Measurement of Active Nucleation Site Density according to Surface Roughness in a Water Electrolysis

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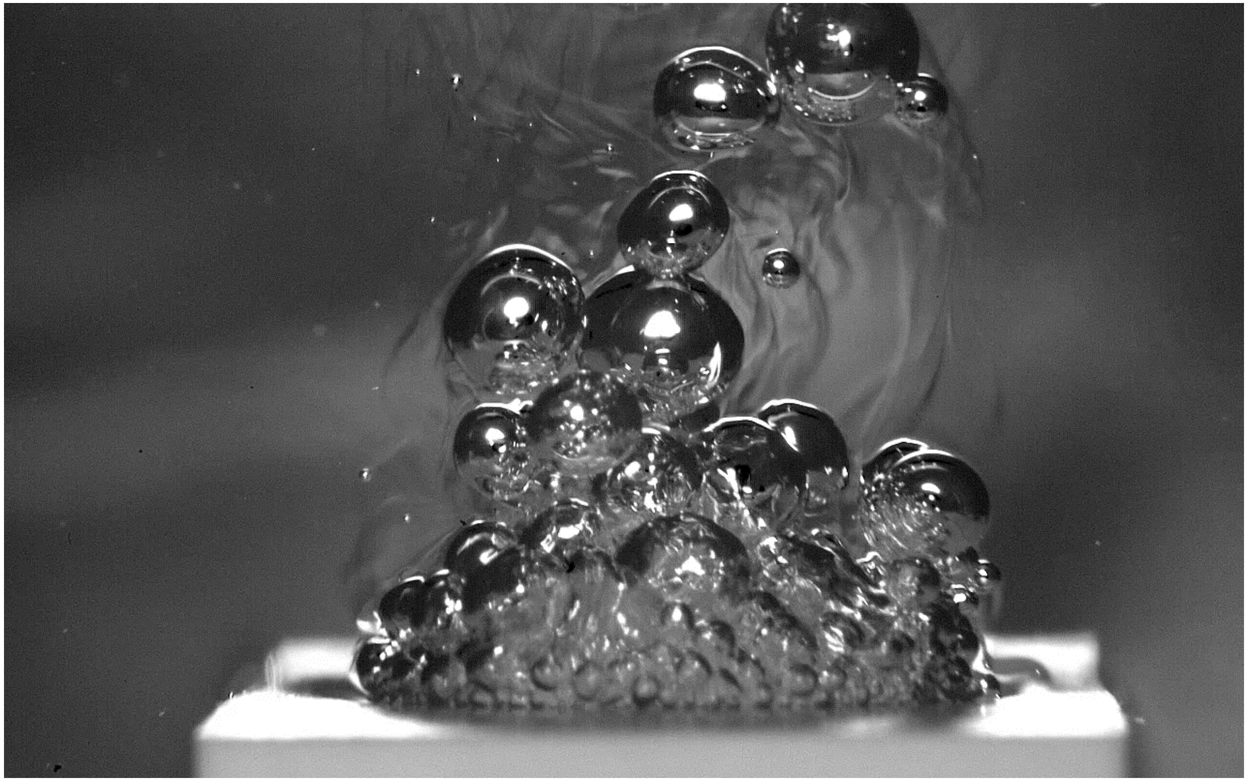
Background

Hydrogen production water electrolysis

- Copper electrode
- 1.5 M of H_2SO_4 solution



Background

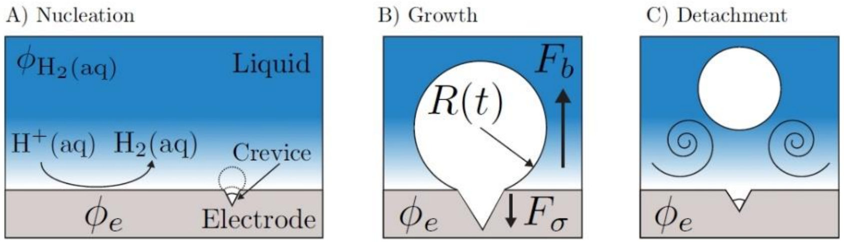
Conventional analogy between heat and mass transfer

