

Imitation of Boiling Curve Depending on the Different Control Modes using a Water Electrolysis

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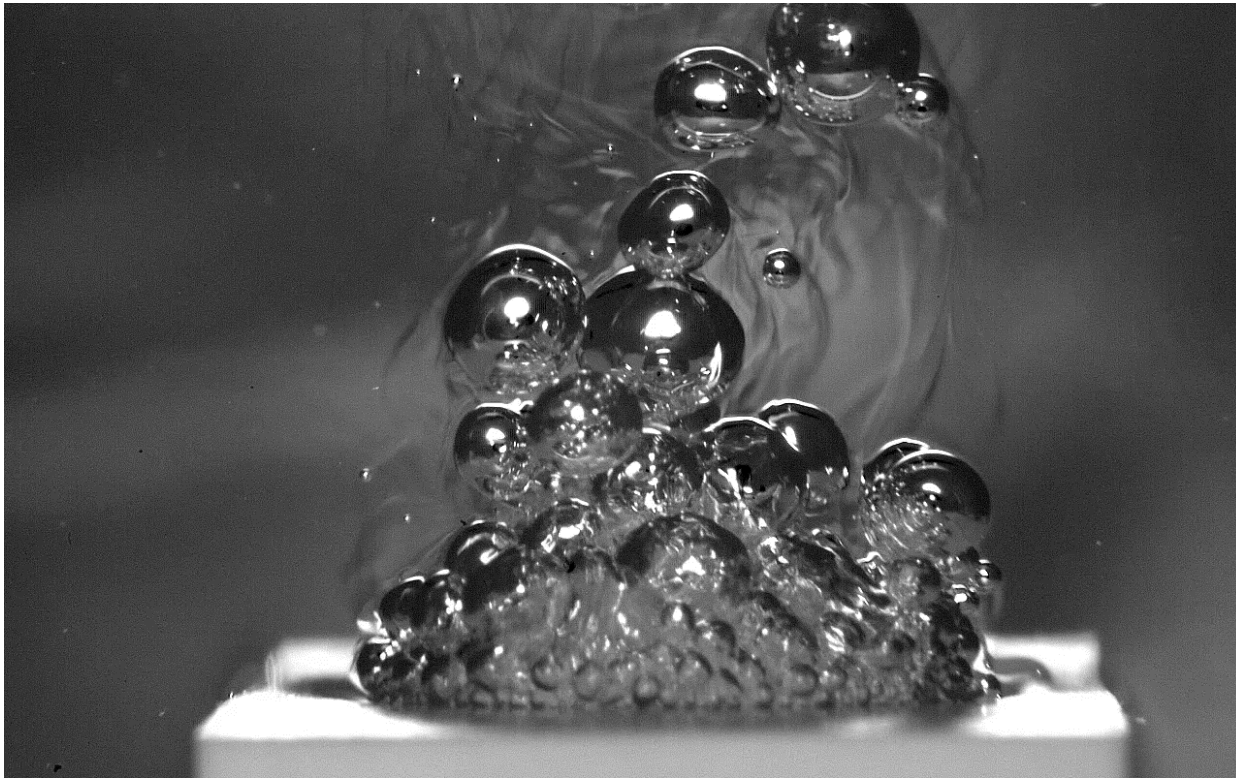
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Presenter: Jeonghun Seo

