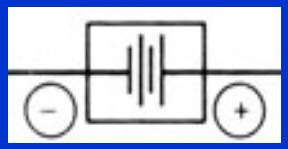

Towards Elimination of the Anode Effect and Perfluorocarbon Emissions from Hall-Héroult Cells

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background

- on anode effect Hall-Héroult cell produces **CF_4** and **C_2F_6** (**PFCs**)
- PFCs have high GWP
- in US, Al smelting is #1 point source of PFCs

premise of the current work:

understanding the anode effect

\+ understanding PFC generation

\+ plan for reducing emissions

outline of today's talk:

- electroanalytical studies
- gas analysis during electrolysis in laboratory cells
- method to avert AE and PFC generation in lab cells
- extension to industrial cells

results of studies in lab cells

- anodic reaction inhibited when potential exceeds a critical value, $E_C \approx 3.0 - 3.5$ V
- anode becomes active again when potential is reduced below a so-called recovery value, $E_R \approx 2.8$ V
- PFCs generated only at extreme potentials, i.e., $E > 4.0$ V

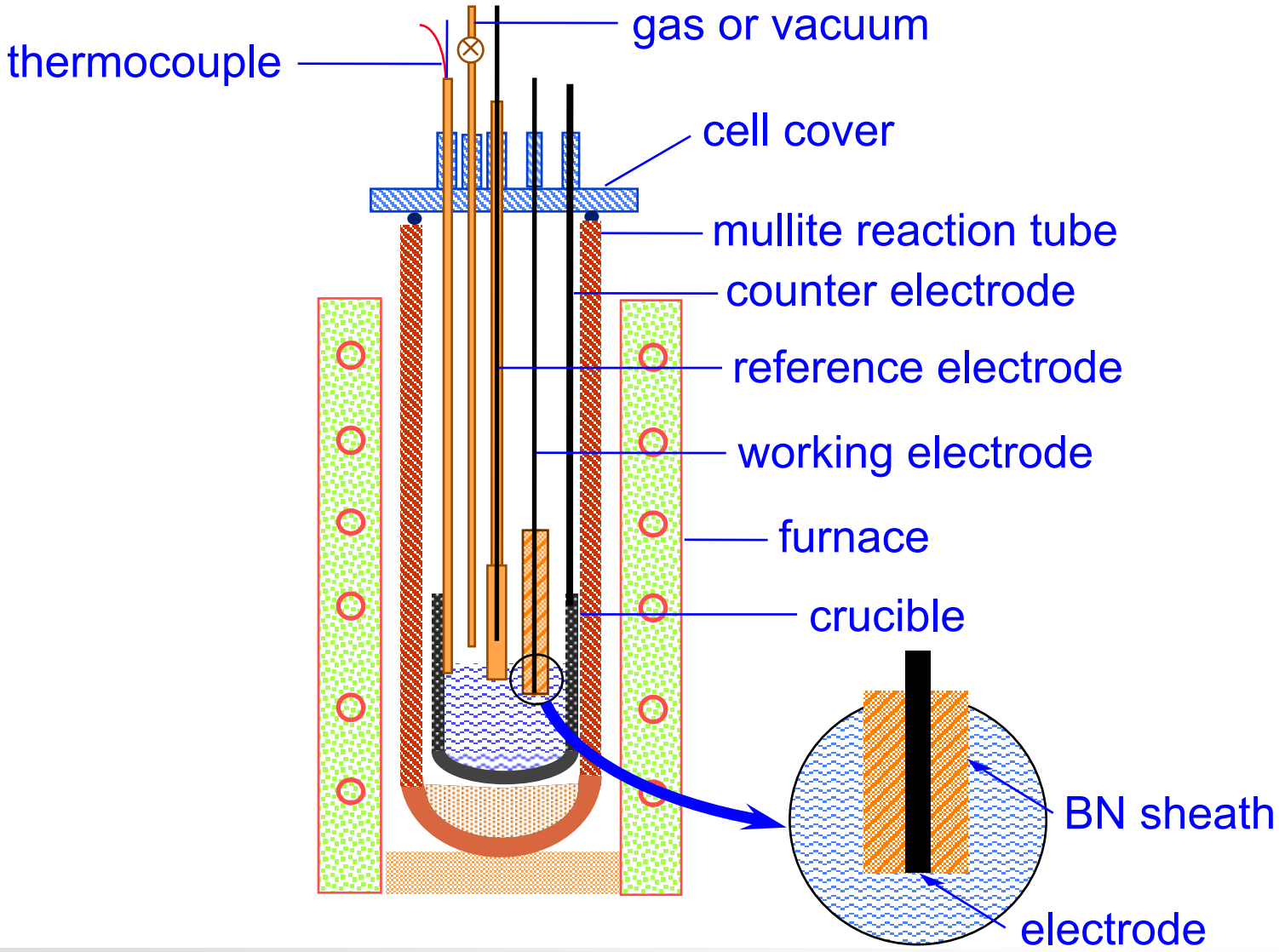
results of studies in lab cells

+ AE linked to formation of highly resistive surface film

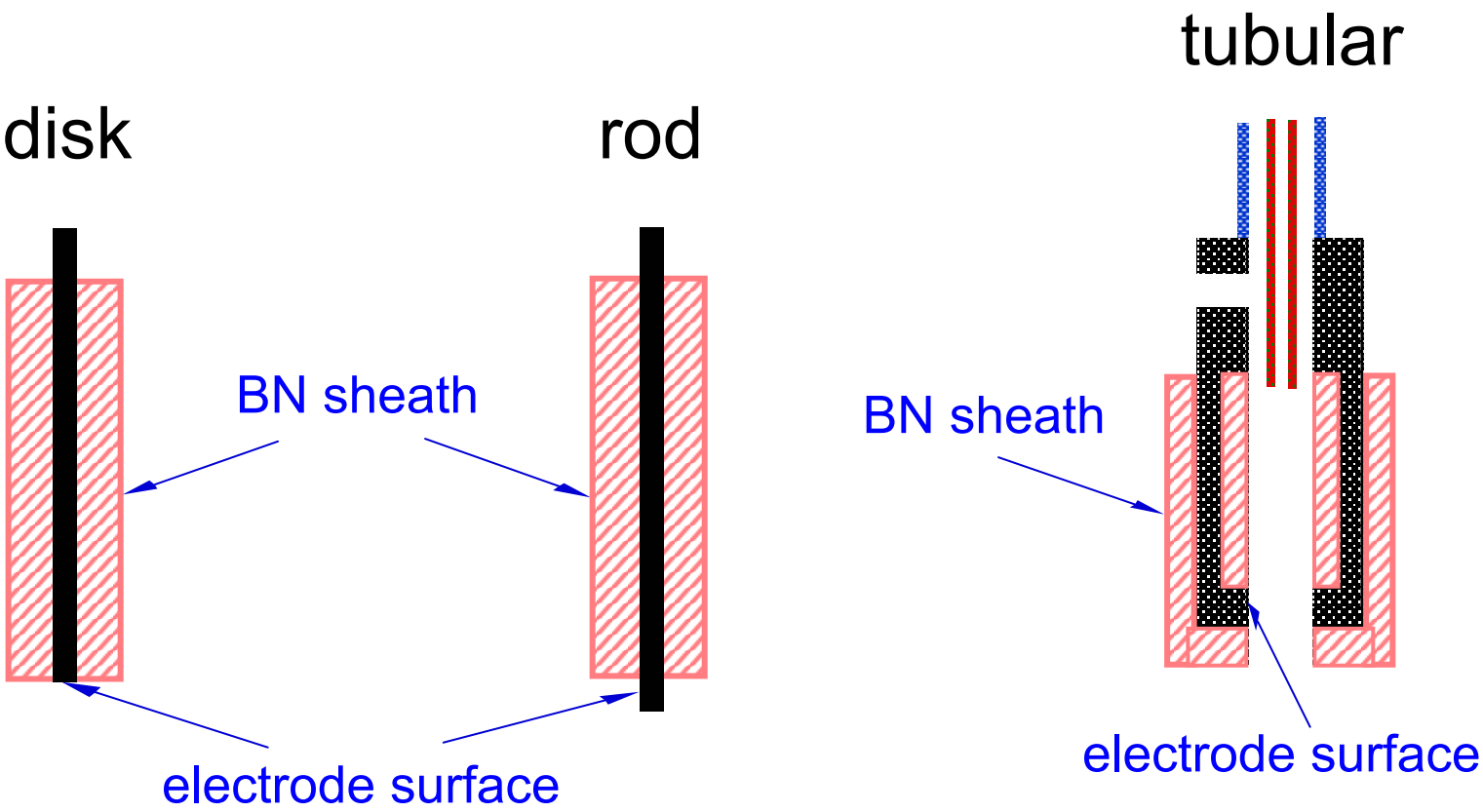
our experiments:

