

# CHF enhancement in pool boiling of nanofluid : effect of nanoparticle-coating on heating surface

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## 1. Introduction

Recently researches to enhance CHF using the nanofluid, a new kind of heat transfer fluid in which nano-particles are uniformly and stably dispersed, were attempted. You [1] showed that nanofluid, containing only 0.005 g/l of alumina nanoparticle, make the dramatic increase (~200%) in CHF in pool boiling at the pressure of 2.89 psia ( $T_{\text{sat}}=60$  °C). They concluded that the abnormal CHF enhancement of nanofluid cannot be explained with any existing models of CHF. Vassallo [2] performed the experimental studies on pool boiling heat transfer in water-SiO<sub>2</sub> nanofluid under atmospheric pressure. They showed a remarkable increase in CHF for nanofluid and also found that the stable film boiling at temperatures close to the melting point of the boiling surface are achievable with the nanofluid. After the experiments, they observed that the formation of the thin silica coating on the wire heater was occurred.

This paper focuses on the experimental study of the effect of nanoparticle-coating on CHF enhancement in pool boiling of nanofluid. In this regard, pool boiling CHF values are measured and compared (a) from bare heater immersed in nanofluid and (b) from nanoparticle-coated heater, which is generated by deposition of suspended nanoparticles during pool boiling of nanofluid, immersed in pure water, and (c) from nanoparticle-coated heater immersed in nanofluid. And the microstructure of each heating surface is investigated from photography taken using SEM.

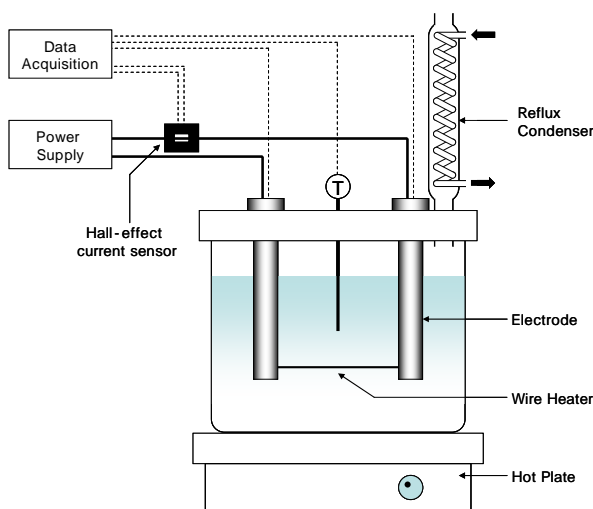


Figure 1. Schematic diagram of experimental facility

## 2. Experiment

### 2.1. Preparation of nanofluid

There are several water-based nanofluids according to the kind of the nanoparticles dispersed in water. In the present investigation, TiO<sub>2</sub> nanoparticles, which are commercially mass-produced as photo-catalyst, were adopted to make the nanofluid. TiO<sub>2</sub> nanoparticles used in this work were produced by Sol-Gel process of Advanced Nano Product Corporation. To produce stable water-TiO<sub>2</sub> nanofluid, TiO<sub>2</sub> nanoparticles were dispersed in water by long ultrasonic vibration of 3 hours.

### 2.2. Pool boiling experiment

Figure 1 shows the experimental facility for pool boiling test. The experiment was performed by slowly increasing the power supplied to wire heater and the occurrence of CHF phenomena was detected by the breakdown of wire heater.

## 3. Result and discussion

Figure 2(a) shows CHF values from bare heater immersed in nanofluids with different particle volume concentration. As increasing the volume concentration of nanoparticle, CHF rapidly increased from  $10^{-7}$  to  $10^{-4}$  and then saturated near  $10^{-3}$ . To compare the results to experimental data of You [1],  $\text{CHF}_{\text{nanofluids}}/\text{CHF}_{\text{water}}$  were evaluated as shown in figure 2(b). The trend of CHF was same, but quantitatively the enhancement was different due to disagreement of experimental parameters such as particle kind, saturation pressure, and heater geometry. As shown in figure 3, CHF enhancement in pool boiling of nanofluid was sufficiently obtained in pool boiling CHF test on nanoparticle-coated heater immersed in pure water. In particular in the high particle concentration, CHF on coated heater immersed in pure water largely exceeded CHF of nanofluid. For this result, figure 4 shows the effect of nanoparticles, floating in nanofluid, on CHF. That is, this result shows that nanoparticle inside cooling liquid reduced CHF enhancement by nanoparticles coated on heating surface.

Figure 5 shows the surface pictures of heaters after above tests. After the pool boiling of nanofluid, a lot of microstructures was formed by the deposition of nanoparticles.

#### 4. Conclusion

The coating of nanoparticles formed on the heating surface during pool boiling of nanofluid accounts rigorously for the enhancement of CHF, however, the existence of nanoparticles in the cooling liquid is expected to degrade the CHF enhancement obtained by nanoparticle-coating of heating surface.

