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Review Article

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A Study on Ionanoliquids: Review Paper

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ABSTRACT

This paper reviews the latest class of nanoliquids known as ionanoliquids. These liquids are having excellent thermophysical properties when compared to their ionic base fluids. Such liquids find a great potential as heat transfer liquids due to the above. An attempt has been made to study the work of researchers on such liquids and highlight the advantages of such coolants, the chemical development methods for such liquids, the characteristic applications in industry of such ionanofluids, along with their disadvantages and stability issues. Researchers investigating the heat transfer and specific heat capacity of such liquids have often found that ionanoliquids have better heat capacity and thermal conductivity but less heat transfer area when compared with their base ionic liquids. Since in the present day thermal world accent has been placed on green technologies the above liquids show immense potential According to researchers, their thermophysical properties influenced the design and performance parameters of physical-chemical processing and reaction units like reactors, heat exchangers and distillation columns. Since green technologies are desirable in most processes the ionic liquids have to be characterized as per their transport, thermodynamic and dielectric properties. So the objective of this review is to study the manufacture and application of ionanoliquids for their application to heat transfer based on their thermodynamic and fluid flow behavior.

Keywords: Ionanoliquids; Thermodynamic; Dielectric; Transport; Thermophysical; Heat exchangers

INTRODUCTION

Nano liquids or Nano coolants have been around for many years since the early nineties as was researched by Choi [1] in the Argonne Laboratory in U.S. by for thermal enhancement applications while supplementing the fluid flow requirements too. These liquids have been advantageous in electronic CPU, IC cooling, refrigeration, thermal power generation etc. as mentioned by Wang and Mazumdar [2] while flowing through micro scale and mini scale heat sinks of different geometries like circular, rectangular, trapezoidal, triangular etc. The ease of construction of small size rectangular silicon and copper heat sinks has led to the wide usage of nanoliquids. Aluminum oxide and copper oxide. Nano liquids when flowing through cylindrical heat sinks or micro channels have also been utilized for Nano coolant technology though with some reservations about fouling /erosion problems in them as seen by Putra et al. [3]. The difficulties experienced in Nano coolant technology are clustering, clogging, and poor stability as suspensions both in working condition as well as shelf life as mentioned in the review paper by Yu and Xie [4]. Higher viscosities, higher densities of the liquids at higher concentrations of Nano suspensions (though with the advantage of higher thermal conductivities) lead to a disadvantage of higher pressure drops across the heat sinks. In order to minimize the above effects, coagulants have to be added to the Nano suspensions. The addition of coagulants may increase the suspension stability but the prediction on the stability of such Nano powder suspensions and use of proper coagulants requires lot of knowledge on the chemical science of Nano powders, base liquids and the coagulants. A new class of liquids have emerged, which can improve on the above, which are known as ionanoliquids or ionanofluids mentioned by Ribiero et al. [5] which are basically suspensions of nanomaterials (rods, tubes and particles)involving nanotechnology, nanoscience, thermal fluids, chemical and mechanical engineering as evidenced in the works by Ribiero et al. [5] and Castro et al. [6]. These types of liquids boast of a host of applications like solar absorbing panels, catalysis, lubricants, luminescent materials and most importantly heat transfer according to the authors, Castro et al. [7] in their article on synthesis of ionanoliquids and their applications. They are a category of Nano liquids made up of nanomaterial and ionic liquid resulting in nanoparticle dispersion similar to Nano liquids used earlier. The authors in their paper stress on the fact that such liquids have improved thermal conductivity, enhanced heat capacity, heat transfer ability and heat storage capability. The basic advantage of using such liquids is that Nano regions are created due to multiple complex reactions between the nano-material surface and the anion/cations of the ionic fluid as mentioned in their work. The creation of such Nano regions results in improving the performance of chemical reactions [8].