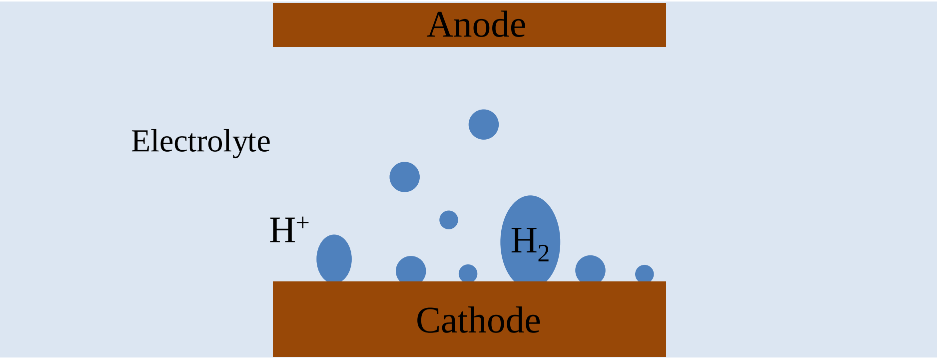
Similar flux equations

- Heat flux (W/m^2) ↔ Current density (A/m^2)
- Temperature ↔ Concentration (Estimated by cell potential)

Similar bubble generation mechanism

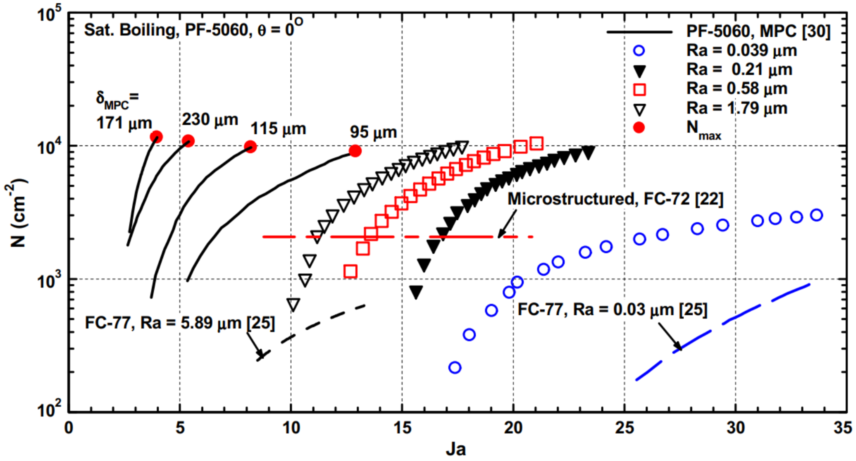
Bubble growth takes place at surface cavity where tiny gas is entrapped in





