MEMS Labs
MEM Departmemt NSYSU

Subcooled Convective Boiling in Structured Surface Microchannels

Shou-Shing Hsieh

Department of Mechanical and Electro-Mechanical Engineering
National Sun Yat-Sen University
Kaohsiung,Taiwan

March 31, 2011

Items

MEMS Labs
MEM Departmemt NSYSU

Abstract

Test Section and Flow Loop

Experimental Results

1.Effect of geometry and flow parameter on CHF

2.Boiling curve/ two phase heat transfer coefficient

3.Bubble ebullition cycle

4.Flow pattern and morphology

5.Enhancement performance ratio

6.Comparison with existing data

Conclusions

Salient References

Abstract

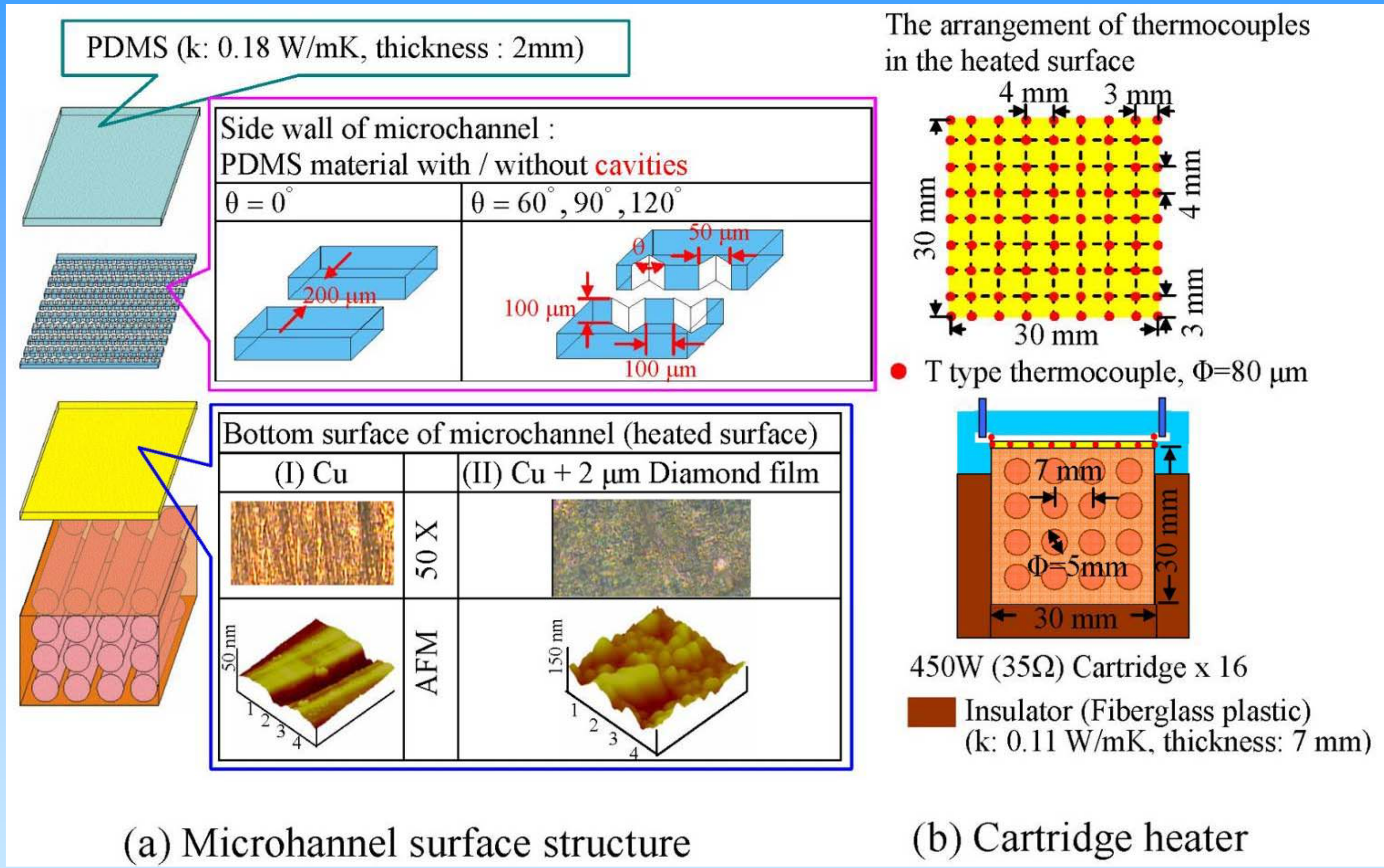
MEMS Labs
MEM Departmemt NSYSU

Experiments are performed to investigate *subcooled flow boiling of DI water and FC-72 in* parallel microchannels, and try to rise the critical heat flux (CHF) and heat transfer coefficient to enhance the cooling efficiency. Three major methods were used in this study below:

1. To add the *cavity angle* of θ = *60°*, *90°*, and *120°* on the microchannel side walls.
2. To coat *2 μm diamond film* in the Cu heated surface.
3. To add *1 vol. %* Multi-walled Carbon Nanotube *(MCNT)* into the working medium (de-ionized water).

