Experimental Study on Critical Heat Flux Characteristics of CuO/DIW Nanofluids according to Manufacturing Methods

Seung Won Lee, Sung Dae Park, Sarah Kang, In Cheol Bang*
Ulsan National Institute of Science and Technology(UNIST)
100 Banyeon-ri, Eonyang-eup, Ulju-gun, Ulsan Metropolitan City 689-798, Republic of Korea
**Corresponding author: icbang@unist.ac.kr*

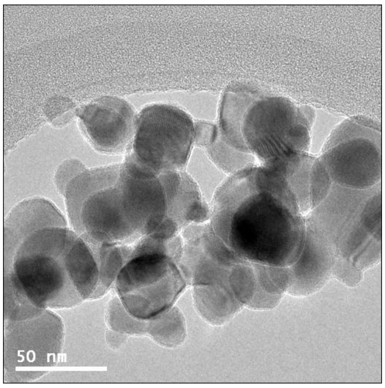
1. Introduction

The critical heat flux (CHF) is characterized by a sudden reduction of the local heat transfer coefficient (HTC) that results from the replacement of liquid by vapor adjacent to the heat transfer surface. Ordinarily, the CHF represents the thermal limitation in which a phase change happens during heating. When the CHF occurs, an inordinate decrease in the heat transfer rate for heat flux controlled system generates, and an inordinate decrease in the heat transfer rate for temperature controlled systems generates. Of the two, the former is generally more important in applications such as power generation because of maintenance of the integrity occurring in heated surface [1]. So, it is very important to enhance the CHF to ensure the system safety and improve the efficiency. Many methods to enhance the CHF have been investigated and a new technique in recent years among these methods is nanofluids technology. Nanofluids are a new class of nanotechnology-based transfer fluids engineered by dispersing and stably suspending nanoparticles in traditional heat transfer fluids such as water, ethylene glycol, and engine oil [2]. The papers about the CHF enhancement according to the different nanoparticles have been reported. But, the paper about the CHF enhancement according to the methods of nanofluids manufacture has been not reported. So, we prepared the pool boiling experiment with nanofluids made by the laser ablation method (one-step method) and the two-step method.

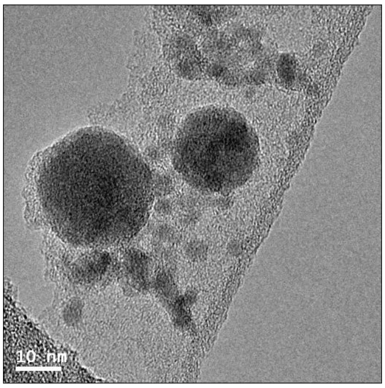
2. Test and Results

2.1 Preparation of the Test

Cu pellets (manufactured by Alfa Aesar, 5.2mm x 3.0mm) were used in one-step method and CuO nanoparticles (manufactured by Alfa Aesar) were used in the two-step method. The nanofluid of 0.001 V% made by one-step method with Cu pellets is same to the nanofluid of 0.001 V% made by the two-step method with CuO nanoparticle because the base fluid is the deionized water. Because the properties of the nanofluids depend on the shape and size of nanoparticles, the image of Fig. 1 was taken by transmission electron microscopy(TEM). As shown in Fig. 1, the size of CuO nanoparticle of nanofluid made by one-step method is more smaller than that made by two-step method.



(a)



(b)

Fig. 1. TEM image of CuO nanoparticles according to manufacturing methods; (a) two-step method, (b) one-step method (laser ablation method)

To look into dispersion stability of two nanofluids, zeta potential and pH were investigated. These data are listed in Table I. As shown in Table I, the dispersion stability of CuO/DIW nanofluid made by one-step method is much better than that made by two-step method.

Table I : Zeta potential and pH of two nanofluids according to manufacturing method

	One-step	Two-step
Zeta Potential	39 mV	15.8 mV
pH	7.6	7.15

2.2 CHF Evaluation

The critical heat flux of CuO/DIW nanofluids is measured with manufactured experiment equipment. The experimental components are the rectangle vessel, two copper electrodes, a Teflon cover, a reflux condenser, power supply, data acquisition system, hot plate and a standard resistor and the heating method on test section is joule heating. The CHF experiment is performed 3 times about DIW, CuO/DIW nanofluid made by one-step method and CuO/DIW nanofluid made by two-step method. The results of these experiments are listed in Table II. The CHF value of CuO/DIW nanofluid made by one-step method is a little greater than that made by two-step method.

