A Novel Benzocyclobutene-Based Device for Studying the Physics of the Ebullition Process

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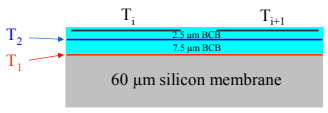
Motivation and Background

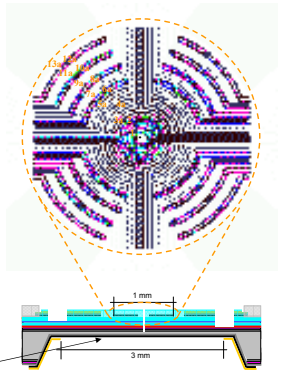
- Nucleation is the fundamental process responsible for high heat transfer during boiling
- Recent high speed photography of liquid film on heat transfer surface in spray cooling process shows massive nucleation within the liquid layer
  - ➢ Potentially a major contributor to heat transfer
- Many hypothesis have been developed over the past century about the mechanism of nucleation and heat and mass transfer
  - The hypothesis have not been experimentally verified due to the difficulties of conducting experiment at microscales
  - New developments in microfabrication of polymer microstructures now provide an avenue to perform microscale measurements

Micro Array Design and Fabrication

- **Main concept:**
  - Fabrication of a high resolution/fast response array of temperature and heat flux sensors around a cavity
  - Local Heat Flux (LHF) α T_1-T_i
  - Average Heat Flux (AHF) α T_1-T_2

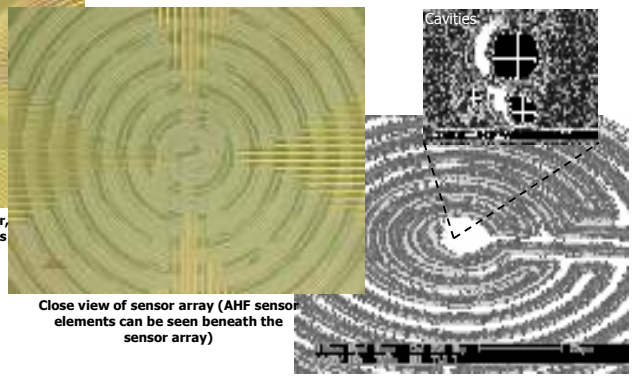


Heat flux measurement concept



Schematic of sensor array and device cross section

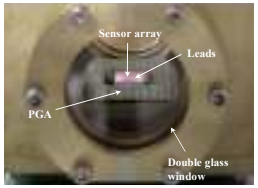
Wide view of sensor array , AHF sensor, and their gold leads (note that sensors are in three different layers)



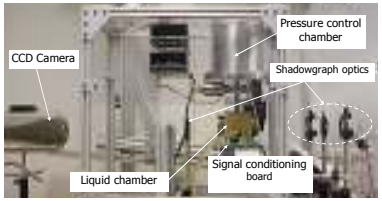
Close view of sensor array (AHF sensor elements can be seen beneath the sensor array)

Experimental Setup

- Sensor array is wire bounded to a PGA
- PGA is epoxied to bottom cap of liquid chamber
- A liquid jacket surrounds the test liquid chamber to keep it at constant temperature



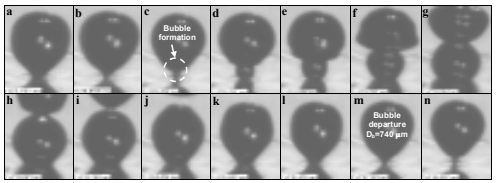
Sensor array and PGA in liquid chamber

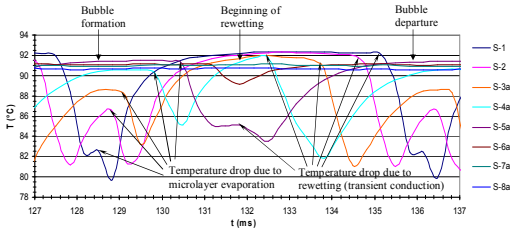


- PGA is connected to a custom made Signal Conditioning Board (SCB)
- SCB is connected to A/D board
- Shadowgraph technique and CCD camera are used to capture the bubble images

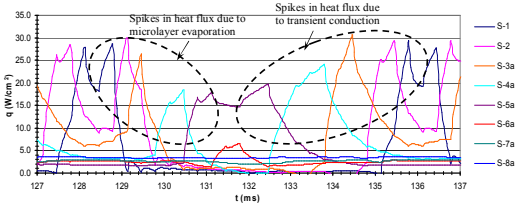
Test Results and Analysis

- **Test Conditions:**
  - Liquid: FC-72 (T_{sat}=56.7 °C)
  - Test condition: saturation
  - A/D sampling rate: 8000 Hz
  - CCD camera : 8000 frames/sec
  - T_1= 90.81 °C
- **Test Results:**
  - Bubble frequency ≅ 110 Hz
  - Bubble diameter ≅ 740 μm
  - Almost no waiting time
  - Symmetric temperature at four quadrants
  - Heat flux increase of 4-5 times underneath the bubble, at the bubble/surface contact area
    - ➢ due to microlayer evaporation (microlayer profile is determined using the heat flux results)
    - ➢ due to surface rewetting
  - Insignificant changes of heat flux outside the contact area





Surface temperature variations under the bubble. Temperatures are symmetric at the four sensor array quadrants.



Heat flux variations at the surface. The area under each curve shows the total heat transfer.