Test Section

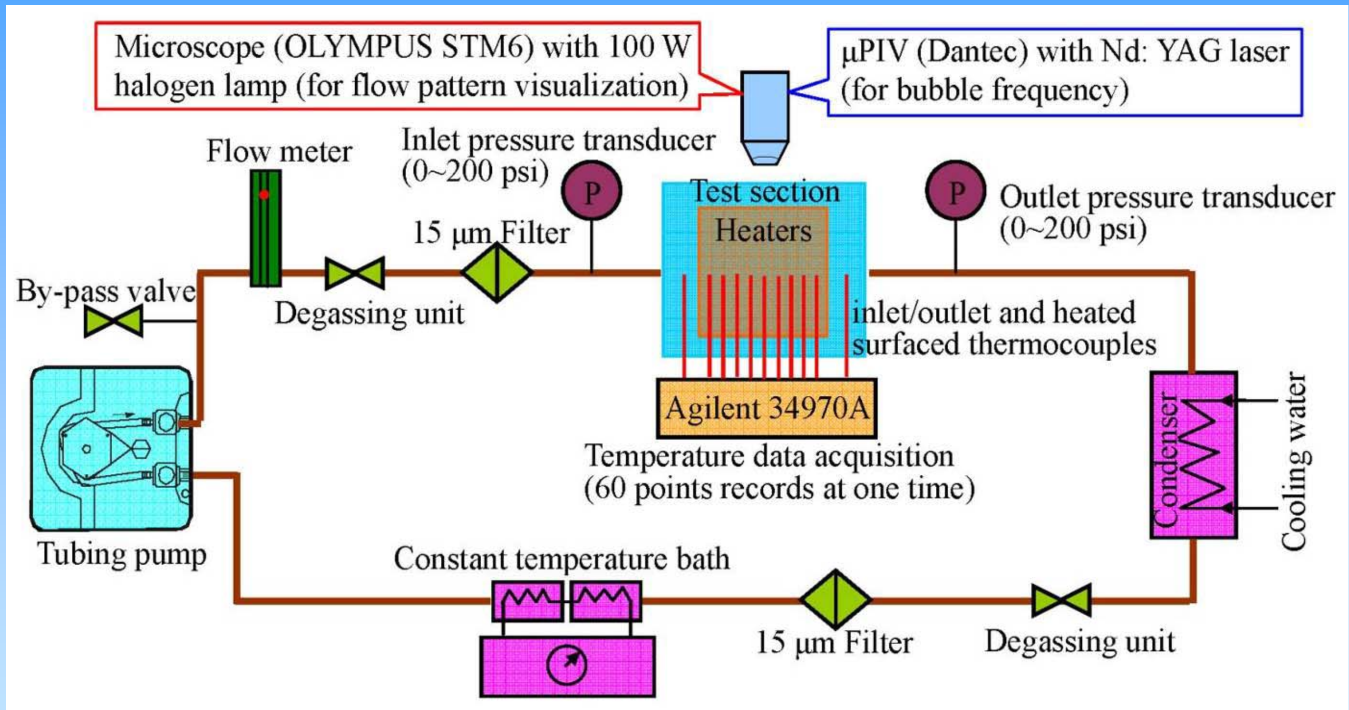
MEMS Labs
MEM Department NSYSU



Schematic of (a) microchannel surface structure (b) cartridge heater

Flow Loop

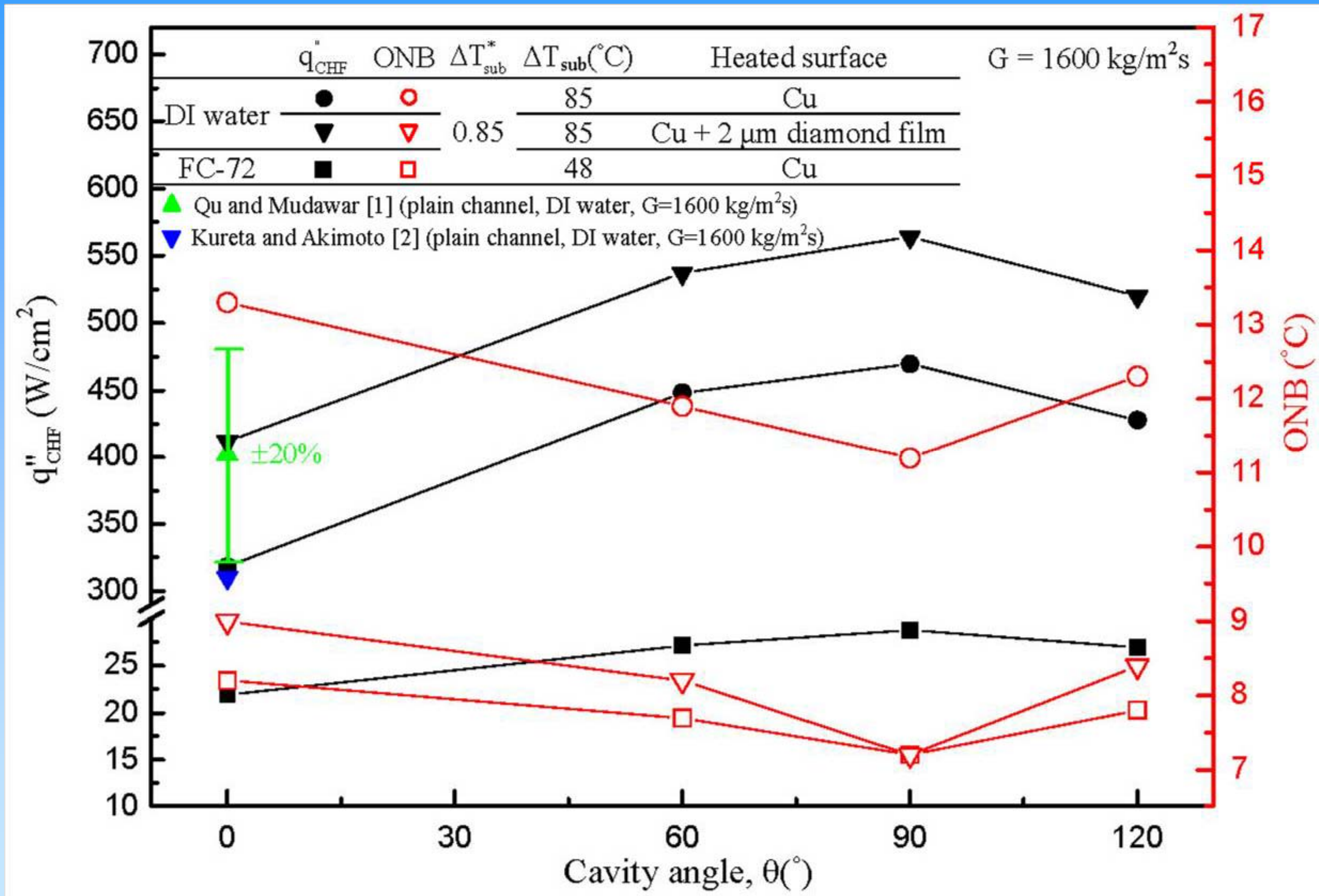
MEMS Labs
MEM Departmemt NSYSU



Test flow loop

Experimental Results

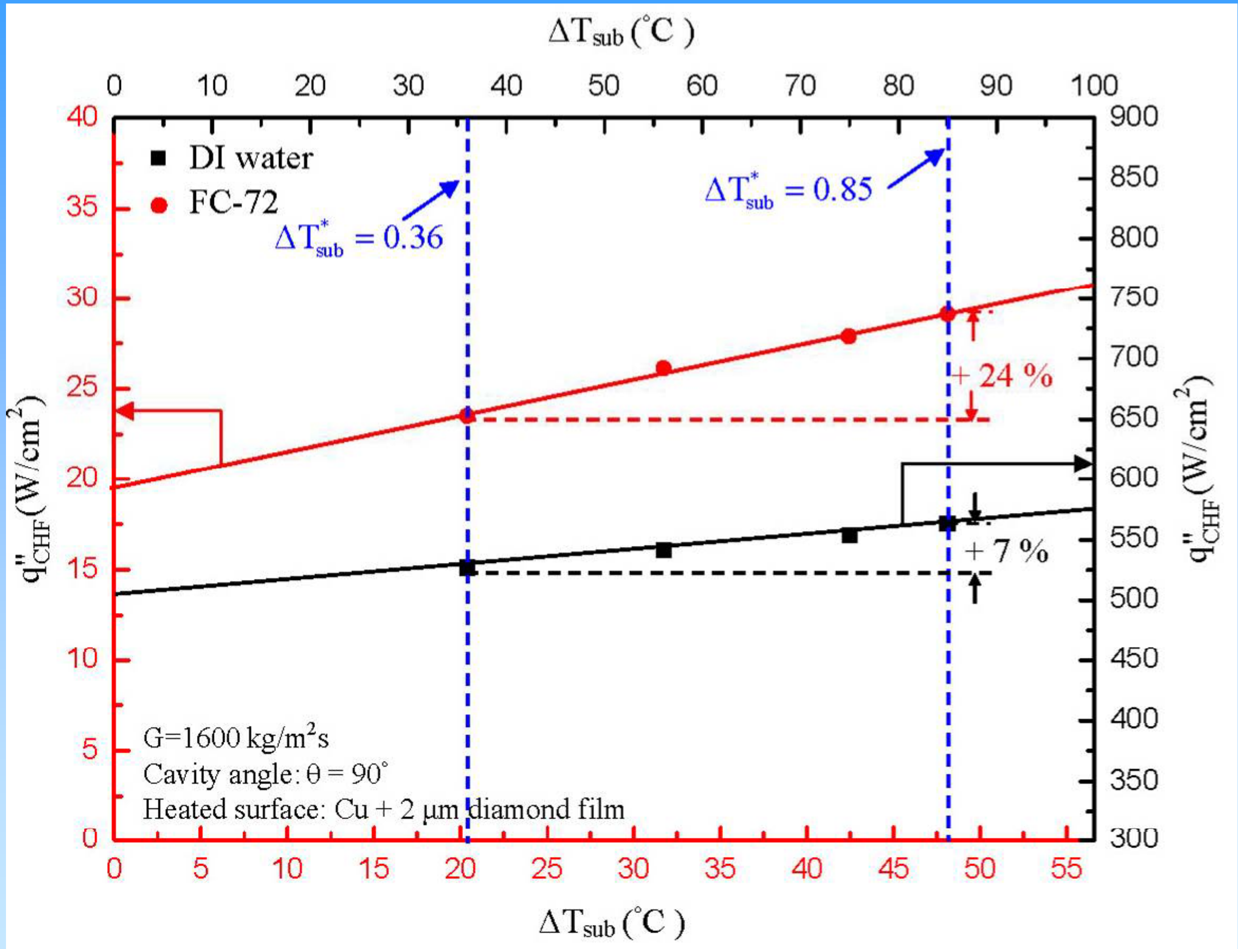
MEMS Labs
MEM Departmemt NSYSU



The cavity angle influence on q''_{CHF} and ONB