Background

Hydrogen production water in electrolysis

- Copper electrode
- 1.5 M of H_2SO_4 solution



Background

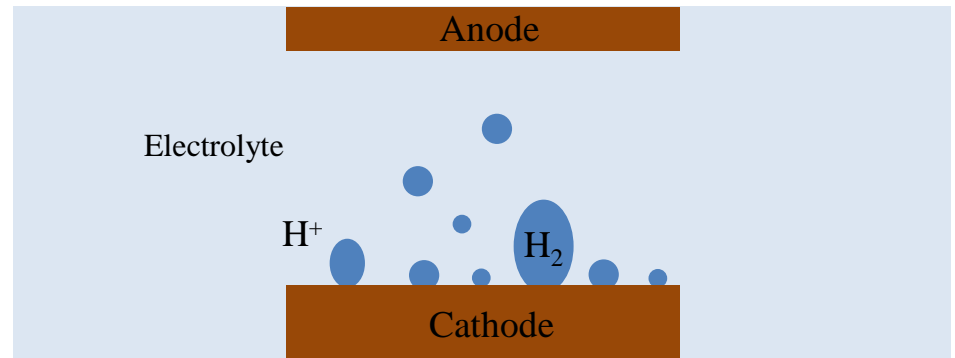
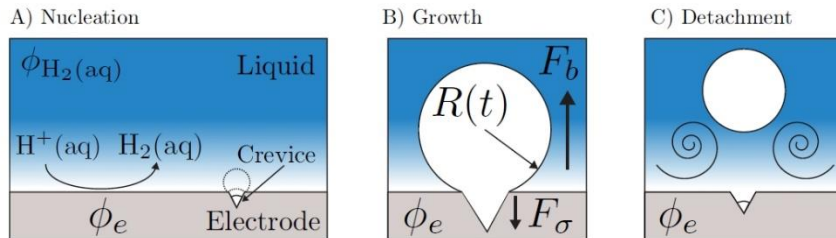
Conventional analogy between **heat** and **mass** transfer

Similar flux equations

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

Similar bubble generation mechanism

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



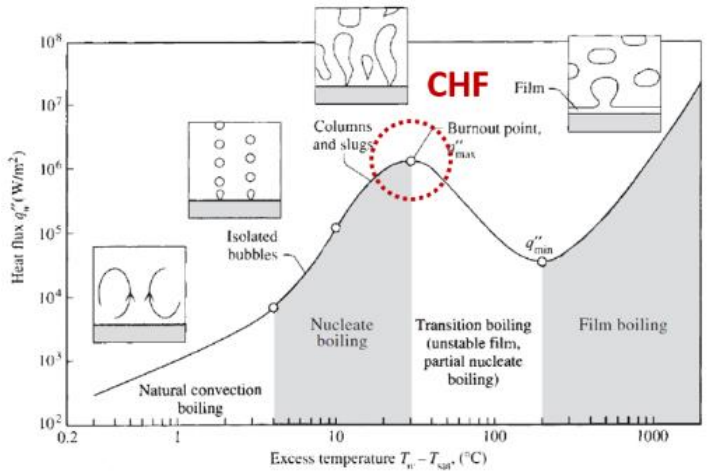
Background

Similar upper limit (Limitation of gas generation)

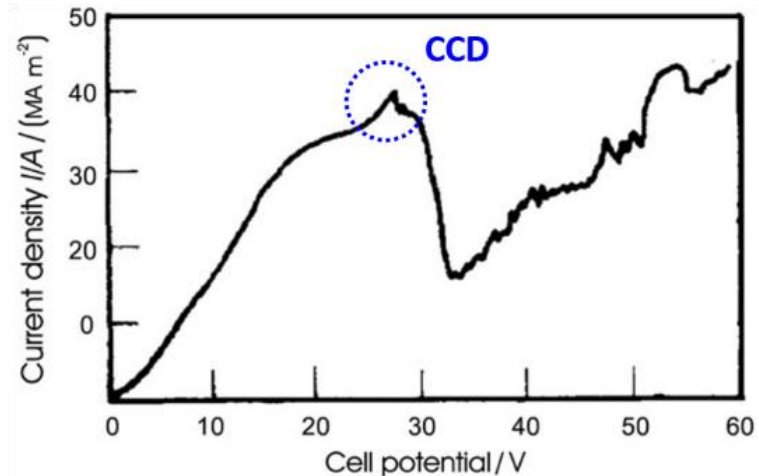
- Critical heat flux & Critical current density

↓
Formation of vapor film

↓
Formation of hydrogen film



Boiling curve (Bejan, 2013)