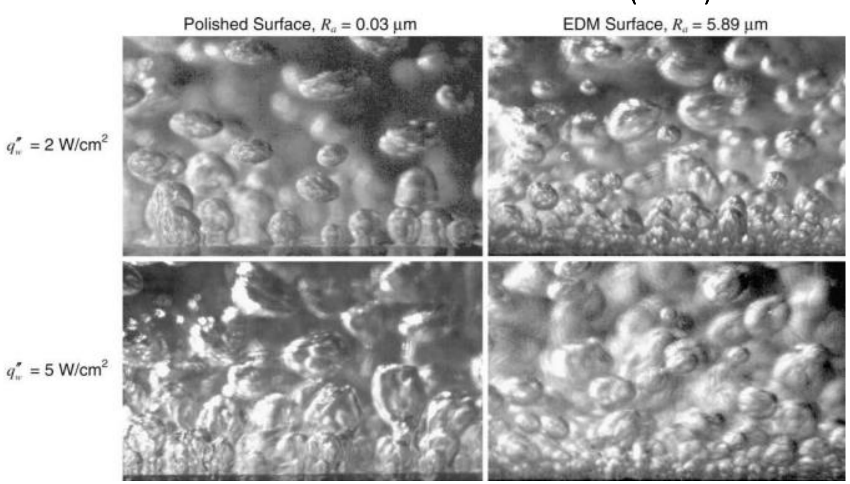
Existing studies

Active nucleation site density (N_a) increased as surface roughness increased



< A. Suszko and M. S. El-Genk (2015)>

$$Ja = \frac{c_{pl}\rho_l (T_w - T_{sat})}{\rho_v h_{lv}}$$



<J.P. McHale and S.V. Garimella (2010)>

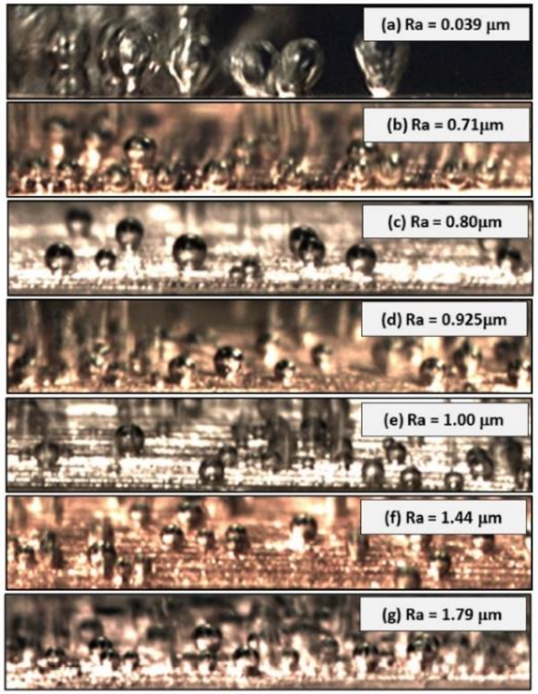


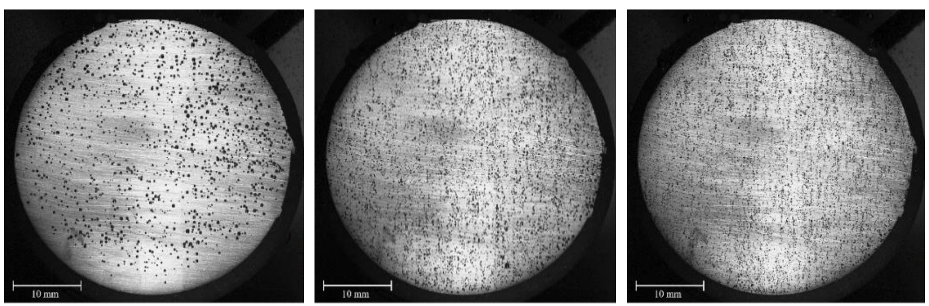
Fig. 7. Still photographs of saturation boiling of PF-5060 on various Cu surfaces at ~0.5 W/cm².

< A. Suszko and M. S. El-Genk (2015)>

Existing studies

Active nucleation site density (N_a) increased as current density increased

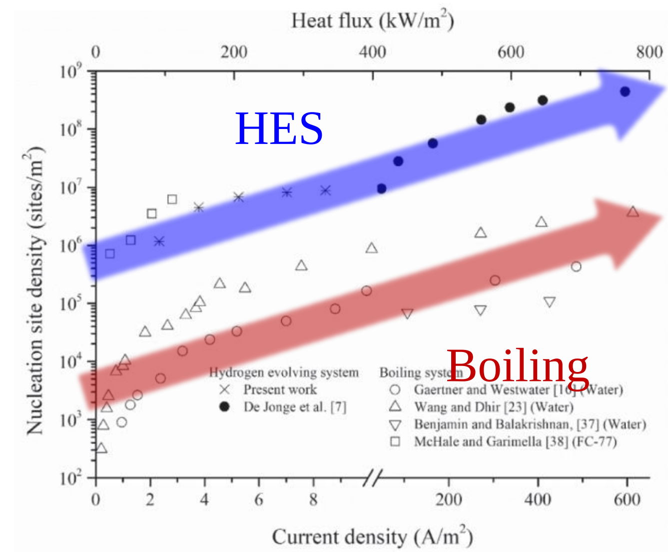
- As the current increased, the N_a increased in both the systems
- However, absolute value of N_a in the hydrogen evolving system was much higher than that in the boiling system