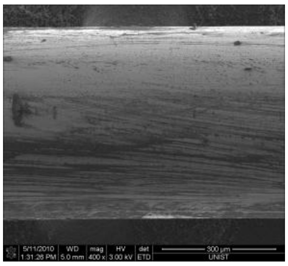
Table II : The CHF value of nanofluids according to manufactured method (unit : kW/m^2)

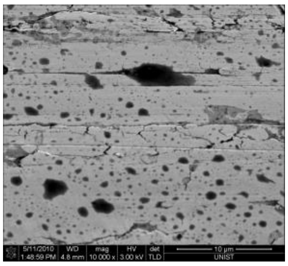
	DIW	One-step	Two-step
CHF	997.133	2605.293	2301.011

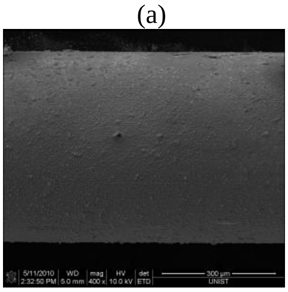
2.3 Test Results

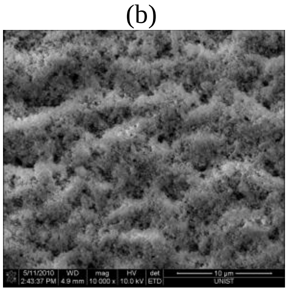
The paper about the CHF enhancement according to the methods of nanofluids manufacture has been not reported. To investigate the cause of CHF enhancement, surface layers and contact angles are observed on the heating surface after pool boiling experiments.

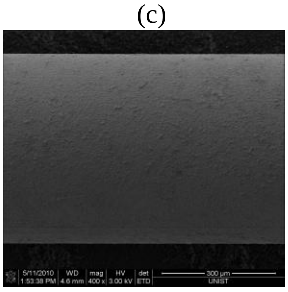
Fig. 2 is the SEM images of surface of heating wires which show the layer structures. The deposition structure of CuO/DIW nanofluids made by one-step and two- step methods is nearly same.


(a)


(b)


(c)


(d)


(e)

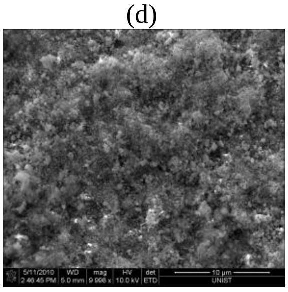
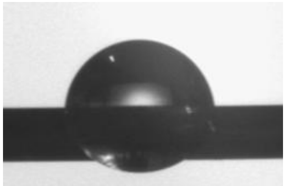
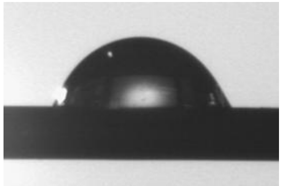

(f)

Fig. 2. SEM image of heater surface; (a) DIW (300 micro-meter, (b) DIW (10 micro-meter), (c) two-step method (300 micro-meter), (d) two-step method (10 micro-meter), (e) one-step method (300 micro-meter), (f) one-step method (10 micro-meter)

The contact angles of surface layer of wires after pool boiling experiments in CuO/DIW nanofluids made by one-step and two-step method are smaller than that of bare wire after pool boiling experiment in DIW and the contact angle of CuO/DIW nanofluid made by one-step method is smaller than that of CuO/DIW nanofluid made by two-step method as shown in Fig. 3.


(a)


(b)


(c)

Fig.3. Contact angles of surface layer of wires after pool boiling experiments with 1 micro-liter water; (a) DIW (75.37°), (b) two-step method (61.05°), (c) one-step method (30.41°)

3. Conclusions

In order to investigate the CHF enhancement characteristics of CuO/DIW nanofluids according to manufacturing methods, pool boiling experiments were performed. Although the contact angle of CuO/DIW nanofluid made by one-step method is smaller than that of CuO/DIW nanofluid made by two-step method, the deposition structure of CuO/DIW nanofluids made by one-step and two-step methods is nearly same. And the CHF values of CuO/DIW nanofluids according to manufacturing methods is nearly same.

The CHF enhancement of CuO/DIW nanofluid compared with DIW is observed because of buildup of deposition layer of nanoparticles. But, the CHF enhancement of CuO/DIW nanofluids according to manufacturing methods is not happened.

REFERENCES

[1] In Cheol Bang, Soon Heung Chang, Boiling heat transfer performance and phenomena of Al_2O_3-water nano-fluids from a plain surface in a pool, International Journal of Heat and Mass Transfer, Vol. 48, 2005

[2] Stephen U. S. Choi, Nanofluids:From Vision to Reality Through Research, Journal of Heat Transfer, Vol. 131, March 2009