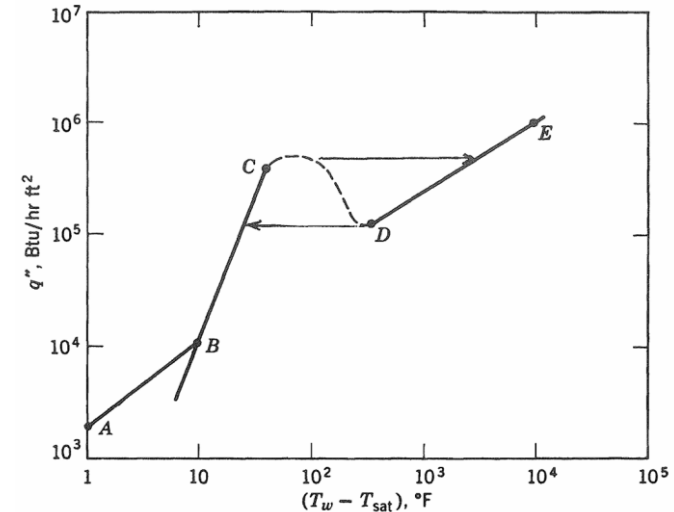


Cell potential-current density curve (Sillen et al., 1982)

Background

Different route depending on the control mode

- Temperature control vs. Power control
 - (Temp. control) Heat flux decreased after CHF
 - Transition boiling occurs (unstable vapor film)
 - (Power control) Surface temperature abruptly increased
 - Never encounters transition boiling regime



Boiling curve (Nukiyama S, 1934)

(Scope of Objective)

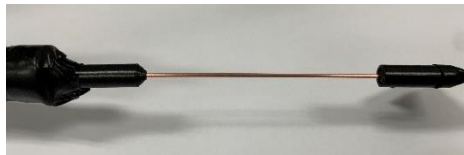
To confirm similarity between boiling and water electrolysis

- From nucleate bubble regime (point B) to post CHF (points D and E)
- To confirm Hydrogen gas behaviors depending on control modes

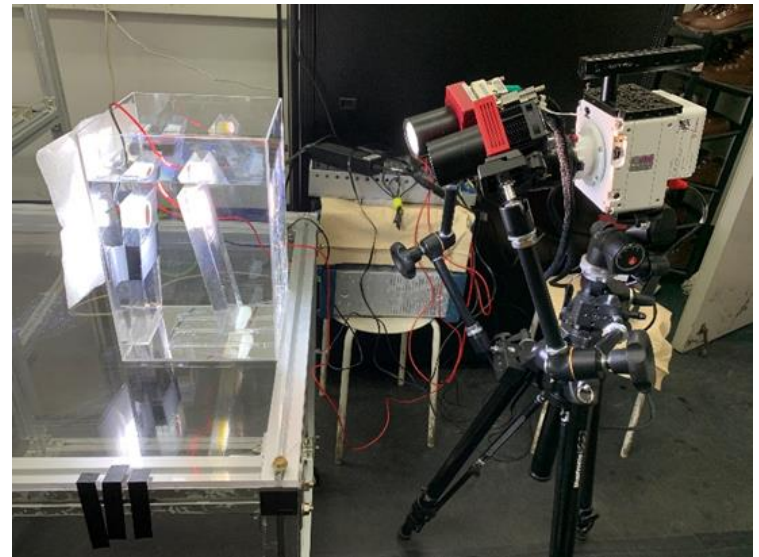
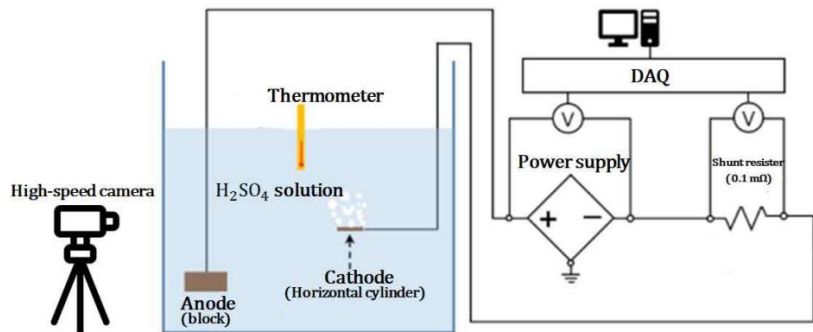
Experimental setup

Two-electrode water electrolysis system for hydrogen evolution

- Working electrode: Cathode (copper)
- Counter electrode: Anode (copper)
- Power supply
- Electrolyte: 1.5 M of H_2SO_4 solution