(a) 9.34 A/m^2 (b) 21.00 A/m^2 (c) 33.76 A/m^2

<H.K. Park and B.J. Chung (2021)>

- Copper electrode
- 1.5 M of H_2SO_4 solution

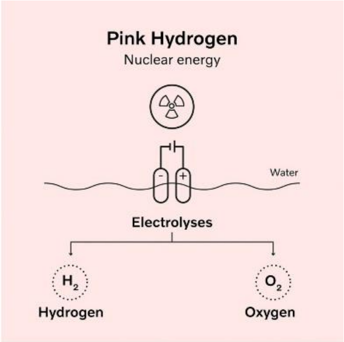


<H.K. Park and B.J. Chung (2021)>

Objectives

Potentially applicable to low-temperature water electrolysis

- For effective hydrogen production (Pink hydrogen)
- Adopting boiling heat transfer knowledge



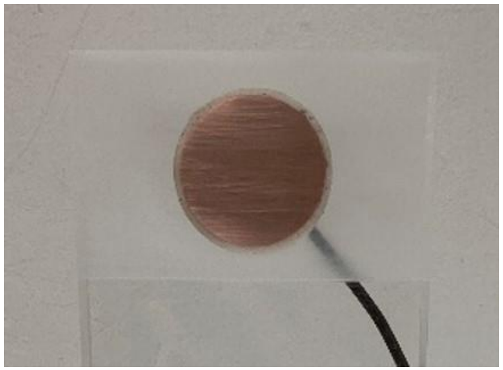
1) To investigate nucleation characteristics of hydrogen in water electrolysis

- Active nucleation site density
- According to surface roughness (hardly found)

2) To extend analogous relationship between heat and mass transfer

- Two-phase flow

Experimental setup



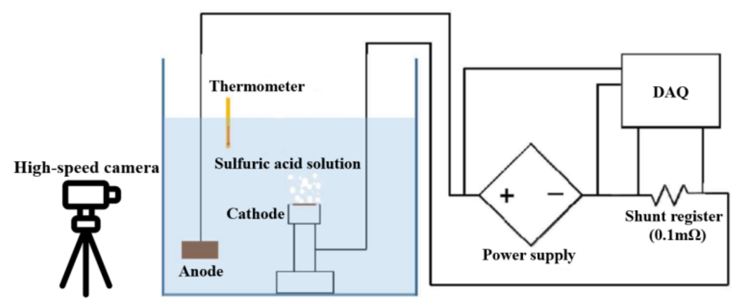
Dia. 40 mm disk
(Vertical, little tilt)

- **Form the roughness of the surface on the cathode**
  - Using #800, #2000, #8000, #15000 Sandpaper
  - Forming a slope of 7 degrees

- **Experimental procedure**
  1. Position 1.5 M sulfuric acid solution in the tank
  2. Apply an electric current (steady-state, 5 min)
  3. Capture the image of cathode using high-speed camera
  4. After capture, increase the current and repeat

Surface geometry	R_a (µm)	Current density (A/m²)
Vertical disk (40 mm dia.)	0.274	2.39
	0.148	3.98
	0.095	5.57
	0.089	7.16
		8.75