Experimental Results *(continued)*

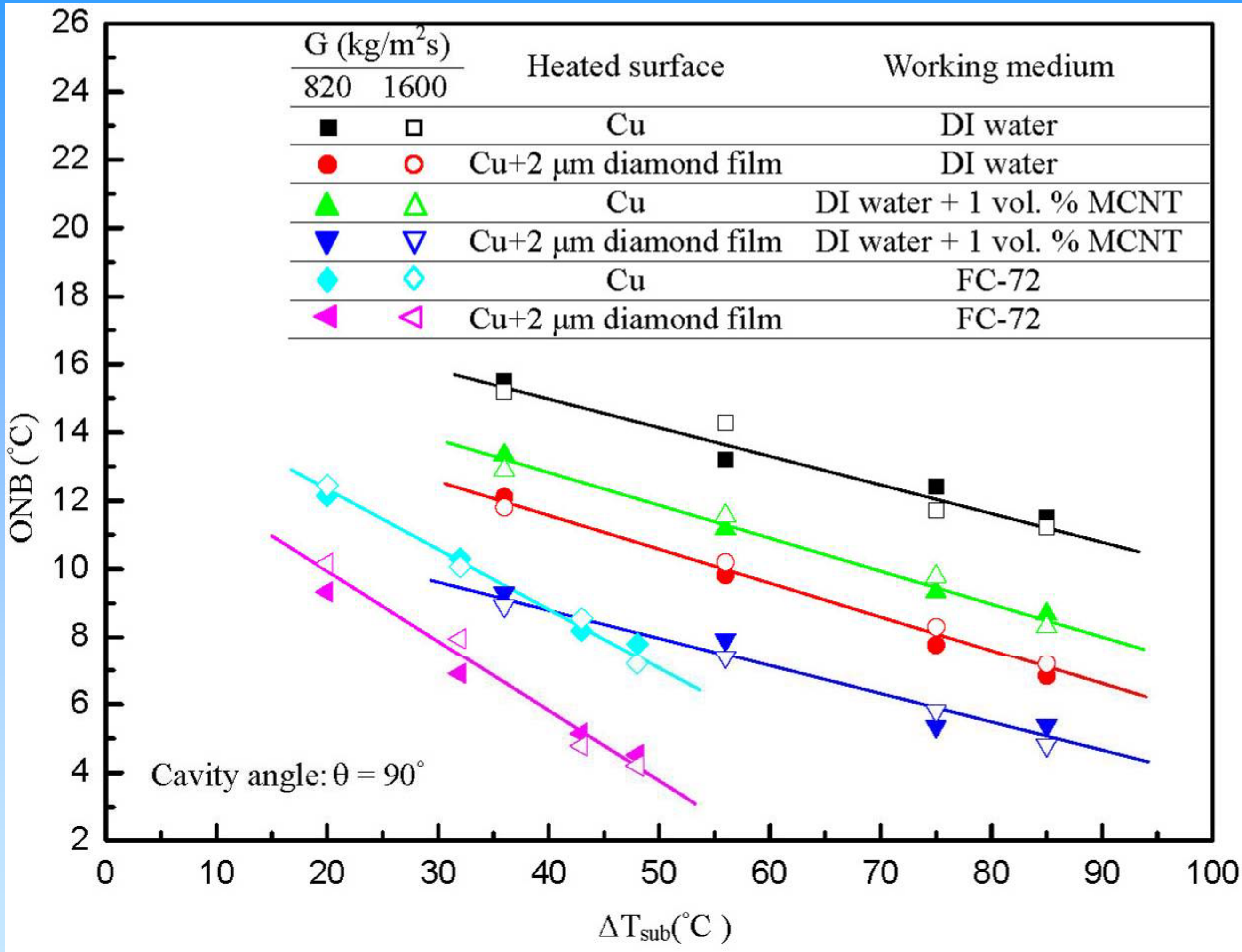
MEMS Labs
MEM Department NSYSU



Effect of subcooling on CHF for Water and FC-72

Experimental Results (continued)

MEMS Labs
MEM Departmemt NSYSU

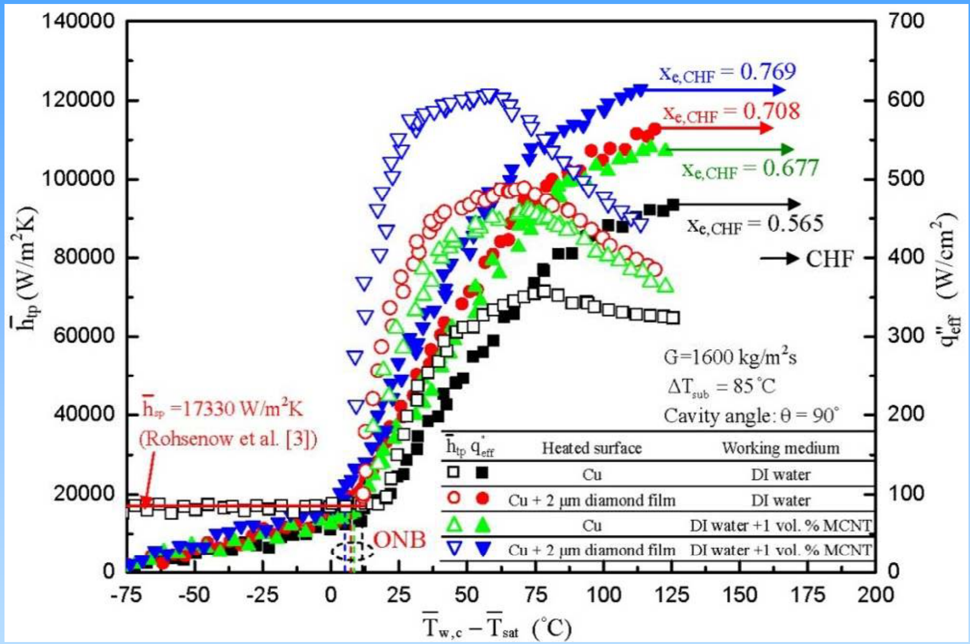


Effect of mass flux and subcooling on ONB for different test fluids

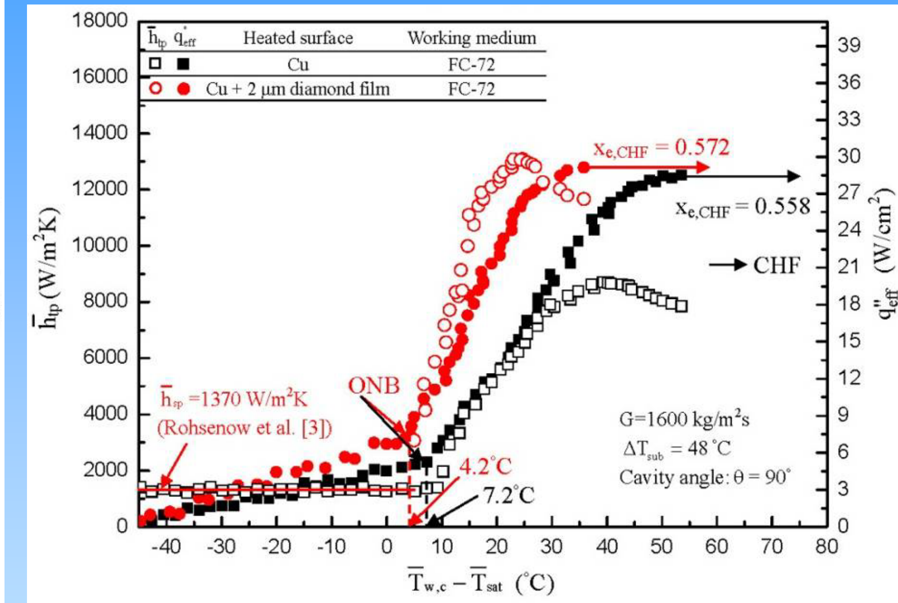
Experimental Results *(continued)*

MEMS Labs
MEM Department NSYSU

(a)

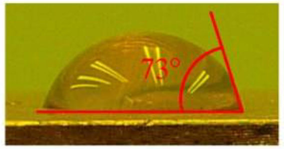
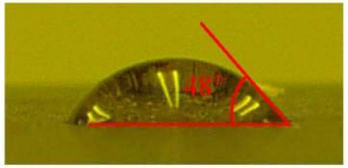
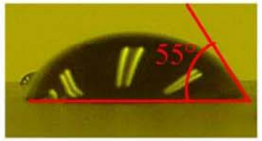
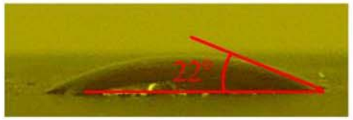
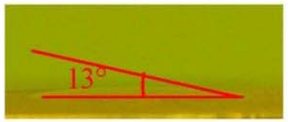
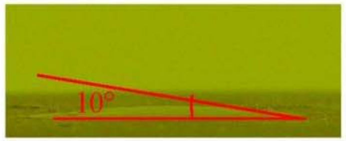


(b)



The boiling curves and average two-phase heat transfer coefficient of
(a) DI water with / without 1 vol. % MCNT (b) FC-72

