

## Preparation and Stability of Deep Eutectic Solvent Based Nanofluids as a Future Heat Transfer Fluid – A Review

Mior Ahmad Nazhan Mior Afendi<sup>1</sup>, Muhammad Arif Ammar Rohazien<sup>1</sup>, Syukrina Imtiyaz Abdul Samat<sup>1\*</sup>

<sup>1</sup>Kolej PERMATA Insan, Universiti Sains Islam Malaysia, 71800 Nilai, Negeri Sembilan, Malaysia

\*Corresponding author: syukrina.imtiyaz@usim.edu.my

### ABSTRACT

Deep eutectic solvents (DESs) have attracted much attention in the field of catalysis, electrochemistry, and material chemistry due to their low cost, stability, and environmental friendliness. The low vapour, less volatile, and wide liquid range features of DESs prompted us to investigate their use in heat transfer, particularly as a base solvent for nanofluids. In this review paper, the method for preparation and stability of deep eutectic solvent based nanofluid have been presented. This paper also highlights the DES preparation method, which includes the characteristics of the materials used and advantages. Moreover, the effect of the nanofluid preparation method and the material properties of the DES towards the stability of the nanofluid was also highlighted.

**Keywords:** nanofluid, deep eutectic solvent, heat transfer fluid, stability

### INTRODUCTION

A heat transfer fluid (HTF) is a liquid used to transport heat from one part of a system to another, commonly found in heating, cooling, and energy systems. It enables efficient thermal energy transfer, allowing a single heat source to serve multiple cold streams. HTFs are essential in applications like moving heat from solar collectors to the point of use, with pressurized water sometimes used for lower-temperature processes (Häberle & Krüger, 2021). In 1995, Choi and Eastman proposed using nanoparticles to improve heat transfer of base liquids. Nanofluids are fluids engineered by suspending metal or non-metal oxide nanoparticles (1–100 nm) in a base fluid. Nanofluids have greatly improved thermal management, particularly in cooling systems for electronics and data centers (Sofiah et al., 2021). However, inconsistent thermophysical properties have been reported due to factors like preparation methods, base fluid types, and nanoparticle shapes.

Deep eutectic solvents (DESs) are mixtures of solvents with melting points lower than those of their individual components. They are inexpensive, less harmful, and recyclable, making them popular as green solvents in organic synthesis, catalysis, extractions, and membrane production. DESs are formed by the complexation of halide salts with cations like quaternary ammonium, phosphonium, or choline (Rajasekharan et al., 2023).

This paper attempts to explore the potential of DES based nanofluid in heat transfer applications and as a replacement for conventional HTF. This would provide more research opportunities for the scientific community to work on DES for future applications. The novelty of this research is the studies of DES in the field of heat transfer, which can be

utilized to overcome the limitations of traditional heat transfer such as high vapor pressure, low thermal stability, low chemical stability, oxidation, and corrosion.

## MATERIALS AND METHODS

### Preparation of Nanofluid

Nanofluids are made by suspending nanoparticles in base fluids like water or ethylene glycol. Two methods are used for their preparation: a one-step process where nanoparticle synthesis and dispersion occur simultaneously, reducing agglomeration and increasing stability, and a two-step process where nanoparticles (like nanorods or nanotubes) are first created using techniques like sol-gel or hydrothermal synthesis. The sol-gel method is used for nanoparticles with a high surface area due to its precise control over particle surface characteristics (H. Ali et al., 2018).

Deep eutectic solvent is being prepared using heating and stirring method which involves mixing of individual components with or without known amount of water followed by heating in water bath or can be done on a hot plate (50–100 °C) until a clear homogenous liquid is obtained (Negi et al., 2024). Several DESs were created by combining quaternary ammonium salts such as choline chloride (ChCl), which functions as a hydrogen bond acceptor, whereas carboxylic acids, urea, amides, and alcohols which act as hydrogen bond donors (Si & Misra, 2020).

### Materials

Different types of hydrogen bond donor and hydrogen bond receiver are used to make deep eutectic solvent, and the stability is shown in Table 1.

**Table 1.** Stability of various deep eutectic solvents

Deep Eutectic Solvent	Nanoparticles	Method	Stability	Result	Reference
Methyltriphenylphosphonium bromide (MTPB) + ethylene glycol	Multi-Walled Carbon Nanotubes (MWCNT)	Two step method	Visual observation Zeta potential measurement Optical microscopy	Stable till 15-20 days -90.12 mV Nanoparticles are uniformly distributed	(Kumar Das et al., 2022)
Phosphonium halide/ammonium halide + ethylene glycol (EG)/triethylene glycol (TEG)	Carbon Nanotube (CNT)	Two step method	Visual Observation  UV spectroscopy	-stable up to 4 days with phosphonium based DES - stable up to few hours with pure EG and TEG only Concentration of CNT decrease	(Chen et al., 2017)

Choline chloride (ChCl) + ethylene glycol (EG)	Magnesium Oxide (MgO)	Two step method	Dynamic light Scattering (DLS)	Uni-Modal and narrow curves in ChCl:EG (1:5) nanofluid	(Jafari et al., 2022)
--	-----------------------	-----------------	--------------------------------	--	-----------------------

## RESULTS AND DISCUSSION

### Adsorption Capacity of Powdered Clinoptilolite

The combination of MTPB salt and EG as the hydrogen bond donor (HBD), with MWCNTs as the dispersed nanoparticles showed excellent stability, up to 15–20 days and a zeta potential of -90.12 mV. Over time, the dispersion stability decreased as sedimentation and aggregation occurred (Kumar Das et al., 2022).