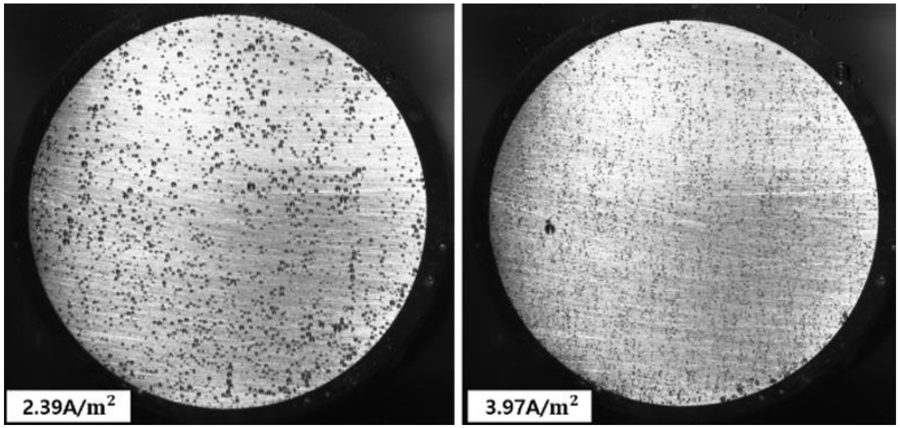
<Test matrix>



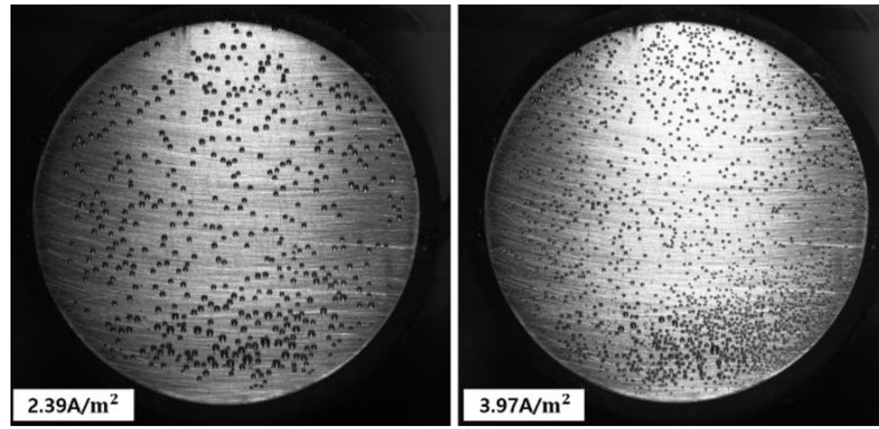
<Test circuit>

Results

(Isolated bubbles were counted manually)



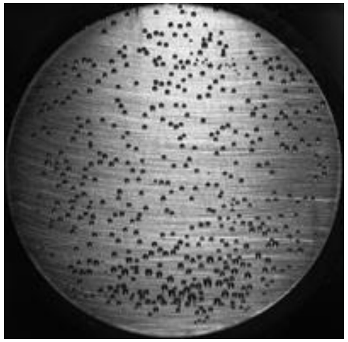
<Number of bubbles in case of R_a = 0.274 μm>



<Number of bubbles in case of R_a = 0.089 μm>

The higher the current density → **Active nucleation site density increases**

<0.089µm> <0.148µm> <0.274µm>



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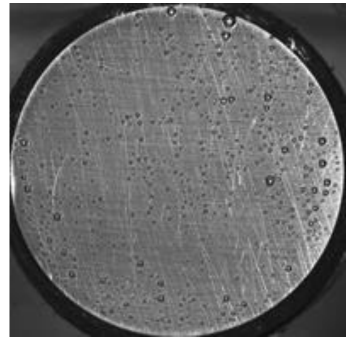

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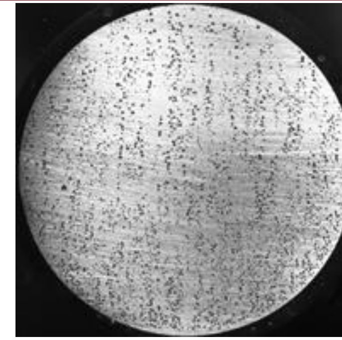

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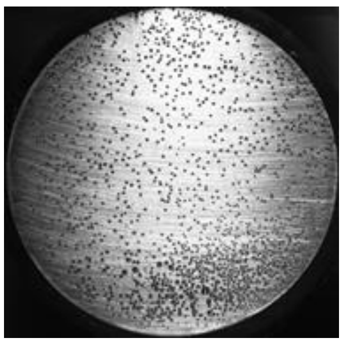