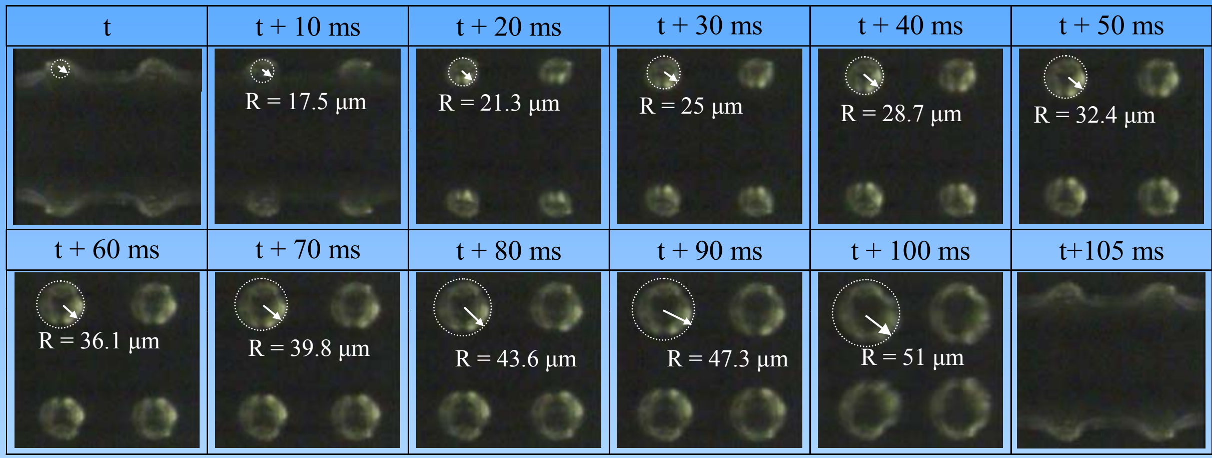
Experimental Results *(continued)*

Working medium	Bottom surface of microchannel (heated surface)	
	Cu	Cu + 2 μm Diamond film
DI water		
DI water + 1 vol. % MCNT		
FC-72		

The contact angle (θ_c) of different heated surface and working medium

Experimental Results *(continued)*

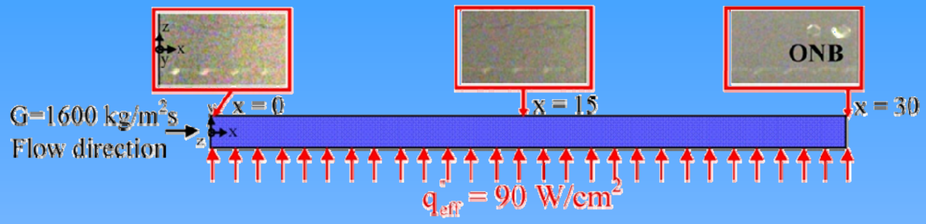
MEMS Labs
MEM Department NSYSU

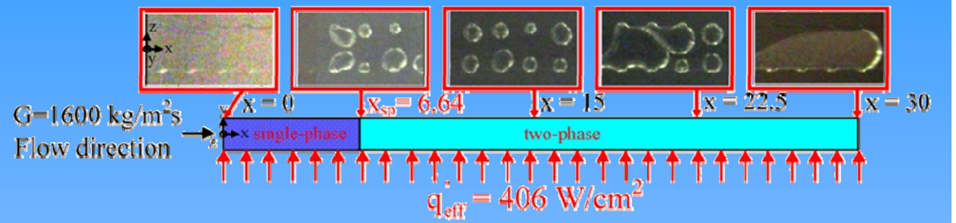


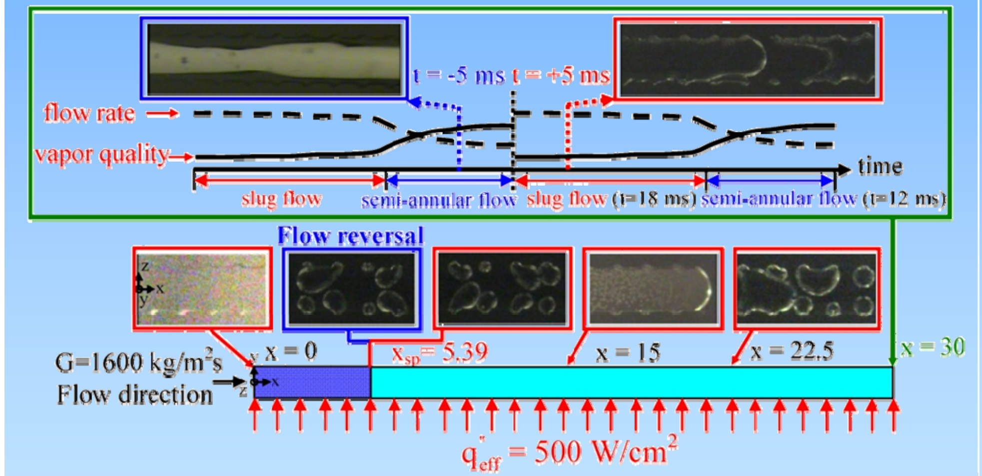
A cycle of bubbles growing near the outlet at q''_{eff} = 105 W/cm^2

