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On Saturated Flow Boiling Heat Transfer Of Deionized Water and Ferrofluid on Structured Surfaces With/Without External Magnetic Field

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Extended Abstract

Flow boiling is one of the most effective methods for achieving high cooling rates[1]. It is possible to categorize the methods for improving boiling heat transfer (BHT) into two broad categories: active and passive methods. The manipulation of magnetic fluids (ferrofluid) under the effect of magnetic field is one of the active methods that use external power to enhance heat transfer [2].

Improvements in heat transfer using magnetically actuated nanoparticles have been the subject of both numerical [3,4] and experimental [5,6] studies. However, few studies have focused on the visualization and analysis of the combination of significant parameters. This study aims to experimentally investigate the effect of magnetic nanoparticles on saturated flow BHT by using microstructured silicon surfaces and comparing the heat transfer performance in the absence and presence of an external magnetic field. Furthermore, bubble force analysis is presented by considering a single bubble under flow boiling conditions which is an important subject in flow boiling [7].

In this study, we used a rectangular minichannel with a cross-section of (0.5mm × 10mm) and two heating blocks on the bottom and top sides of the channel. Two side polished silicon wafers with a 500µm thickness and rectangular shape with a dimension of (0.5mm × 10mm) were used as our substrate. Two different structures, including square and circular cavities with a dimension of 300µm, depth of 50µm, and 1mm pitch sizes were tested. Superparamagnetic Iron Oxide Nanoparticles (SPION) were employed as magnetic nanoparticles. Two different types of working fluid, including deionized water and ferrofluid, which contained diluted SPION in water, were utilized. We used Helmholtz coils with 3.7 (mT) magnetic flux density to generate an external magnetic field. In addition, visualization with a high-speed camera revealed BHT and bubble dynamics characteristics as well as the parametric effects.

Experimental tests were performed under three different conditions, including tests with (DW), tests with ferrofluid (FF), and tests with ferrofluid in the presence of a magnetic field (FF/MF) at two mass flux of 300, 400 (kg/m^2s) and heat flux range of 26.28 - 142.8 (W/cm^2). BHT results show that due to the orientation of the heating blocks, heat transfer coefficient on the bottom surface was higher than on the top surface. Moreover, adding nanoparticles enhanced heat transfer and caused an increase in heat transfer coefficient (HTC) up to 21.5%. Application of an external magnetic field to ferrofluid decreases the bubble departure size and increases HTC on the top surface at high heat fluxes. The maximum HTC enhancement in the presence of a magnetic field was 25%. However, for the bottom surface, HT was enhanced more for the ferrofluid case in the absence of magnetic field in comparison with the ferrofluid case in the presence of magnetic field.

References

[1] B. Parizad Benam, A.K. Sadaghiani, V. Yağcı, M. Parlak, K. Sefiane, A. Koşar, Review on high heat flux flow boiling of refrigerants and water for electronics cooling, Int J Heat Mass Transf. 180 (2021) 121787. https://doi.org/10.1016/j.ijheatmasstransfer.2021.121787.

[2] M. Kole, S. Khandekar, Engineering applications of ferrofluids: A review, J Magn Magn Mater. 537 (2021) 168222. https://doi.org/10.1016/j.jmmm.2021.168222.

[3] S. Ahangar Zonouzi, H. Aminfar, M. Mohammadpourfard, A review on effects of magnetic fields and electric fields on boiling heat transfer and CHF, Appl Therm Eng. 151 (2019) 11–25. https://doi.org/10.1016/j.applthermaleng.2019.01.099.

[4] K. Guo, H. Li, Y. Feng, T. Wang, J. Zhao, Numerical simulation of magnetic nanofluid (MNF) film boiling using the VOSET method in presence of a uniform magnetic field, Int J Heat Mass Transf. 134 (2019) 17–29. https://doi.org/10.1016/J.IJHEATMASSTRANSFER.2018.12.148.

[5] A.K. Sadaghiani, H. Rajabnia, S. Çelik, H. Noh, H.J. Kwak, M. Nejatpour, H.S. Park, H.Y. Acar, B. Mısırlıoğlu, M.R. Özdemir, A. Koşar, Pool boiling heat transfer of ferrofluids on structured hydrophilic and hydrophobic surfaces: The effect of magnetic field, International Journal of Thermal Sciences. 155 (2020) 106420. https://doi.org/10.1016/J.IJTHERMALSCI.2020.106420.

[6] K. Guo, H. Li, Y. Feng, T. Wang, J. Zhao, Enhancement of non-uniform magnetic field on saturated film boiling of magnetic nanofluid (MNF), Int J Heat Mass Transf. 143 (2019) 118594. https://doi.org/10.1016/J.IJHEATMASSTRANSFER.2019.118594.

[7] N. Zuber, The dynamics of vapor bubbles in nonuniform temperature fields, Int J Heat Mass Transf. 2 (1961) 83–98. https://doi.org/10.1016/0017-9310(61)90016-3.