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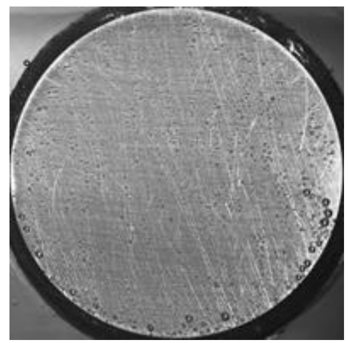

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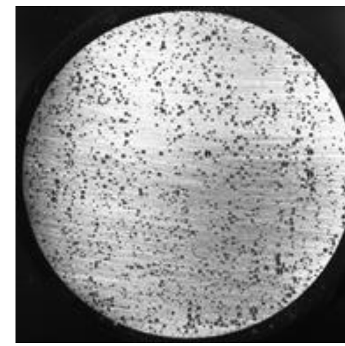

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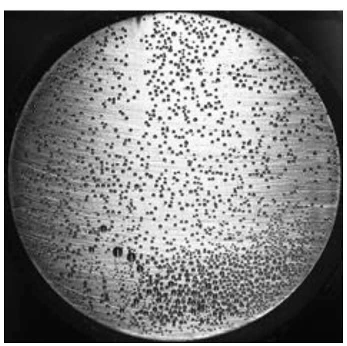

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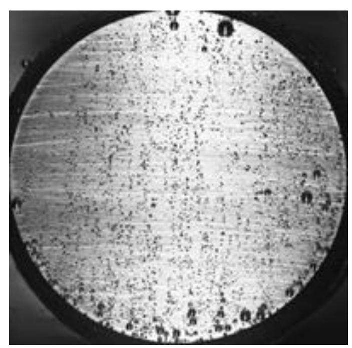

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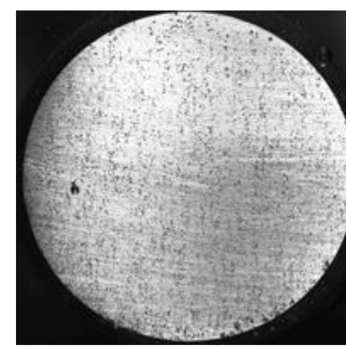

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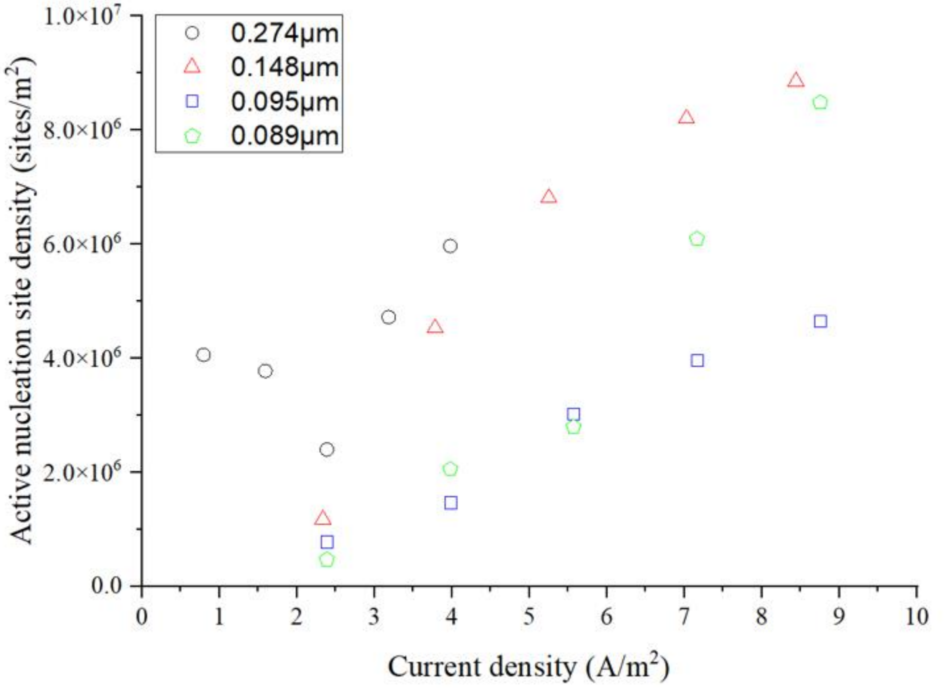
Results