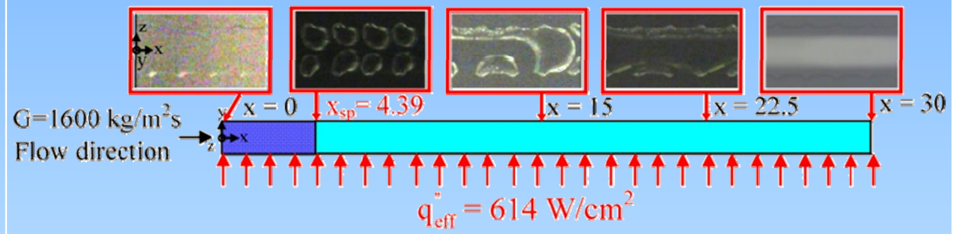
Experimental Results *(continued)*

MEMS Labs
MEM Departmemt NSYSU







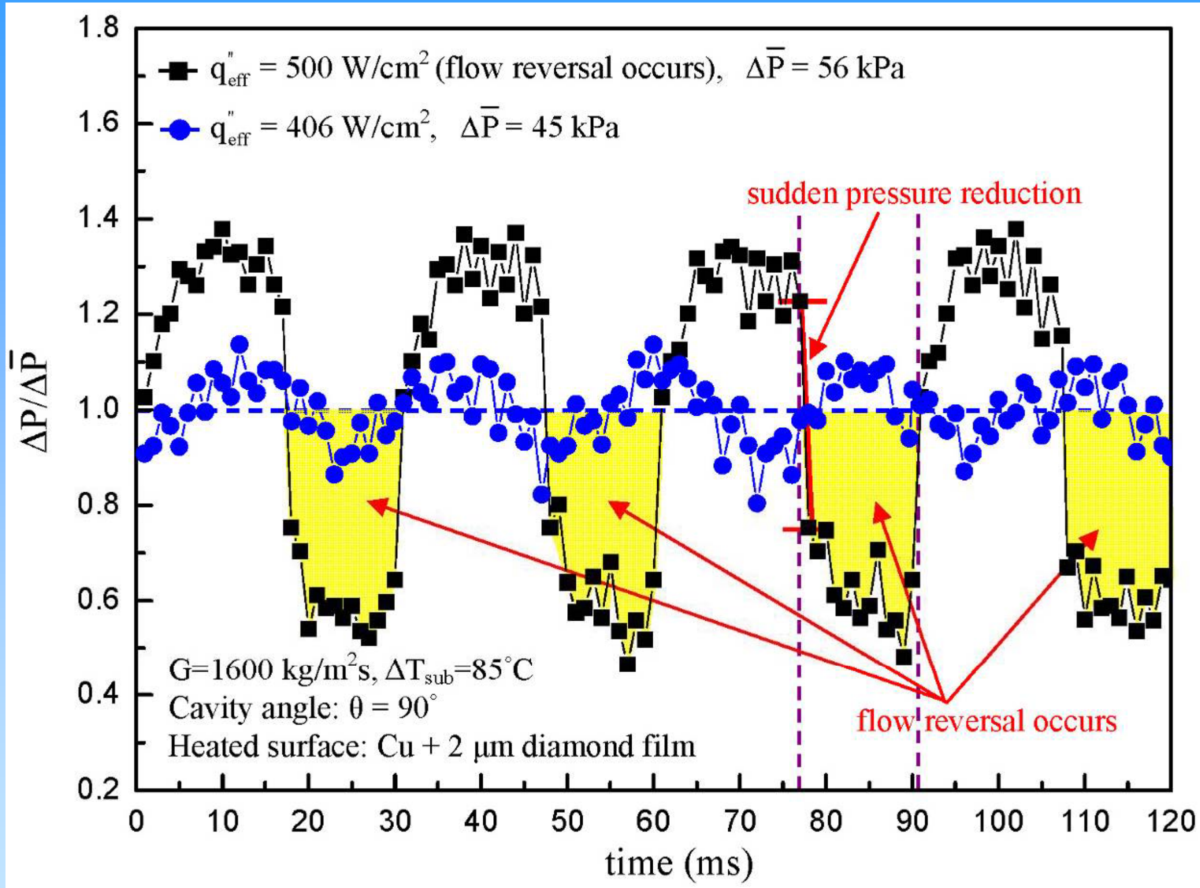


Unit: mm

Flow patterns visualization from inlet to outlet at heat flux q''_{eff} = 90 W/cm^2, 406 W/cm^2, 500 W/cm^2 and 614 W/cm^2 of DI water + 1 vol. % MCNT in the cavities (θ =90°) channel

Experimental Results (continued)

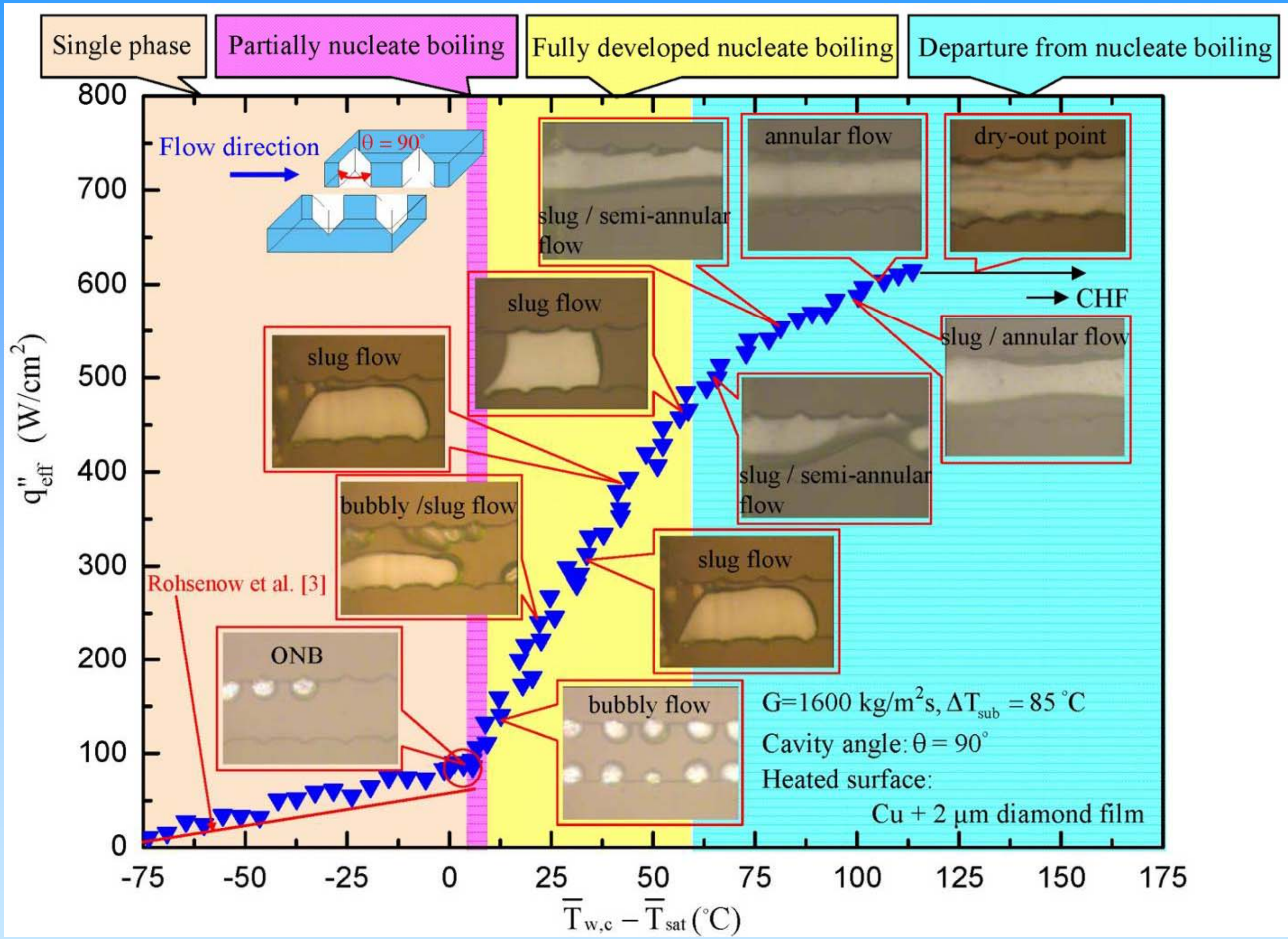
MEMS Labs
MEM Departmemt NSYSU



Pressure drop fluctuations of DI water + 1 vol. % MCNT with / without flow reversal