#### REFERENCES

- [1] S. M. You, J. H. Kim, and K. H. Kim, Effect of nanoparticles on critical heat flux of water in pool boiling heat transfer, Applied Physics Letters Vol. 83, No. 16, pp. 3374-3376, 2003.  
 [2] P. Vassallo, R. Kumar, and S. D'Amico, Pool boiling heat transfer experiments in silica-water nano-fluids, Int. J. Heat Mass Transfer, Vol. 47, No. 2, pp. 407-411, 2004.

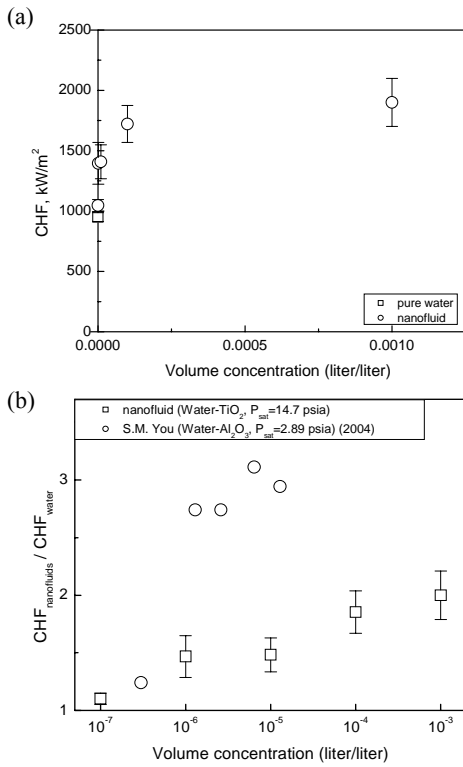


Figure 2. CHF of nanofluid

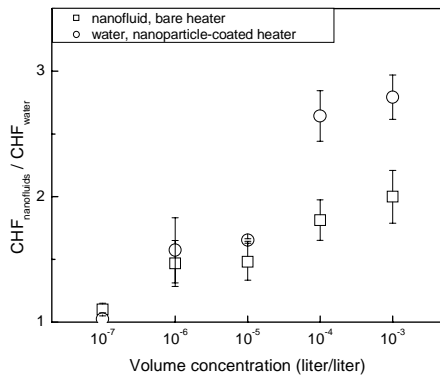


Figure 3. CHF (□) on bare heater immersed in nanofluid, (○) on nanoparticle-coated heater immersed in pure water

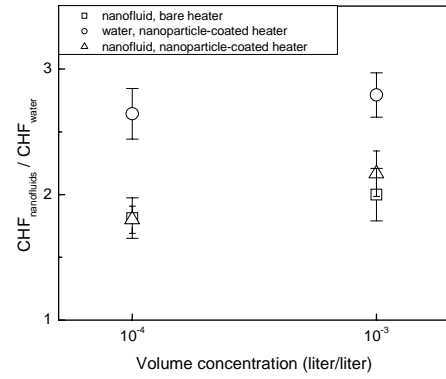


Figure 4. CHF (□) on bare heater immersed in nanofluid, (○) on nanoparticle-coated heater immersed in pure water, (Δ) on nanoparticle-coated heater immersed in nanofluid

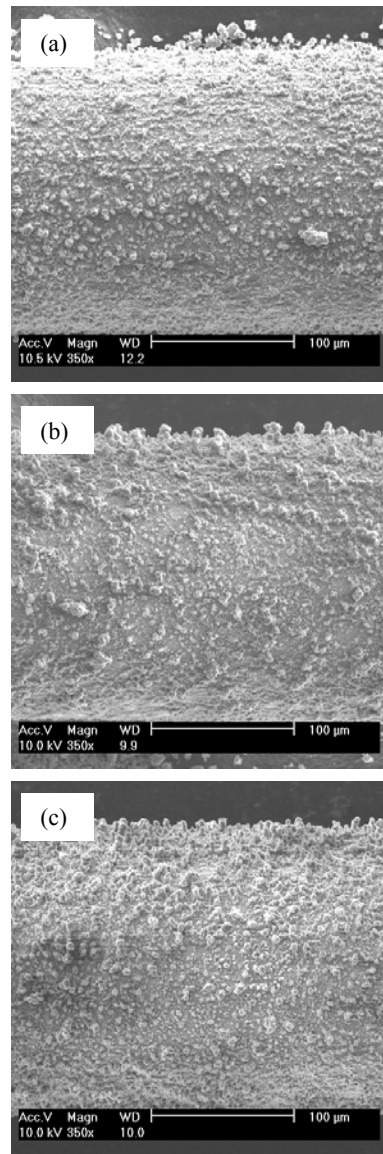


Figure 5. SEM pictures of heater surface after pool boiling CHF (a) on bare heater immersed in nanofluid, (b) on nanoparticle-coated heater immersed in pure water, (c) on nanoparticle-coated heater immersed in nanofluid (with particle volume concentration of 10⁻³ liter/liter)