An Experimental Study on Enhancement of Critical Heat Flux in Pool Boiling using Graphene Oxide Nanofluid

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1. Introduction

Critical heat flux (CHF) means interfacial heat flux between nucleate boiling which heat transfer is effective during boiling by evaporization of fluid that contact with heating surface and film boiling which heat transfer coefficient decreases dramatically by phase change of fluid of heating surface to vapor [1]. Therefore, enhancement of CHF can achieve higher thermal limit and safety margin of plants. Many enhancing CHF methods exist and one of the methods is use of nanofluids due to advantage of nanoparticles like large surface area that can effective on heat transfer. Graphene is in spotlight by many engineering field due to excellent properties. Thermal conductivity of graphene is also high. So, Graphene Oxide (GO)/water nanofluid (0.01 v%) was used in order to enhance CHF in this experiment.

2. Description of experiment

In this section procedure of pool boiling experiment and manufacture of GO/water nanofluid, and properties of GO/water nanofluid measured are described.

2.1 Experiment

The device of experiment is composed of Pyrex container contains fluid (300 ml), and NiCr wire (75 mm length) which was connected to copper lead wire is horizontally suspended in saturated fluids. By passing current through the NiCr wire, heat flux was measured. Current passing NiCr wire increased steadily every 40 seconds and break of wire due to critical heat flux shut down circuit [2].

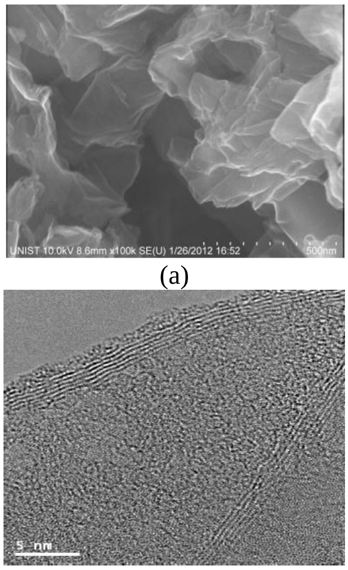
The heat flux was obtained from:

$$q'' = \frac{I^2 R}{\pi D L} \quad (1)$$

Where R is resistance of NiCr wire, D is diameter of wire and L is the length of wire.

2.2 Preparation of GO/water nanofluid

GO nanosheets used in this study were manufactured by chemical vapor deposition (CVD) method. Produced GO nanosheets were dispersed in water as follows: (1) weigh the mass of GO nanosheets with a digital electronic balance; (2) mix GO nanosheets and water which also weighed; (3) sonicate the mixture continuously for six hours with a sonicator for uniform dispersion of GO nanosheets in the water. In order to observe morphology and size of GO nanosheets, scanning electron microscopy (SEM) and transmitting electron microscopy (TEM) were used. As can be seen in the Fig. 1, morphology of GO nanosheets is plate.



(a)

(b)

Fig. 1. SEM and TEM images of GO nanosheets : (a) SEM image and (b) TEM image

2.3 Measurement of zeta potential and pH of GO/water nanofluid

Stability of nanofluid is related to dispersion of nanoparticles in base fluid. Stability can be measured and determined by measurement of zeta potential which is potential difference between surface of nanoparticles and base fluid. High absolute value of zeta potential means good stability. Measured pH of GO/water nanofluid was 3.58 and zeta potential was -31.5 mV that show good stability of nanofluid.

2.4 Measurement of thermal conductivity of GO/water nanofluid

Thermal conductivity of GO/water nanofluid at different temperature of nanofluid is measured with KD2 pro (Decagon Devices Inc., USA) after calibration using deionized water. As can be seen in the Table. 1, thermal conductivity of GO/water nanofluid is higher than that of deionized water and thermal conductivity increase as temperature increase.