Experimental Results (continued)

MEMS Labs
MEM Departmemt NSYSU

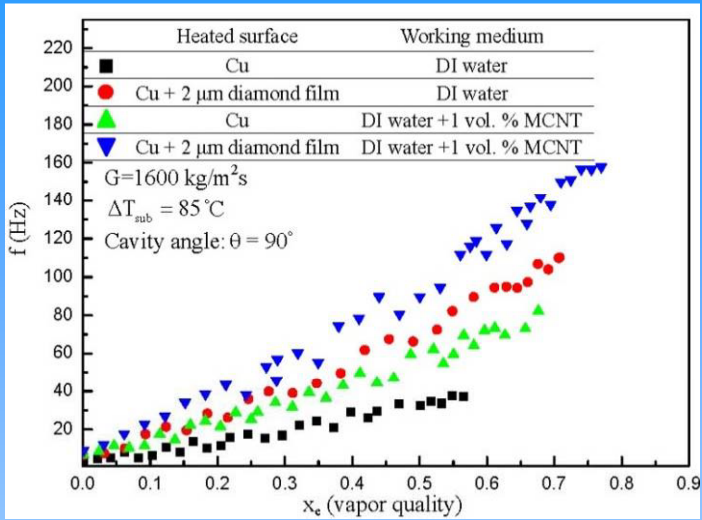


The boiling curve and corresponding flow patterns of DI water + 1 vol. % MCNT

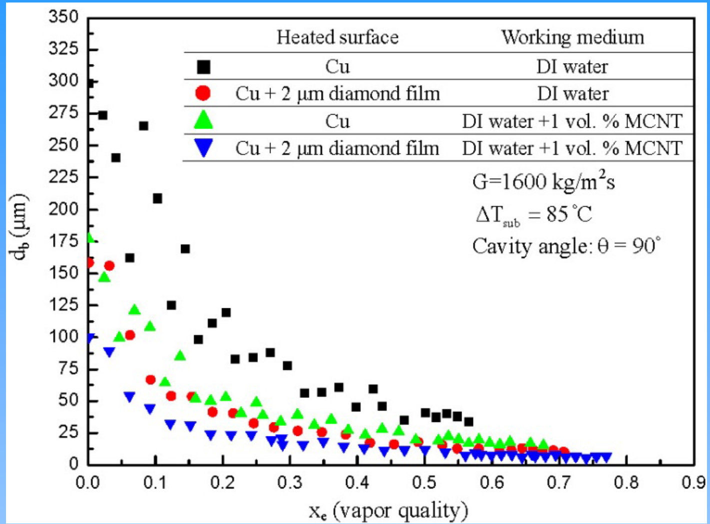
Experimental Results *(continued)*

MEMS Labs
MEM Department NSYSU

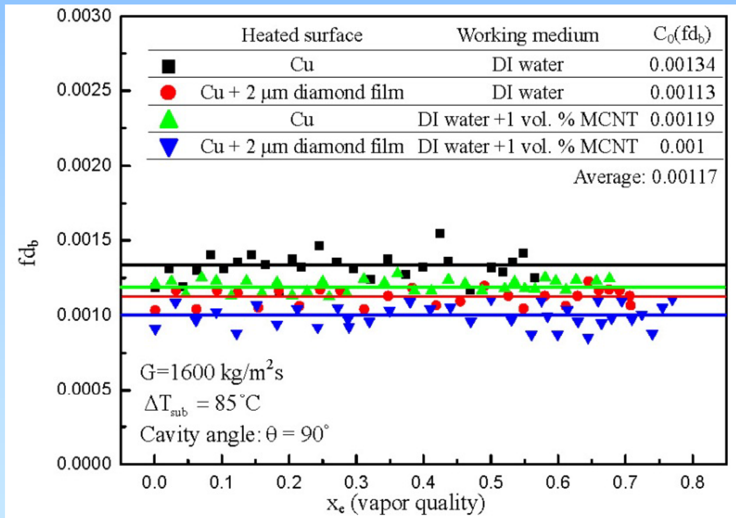
(a)



(b)



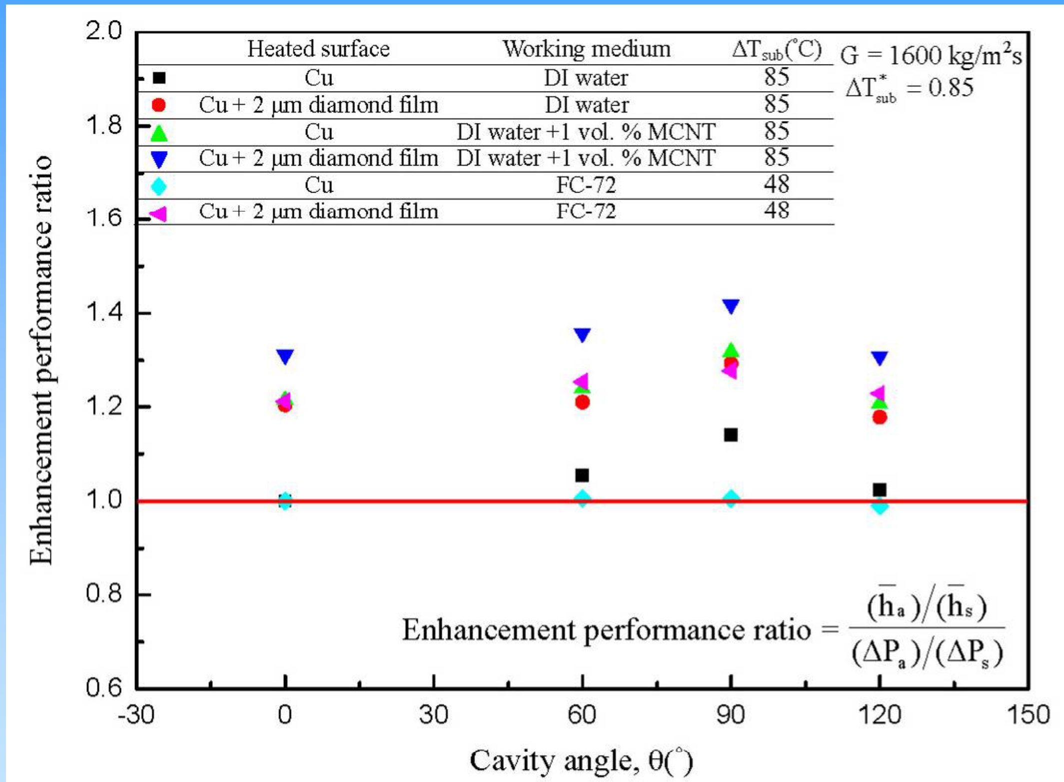
(c)