A unimodal size distribution curve with a narrow peak, indicating good stability of ChCl/EG nanofluid. Notably, the suspension of MgO nanoparticles in DES ChCl:EG (1:5) exhibited better dispersion compared to other formulations, demonstrating enhanced stability and uniformity within the medium (Chen et al., 2017).

Furthermore, phosphonium and ammonium halide salts and carbon nanotubes (CNTs) as the nanoparticles create a stable nanofluid, tested using both visual observation and UV spectroscopy. The qualitative assessment revealed that from day 1 to day 22, sedimentation of CNTs resulted in the formation of loose aggregates. Quantitatively, UV spectroscopy indicated a decreasing concentration of CNTs in the nanofluid over time, highlighting a loss of dispersion stability as sedimentation progressed (Jafari et al., 2022).

The two-step process is always utilised to manufacture nanofluid since it is the most cost-effective method for large-scale preparation. The two-step process generates nanoparticles in a variety of ways before distributing them into the base liquid to create the needed nanofluid. This production technology is both economical and massive. The main downside of the two-step technique is that nanoparticles tend to agglomerate. Surfactants are used to decrease instability. This is the commercial way of producing nanofluid. Most researchers prefer this approach of preparing nanofluid for research (A. R. I. Ali & Salam, 2020).

## CONCLUSION

In conclusion, deep eutectic solvents (DES) derived from choline chloride and ethylene glycol with MgO nanoparticles demonstrate superior dispersion stability, characterized by a unimodal size distribution. In contrast, the combination of MTPB salt and ethylene glycol with MWCNTs initially shows stability, indicated by a zeta potential of -90.12 mV, but experiences sedimentation and aggregation over time. Similarly, formulations with phosphonium and ammonium halide salts and CNTs reveal a decline in dispersion stability, leading to sedimentation over 22 days. The unique properties of nanofluids and DES enable their significant roles in various industries; nanofluids enhance thermal conductivity and heat transfer for applications in cooling systems, automotive technologies, and nanomedicine, while DES offer environmentally friendly solutions for extraction, electrochemistry, and catalysis. Together, these materials contribute to advancements in technology and sustainability across diverse fields.

## ACKNOWLEDGEMENT

The authors express deepest gratitude and pleasure towards Kolej PERMATA Insan for providing the apparatus and equipment used in the laboratory.

## REFERENCES

- Ali, A. R. I., & Salam, B. 2020. "A Review on Nanofluid: Preparation, Stability, Thermophysical Properties, Heat Transfer Characteristics and Application". *SN Applied Sciences*, Vol. 2(10). p. 1636.
- Ali, H., Babar, H., Shah, T., Sajid, M., Qasim, M., & Javed, S. 2018. "Preparation Techniques of TiO<sub>2</sub> Nanofluids and Challenges: A Review". *Applied Sciences*, Vol. 8(4). p. 587.
- Chen, Y. Y., Walvekar, R., Khalid, M., Shahbaz, K., & Gupta, T. C. S. M. 2017. "Stability and Thermophysical Studies on Deep Eutectic Solvent Based Carbon Nanotube Nanofluid". *Materials Research Express*, Vol. 4(7). p. 075028.
- Häberle, A., & Krüger, D. 2021. "Concentrating Solar Technologies for Industrial Process Heat". *Concentrating Solar Power Technology*. p. 659–675.
- Jafari, K., Fatemi, M. H., & Lugo, L. 2022. "Influence of MgO Concentration and Water Content on Thermal Conductivity Enhancement of Nanofluids Based on Deep Eutectic Solvent (Choline Chloride: Glycerol)". *Journal of Molecular Liquids*, Vol. 367. p. 120319.
- Kumar Das, N., Kumar Naik, P., Reddy, D. N., Mallik, B. S., Bose, S., & Banerjee, T. 2022. "Experimental and Molecular Dynamic Insights on The Thermophysical Properties For MWCNT-Phosphonium Based Eutectic Thermal Media". *Journal of Molecular Liquids*, Vol. 354. p. 118892.
- Negi, T., Kumar, A., Sharma, S. K., Rawat, N., Saini, D., Sirohi, R., Prakash, O., Dubey, A., Dutta, A., & Shahi, N. C. 2024. "Deep Eutectic Solvents: Preparation, Properties, and Food Applications". *Heliyon*, Vol. 10(7). p. e28784.
- Rajasekharan, R., Paul, S. A., Madhavan, A., Sindhu, R., Binod, P., Awasthi, M. K., & Pandey, A. 2023. "Green Strategies for Extraction of Nanocellulose from Agricultural Wastes—Current Trends and Future Perspectives". *Green Sustainable Process for Chemical and Environmental Engineering and Science*, p. 269–288.
- Si, A., & Misra, A. K. 2020. "Perspective on the Transformation of Carbohydrates Under Green and Sustainable Reaction Conditions". *Recent Trends in Carbohydrate Chemistry*, p. 3–71.
- Sofiah, A. G. N., Samykano, M., Pandey, A. K., Kadirgama, K., Sharma, K., & Saidur, R. 2021. "Immense Impact from Small Particles: Review on Stability and Thermophysical Properties of Nanofluids". *Sustainable Energy Technologies and Assessments*, Vol. 48. p. 101635.