MANUFACTURE OF NANO LIQUIDS AND IONANOLIQUIDS

Manufacturing Nano powders is a purely chemical process involving either dispersion of very fine metallic nanopwders into the base fluid or dispersing very fine metallic oxides or non-metals like Graphene, CNT etc. into the base fluid. There are various methods of preparing Nano powders like single step evaporation method mentioned by Akoh et al. [9] in their work (involving vacuum evaporation running into an oil substrate) called as VEROS method or the improved VEROS method of Eastman et al. [10]. The problem with the VEROS method was separating Nano powder from the liquid. But the advantage in the work of Eastman et al. was that Copper vapor was directly condensed into nanoparticles on contact with ethylene glycol having low vapor pressure. The commonest and most useful method is the one step Nano powder single-step chemical process proposed by Zhu et al. [11] for preparation of Cu Nano liquids by reducing $CuSO_4.5H_2O$ with NaH_2PO_2, H_2O in ethylene glycol under the influence of microwave irradiation. This method could also be utilized to produce Silver Nano liquids with mineral oil as base liquid. But the drawback associated with this method is that though Nano powder accumulation is minimal but it is more suitable for liquids having low vapor pressure. Yet another method to prepare Nano liquids is the two step synthesis as researched by Lee et al. [12], Wang et al. [13] and Eastman et al. [10] to make alumina nanoliquids. This involves a process of manufacturing Nano liquids by mixing base fluids with industrially available Nano powders made from milling, grinding, sol-gel and vapor phase methods. A new class of Nano liquids has emerged which a mixture is created from Nano powder and base liquids which are ionic. Interest has been generated in such types of liquids called as “ionanoliquids”, due to their improved heatstorage, heattransfer, heat capacity and thermal conductivity. The very fact that ionic liquids are used as base fluids for the Nano powderssuggest that such types of liquids can be used for a variety of applications. The liquids, being non-volatile and non-inflammable at ambience, can be considered as green liquids. Ribiero et al. [8] in their review paper have talked about the synthesis and preparation of such ionanoliquids based on the publications of various researchers. Ribiero et al. [8] in their work have coined the word “IoNanofluids” or ionanoliquids as we understand it. In this type of liquids, not only Nano powders but also tubes and rods are dispersed in ionic liquids. Other researchers, Fukushima et al. [14] have talked of suspensions or blends of ionic liquids with nanomaterials majority being Nano carbons (fullerenes, single walled carbon nanotubes and multiwall carbon nanotubes). The basic processes of manufacturing of ionanoliquids are similar in nature to the development of Nano liquids like the single step process and the two-step process. Aida and Fukushima [15] discovered in their researches that imidazolium –cation based-ionic liquids enabled CNT to be dispersed well in them, resulting in gels from sonification process or by grinding the suspension using a mortar and pestle. These techniques resulted in stable suspensions with 0-3% multi walled CNTs with ionic liquids like pyrrolidinium and imidazolium. Conditions for manufacture include that the purity of ionic liquid was very important as found by other researchers while making similar liquids. The present researchers concentrated more on using CNTs but still other research papers of Vieira et al. and Queirós et al. [16-18] have shown TiO_2, Ag and other natural materials. As far as the nanomaterials shape was concerned, most of the present and earlier researches showed that the nanomaterials were either spherical, oblong or rod in shape. Also dispersions of the ionanoliquids were measured within an interval of one year by Franca et al. [19] and the authors found that their values did not change beyond 2%, inside the uncertainty range of the measurements. Desirable conditions of the ionanoliquids, as envisaged by the researchers working on multiwalled CNTs were, stability over a large time period(without phase separation),uniform dispersion and additive-free without any salts and surfactants. Also such liquids having high viscosities would affect the heat transfer properties. Rodriguez et al. [20] in their work on ionanoliquids have synthesized silver iodide rihexyl (tetradecyl) phosphonium chloride ionanofluids instead of merely dispersing the AgI nanoparticles in water.

The researchers in their synthesis up to 50% concentrations of the Nano powder have found improvements in thermal conductivity up to a maximum of 20% concentration of the silver iodide nanopowder. The authors observed in their work that low electric conductivity of the ionic base fluid (which had an ability to stabilize the nanoparticles) was offset by large amount of Silver Iodide nanoparticles having high conductivity and dispersed well in the ionic liquid.