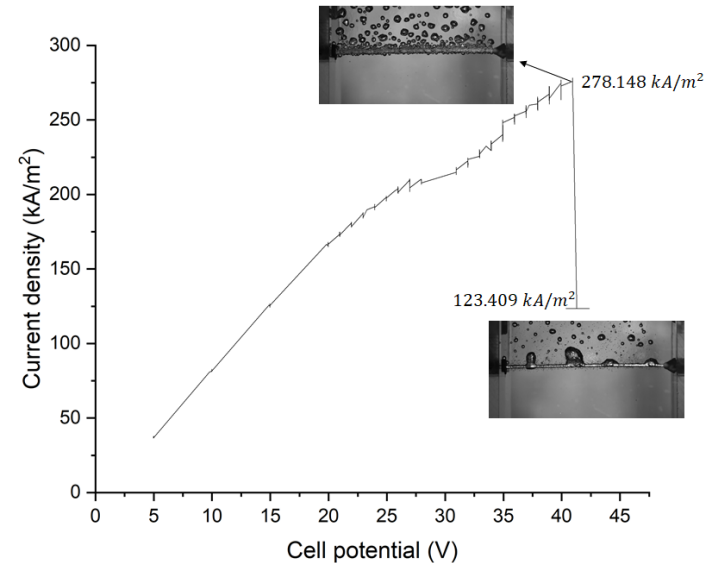
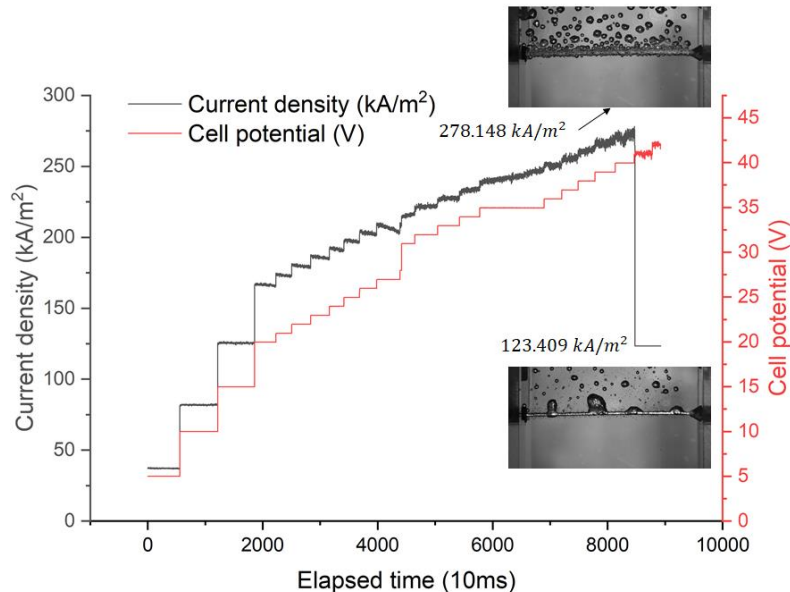
0.1 mm thick copper wire



Results

Cell potential control mode (similar to temperature control mode in boiling system)

