacity, a comparatively lesser melting point, considerable ionic conductivity, and strong solution capacity. In addition to their utilisation as heat transfer fluids, ionic liquids have numerous industrial uses. It has several uses, particularly as solutions in chemical, oil-gas industries, processing of coal, and pharmaceutical preparations [5–7].

The integration of nanomaterials into various ILs (ionic liquids) creates a new domain, referred to as ‘ionanofluids’. The idea that the use of nanofluids enhances the thermodynamic characteristics is due to the dispersal of a small amount or mass fraction of particles in the ionised liquids (ILs). Multiple groups of researchers [8–11] are investigating ILs-based nanofluids, and various efforts have been undertaken to evaluate their thermophysical characteristics, including temperature stability, rheological actions, electrical conductivity, heat retention, and thermal stability under both ambient and induced convection circumstances.

The integration of ionic liquids with nanoparticles creates an effective platform for the preparation and stability of metal oxides and other nanomaterials (Fig. 1). Ionic liquids serve as solvents, stabilisers, and surface modifications,