Yet another research work on ionanoliquids was done on graphene by Wang et al. [13] using ionic Nano liquids which resulted in a very stable liquid without the use of any surfactant. The properties of the liquids were also observed like thermal conductivity, specific heat and viscosity. Graphene microstructure was also observed by the authors under an electron microscope. Interestingly, the authors in their above work found that the thermal conductivity of graphene based ionanoliquid increased to as high as 15.5% and 18.6% at respective temperatures of 25°C and 65°C but for a mass concentration as low as 0.06%. Understandably with temperature rise the viscosity decreased with an increase in thermal conductivity and interestingly an increase in specific heat. Also yet, according to the authors the viscosity of the ionanoliquid was found lower than the viscosity of the base ionicliquid. The authors under reference have prepared the ionanoliquid by dispersing graphene Nano powder into [HMIM] BF4 using a 100-W, 40-kHz ultrasonicator for a time of 8 hours. Further, the authors sonicated the mixed compounds for a time of 2 minutes making use of a 25-W Ultrasonic Cell Disrupter System. Interestingly in this paper, ionanofluids have been prepared at very small weight percentages of 0.03% and 0.06%; and as the concentration was increased up to 0.09%, the ionanofluids became unstable and coagulated within two hours.

POTENTIAL APPLICATIONS OF IONANOLIQUIDS

Graphene and MWCNT based ionanoliquids have a wide range of applications according to Wang et al. [13] from solar collectors to refrigeration systems due to their thermal stability, low vapor pressure and a wide range of liquid temperatures. Ionicliquids (ILs) are basically salts which are liquid at room temperatures according to Kirchner and Clare [21]. Such liquids consist of an inorganic anion and organic cation according to Khamooshi et al. [22]. Ionic liquids can be classified as liquid metals, ionic solutions and molten salts as per the works of Hansen and MacDonald [23] and MacFarlene et al. [24].Ionic liquids help in thermal energy storage because of their electrochemical behavior. The work of Ribiero et al. [8] clearly indicates that ionanoliquids could be applied as heat transfer coolants as they exhibited increased heat transfer capacity and thermal conductivity due to the nanoparticles dispersed in them. Energy storage applications of ionanoliquids indicate possible usage in photovoltaic cells too. The work of Castro et al. [7] showed that Ionanofluids are better heat transfer fluids for heat exchangers or other heat transfer devices than base ionic liquids. Their results showed that less heat transfer surface area was needed for the above when compared to the base ionic liquids. This indicated that such liquids could be used even for superior heat transfer systems. As already mentioned previously, the above mentioned researchers have indicated that ionanoliquids can be used as luminescent materials, lubricants and in solar absorbing panels. Further they have also mentioned that ionanoliquids can be used in heat transfer as well as in catalysis. All the above researches indicate that ionanoliquids can be effectively applied to both chemical and engineering applications.

CONCLUSION

In conclusion, we can say that after the advent of nanoliquids, ionanoliquids also pose very interesting applications in heat transfer, energy storage systems, catlalysisetc. Also they exhibit high thermal conductivities at lower mass fractions when compared to normal nanoliquids. A few researchers claimed that synthesis of surfactant free ionanoliquids ensured longer stability of the dispersions when compared to the shorter life of Nano liquid dispersions. Also still other researchers claimed that ionic liquids were more like green solvents. Only question remaining was the toxicity of the Nano powders like Graphene and MWCNT and their interaction with the ionanoliquids. If a way could be found out to minimize the effects of the toxicity of the nanopowders, then such liquids would be very well used in future, especially in heat transfer applications. Another important point applicable to future usage of ionanoliquids and the existing Nano liquids in heat transfer applications would be the costs of production. But since it has been established by many of the researchers that increasing the mass concentration of Nano powders in the ionanoliquids or Nano liquids as well would create clustering, agglomeration, blockages, erosion of passages etc. Hence large thermal conductivities needed, due to large heat fluxes from high-end electronic CPUs using fast computing speeds or other applications demanding high heat removal rate, may result in high pressure drops due to the above and economically not feasible. Hybridizing the heat exchange process, optimizing the heat exchanger geometry and use of minimal mass fractions may help in better performance of such ionanoliquids in the future.

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