Table. 1. Thermal conductivity according to the temperature of GO/water nanofluid and deionized water

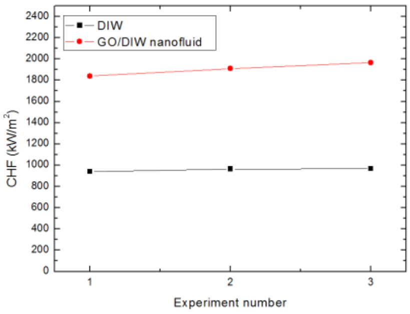
Temperature (℃)	Thermal conductivity ratio	Thermal conductivity (W/m·K)	
		Water	GO/DIW nanofluid
21.11	1.0456	0.614	0.642
21.52	1.0547	0.623	0.657

3. Results and discussion

The CHF of GO/water nanofluid was enhanced two times than that of water. Fig. 2 and Table. 2 show the result of critical heat flux.

Table. 2. CHF data according to experiment number (kW/m^2)

	Experiment number	Water	GO/water nanofluid
CHF	1	940	1,839
	2	965	1,910
	3	967	1,967



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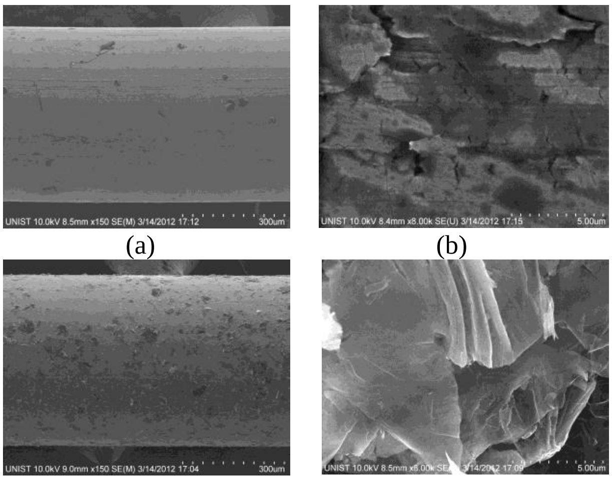
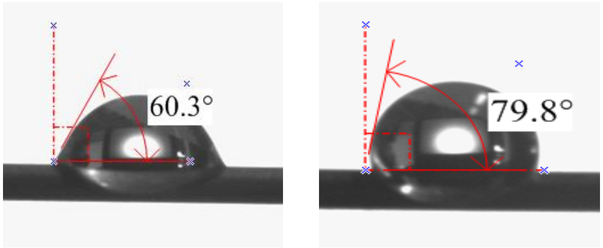


(a) (b) (c) (d)

Fig. 3. SEM image of heater surface; (a) Water (x150), (b) water (x8000), (c) 0.01 v% GO/water nanofluid (x150), (d) 0.01 v% GO/water nanofluid (x8000)

The cause of critical heat flux enhancement using nanofluid is generally increased wettability by coating of heating wire surface with nanoparticle [3]. Therefore, surface of heating wire and contact angle are measured. Fig. 3 is SEM images of heating wire surface which show the deposition of GO nanosheets.

The contact angle of heating surface after pool boiling experiment with GO/water nanofluids (79.8˚) is larger than that of wire used with water (60.3˚) in pool boiling experiment as shown in the Fig. 4.



(a) (b)

Fig. 4. Contact angles of heating surface after pool boiling experiments with 300 ml fluid; (a) water (60.3˚), (b) GO/water nanofluid (79.8˚)

4. Conclusions

CHF was enhanced about 200 % in pool boiling experiment using GO/water nanofluid compared to water used as fluid. Conventionally, enhancements of CHF in pool boiling experiment using nanofluids are due to enhancement of capillary wettability. But, result of contact angle of heating surface after pool boiling experiment in GO/water nanofluid show that the cause of CHF enhancement using GO/water nanofluid is not enhanced wettability. High thermal activity (due to high effusivity) of GO nanosheets may attribute to the enhancement of CHF by dissipating hot spot with high radial conduction.

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