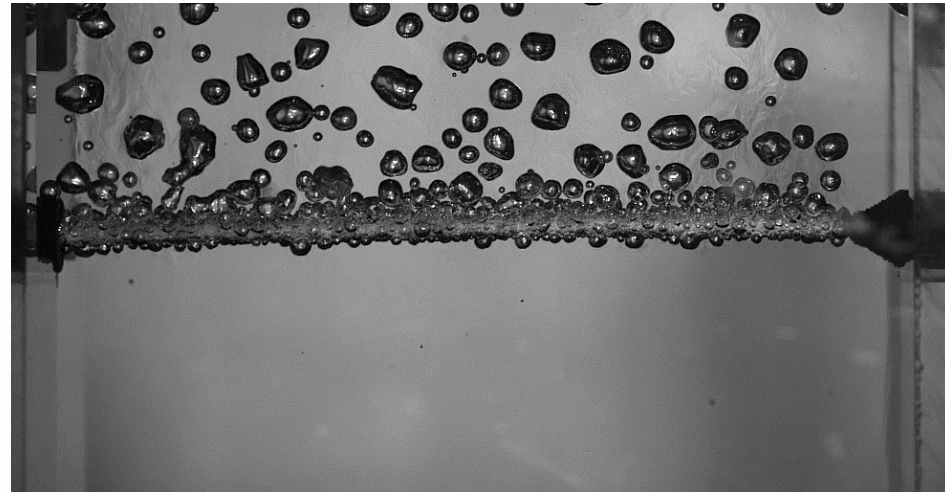
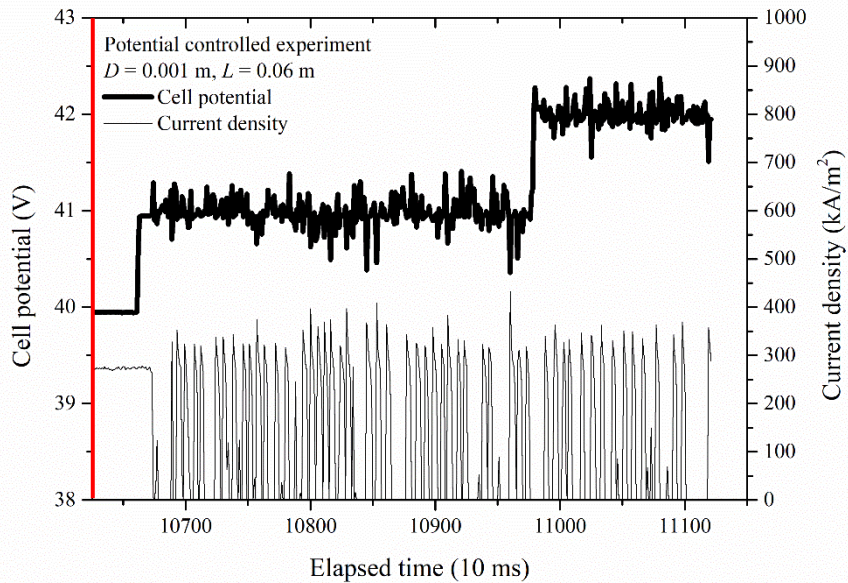
- Current density increased as cell potential increased
- Peak of current density measured (CCD) → abruptly dropped after CCD
- Stable hydrogen film can be observed (similar to Leidenfrost point)
- Inverted U shaped-curve was obtained (similar to boiling curve)



Results

Cell potential control mode (similar to temperature control mode in boiling system)

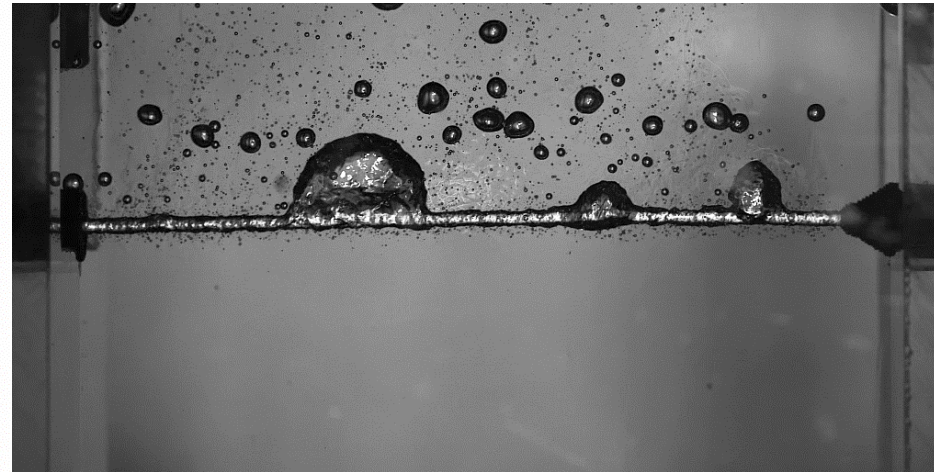
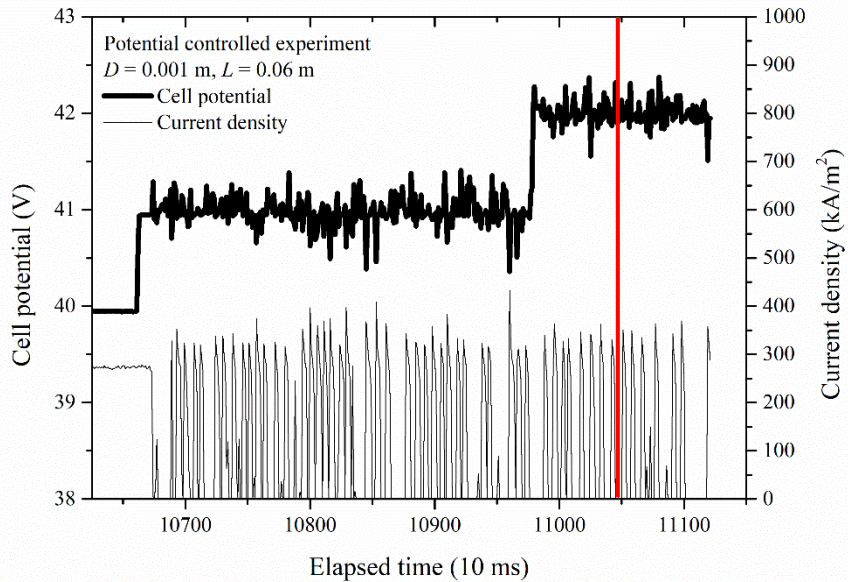
Unstable hydrogen film (= transition boiling)