Active nucleation site density (N_a) increased as roughness increased

- Almost similar trend according to current density



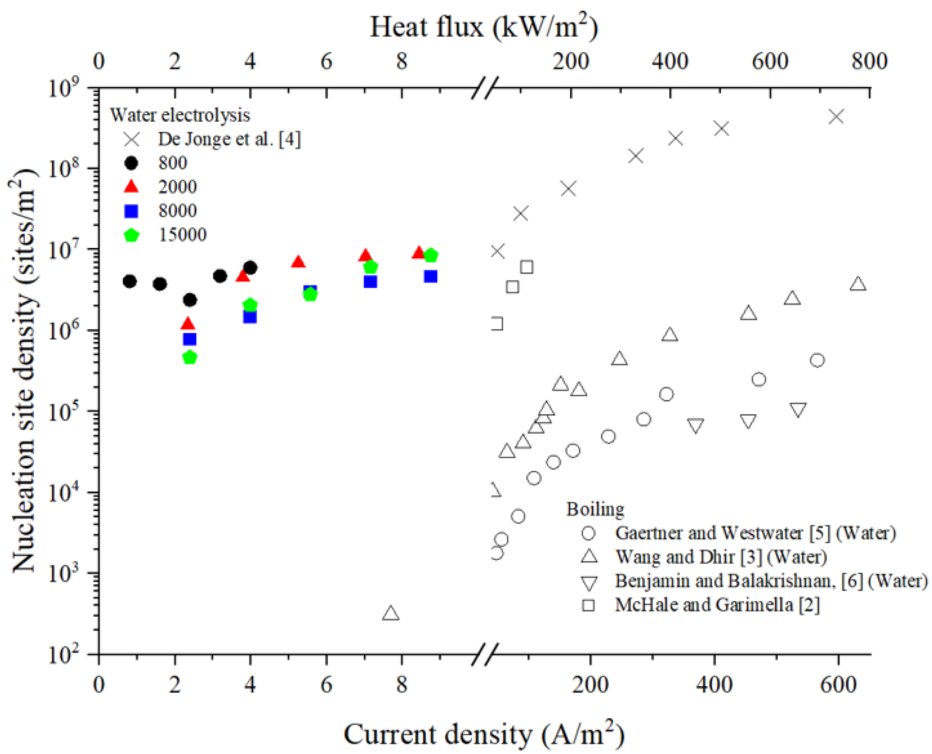
At a roughness of 0.274 μm, the nucleation site density first increases with current density but later decreases in specific regions.

Additional parameters have influenced the nucleation site density, requiring further investigation.

Results

Results showed similar trend to the existing boiling system

- Much higher value in water electrolysis
  - Due to the smaller energy barrier for nucleation than boiling system



Conclusion

- **Active nucleation site density (N_a) in dilute sulfuric acid water electrolysis was measured according to the surface roughness**

- **N_a increased as current density increased**
  - Similar to existing water electrolysis and boiling system

- **N_a increased as surface roughness (R_a) increased**
  - Similar to existing boiling system
  - Much higher value

- **Bubble departure diameter & bubble frequency will be measured (future work)**

Reference

[1] H.K. Park and B.J. Chung, Comparison of bubble parameters between boiling and hydrogen evolving systems, Experimental Thermal and Fluid Science, Vol. 122, 110316, 2021.

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[3] C.H. Wang and V.K. Dhir, Effect of Surface Wettability on Active Nucleation Site Density During Pool Boiling of Water on a Vertical Surface, J. Heat Transfer. Vol. 115, No. 3, pp. 659-669, 1993.

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[7] A. Suszko and M. S. El-Genk, Saturation boiling of PF-5060 on rough Cu surfaces: Bubbles transient growth, departure diameter and detachment frequency, International Journal of Heat and Mass Transfer, Vol.91, pp. 363-373, 2015.

Thank you!