(a) bubble departure frequency and (b) the corresponding bubble departure diameter
(c) $fd_b = C_0$ at an active nucleation site near the outlet

Experimental Results *(continued)*

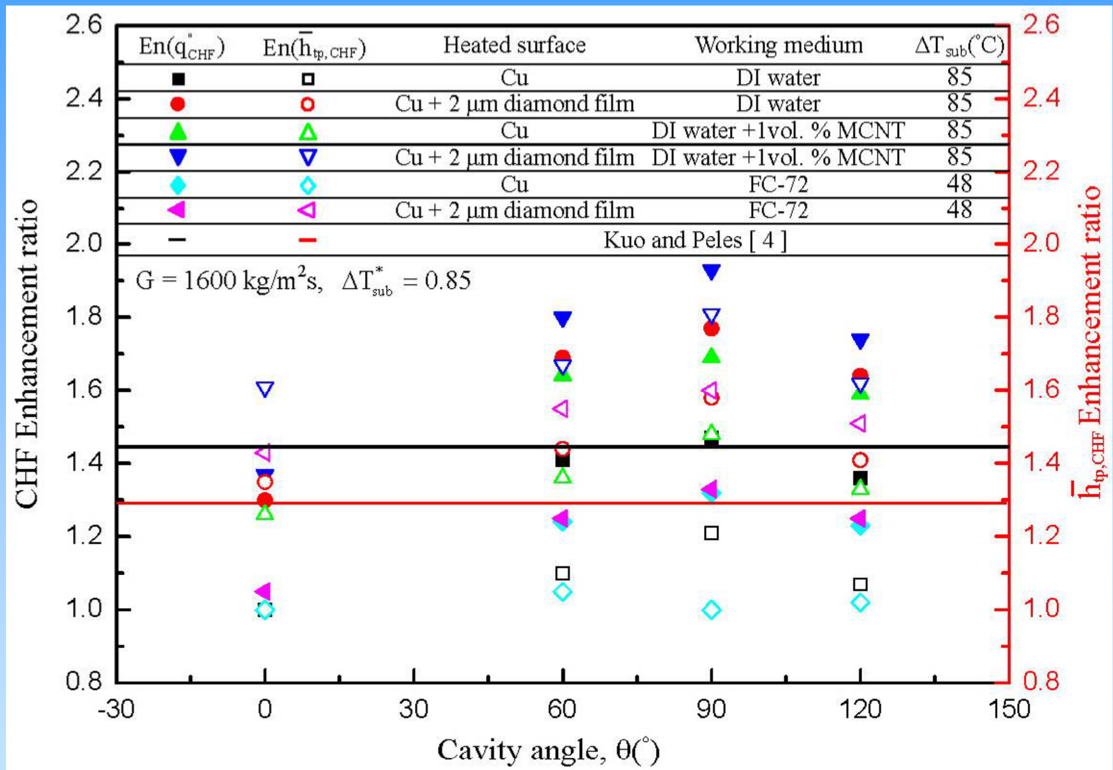
MEMS Labs
MEM Departmemt NSYSU



The enhancement performance ratio with different experimental conditions

Experimental Results *(continued)*

MEMS Labs
MEM Department NSYSU



The comparison with present study and existing data in CHF and enhancement ratio

Conclusions

MEMS Labs
MEM Departmemt NSYSU

1. The effects of test fluids, heating / wall surface conditions, degree of subcooling, and mass velocity on ONB, $\bar{h}_{tp}$, q''_{eff} and q''_{CHF} were clearly noted.

2. DI water with *1 vol. % MCNT* particle additive in a Cu + 2 μm diamond film coating heating surface microchannel with internally structured surfaces had a superior thermal performance. It was found that the heat transfer enhancement ratio could be as high as *1.9* for a definite cavity angle.

3. An optimal cavity angle (θ) of 90° with *an enhancement performance ratio of 1.4* was found, as far as both heat transfer and pressure drop were concerned.

4. Following remark 1 and 2, a much higher heat flux was found at *614 W/cm²*.

5. The complex/combined effect of structured/thin film coating surface and nanofluids working medium on heat transfer enhancement in a flow boiling microchannel was found to be significant.

Salient References

MEMS Labs
MEM Departmemt NSYSU

1. W. Qu, and I. Mudawar, “Measurement and correlation of critical heat flux in two-phase micro-channel heat sinks,” International Journal of Heat and Mass Transfer, Vol. 47, 2004, pp. 2045-2059.

2. M. Kureta, and H. Akimoto, “Critical Heat Flux Correlation for Subcooled Boiling Flow in Narrow Channels,” Int’l. J. Heat Mass Transfer, Vol. 45, 2002, pp. 4107-4115.

3. W. M. Rohsenow, J. P. Hartnett, and E. N. Ganic, Handbook of Heat Transfer Fundamentals 2nd edn, New York: McGraw-Hill, 1985. pp. 7-94.

4. C. J. Kuo, and Y. Peles, “Local Measurement of Flow Boiling in Structured Surface Microchannels,” Int. J. Heat and Mass Transfer, Vol. 50, 2007, pp.4513-4526.

5. S. -S. Hsieh, and C. Y. Lin, “Scbcooled Convective Boiling in Structured Surface Microchannels,” Journal of Micromechanics and Microengineering, Vol. 20, 2010, 015027(13pp).

MEMS Labs
MEM Departmemt NSYSU

Thanks for Your Attention !