Results

Cell potential control mode (similar to temperature control mode in boiling system)

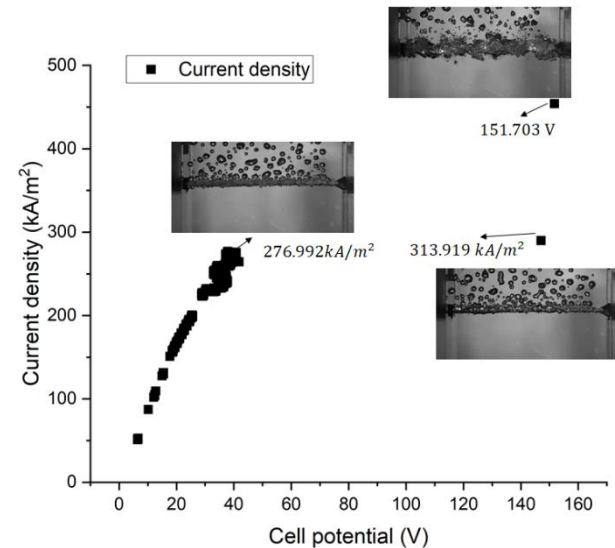
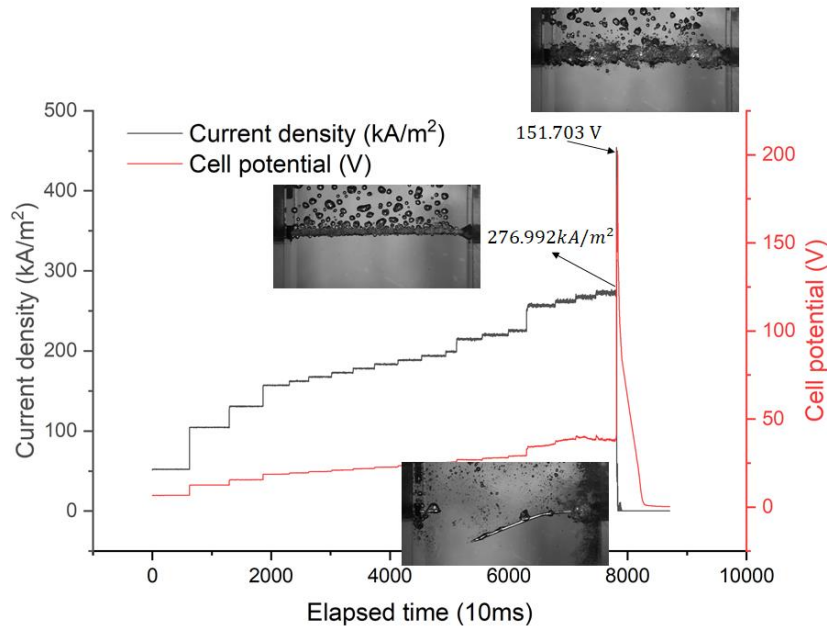
Stable hydrogen film (= near Leidenfrost point)



Results

Current control mode (similar to heat flux control mode in boiling system)

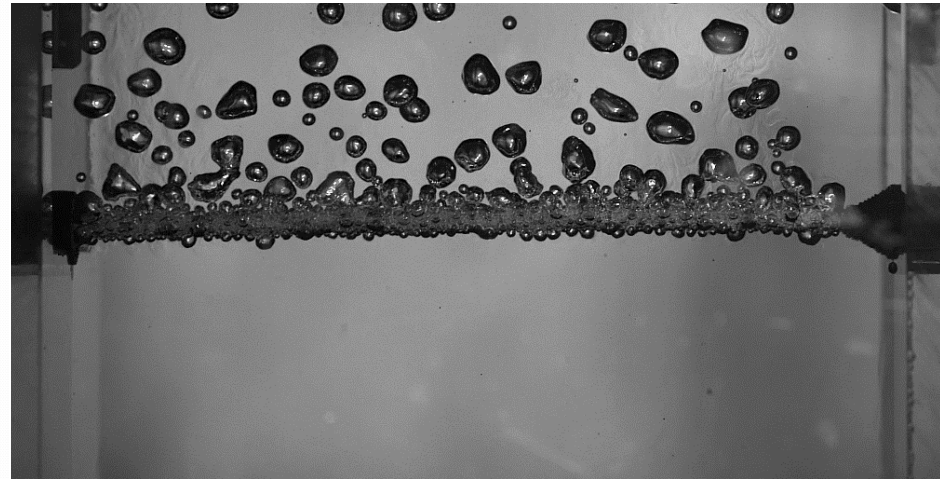
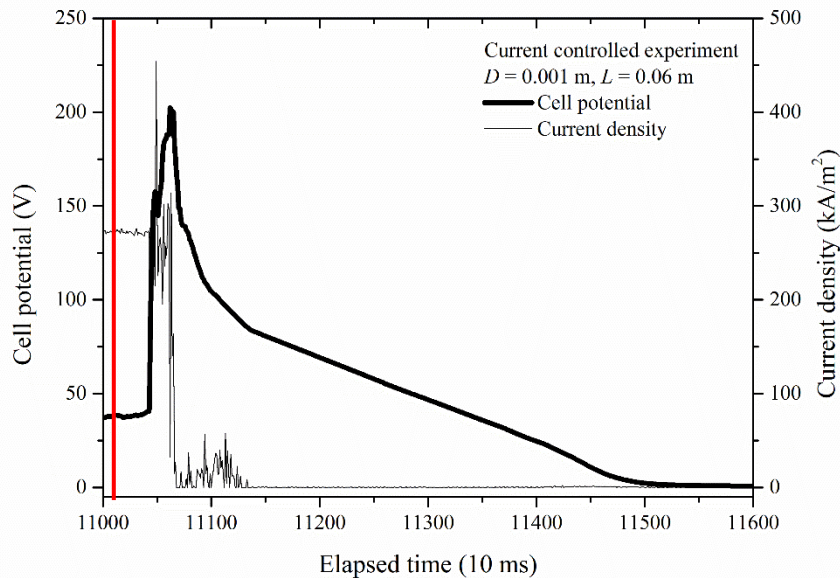
- Cell potential increased as current density increased
- Failure of cathode wire (soon after the CCD) → Similar to surface failure at CHF



Results

Current control mode (similar to temperature control mode in boiling system)

Failure of surface (like CHF in power control mode)



Conclusion

- **CCD was measured according to the two different control modes**
 - Cell potential and current control mode
 - Similar to temperature and heat flux control modes in boiling system)
- **Cell potential control mode**
 - Hydrogen film was formed after the CCD (similar to boiling system)
- **Current control mode**
 - Surface failure occurred soon after the CCD
- **Future works will be performed using Alkaline water electrolysis**
 - For effective hydrogen production

Thank you!

References

- [1] H.K. Park and B.J. Chung, Comparative analysis of bubble behavior between boiling and hydrogen evolving system at horizontal cylinders, *Heat and Mass Transfer*, Vol. 58, pp. 779–789, 2022.
- [2] B. Mazza, P. Pedferri, G. Re, Hydrodynamic instabilities in electrolytic gas evolution, *Electrochim Acta*, Vol. 23, pp. 87–93, 1978.
- [3] H. Vogt, Heat transfer in boiling and mass transfer in gas evolution at electrodes – The analogy and its limits, *Int J Heat Mass Transf*, Vol. 59, pp. 191-197, 2013.
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- [6] Nukiyama S, Film boiling water on thin wires. *Society of Mechanical Engineering*, 37