- ☑ 3-electrode cell featuring
  - O rotating rod anode (WE)
  - O reference electrode
  - O large counter electrode
- ☑ electrolysis cell featuring
  - O tubular anode for improved gas sampling

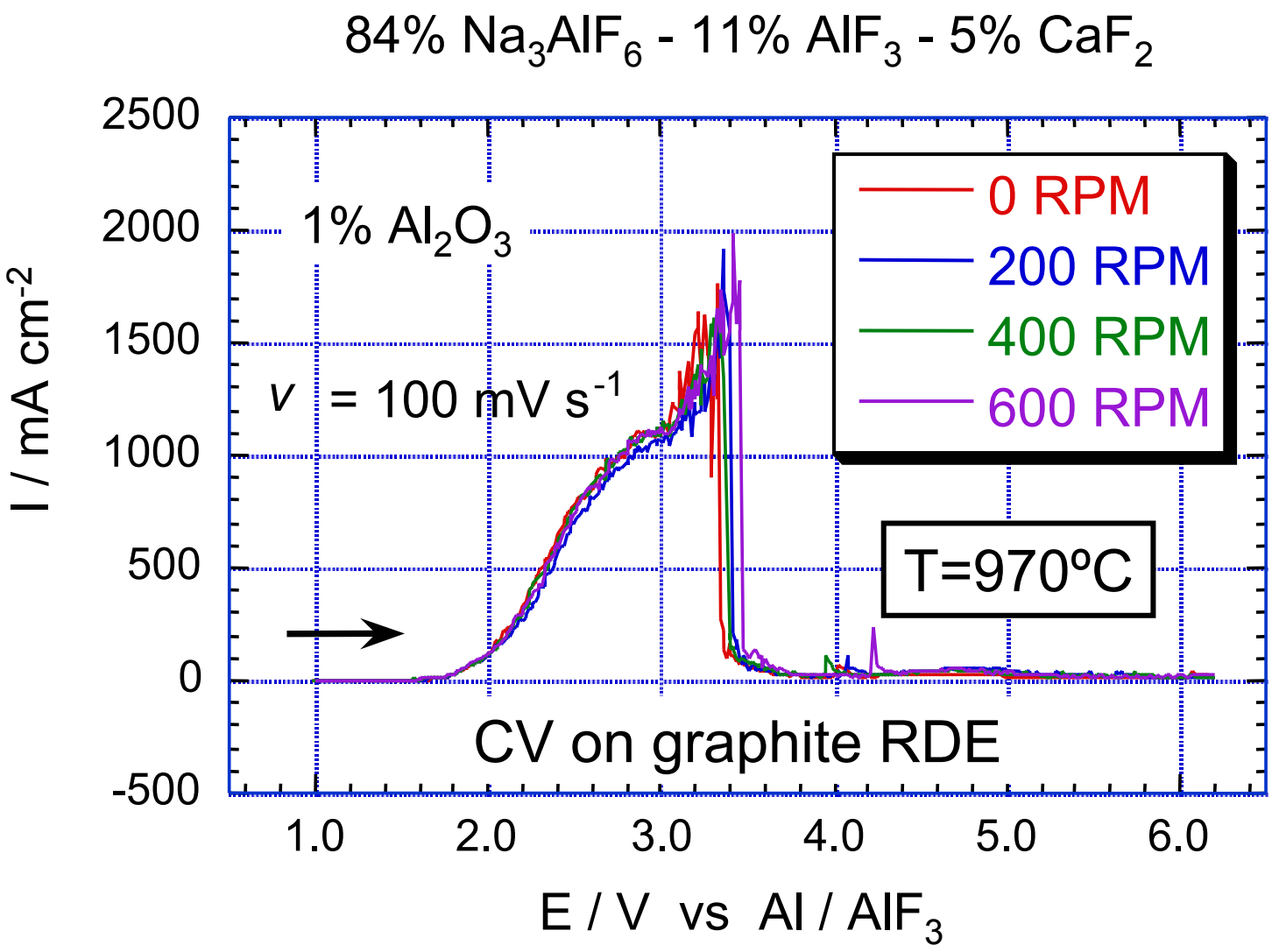
cell for electrokinetic studies



various types of electrodes



evidence of a passivating film



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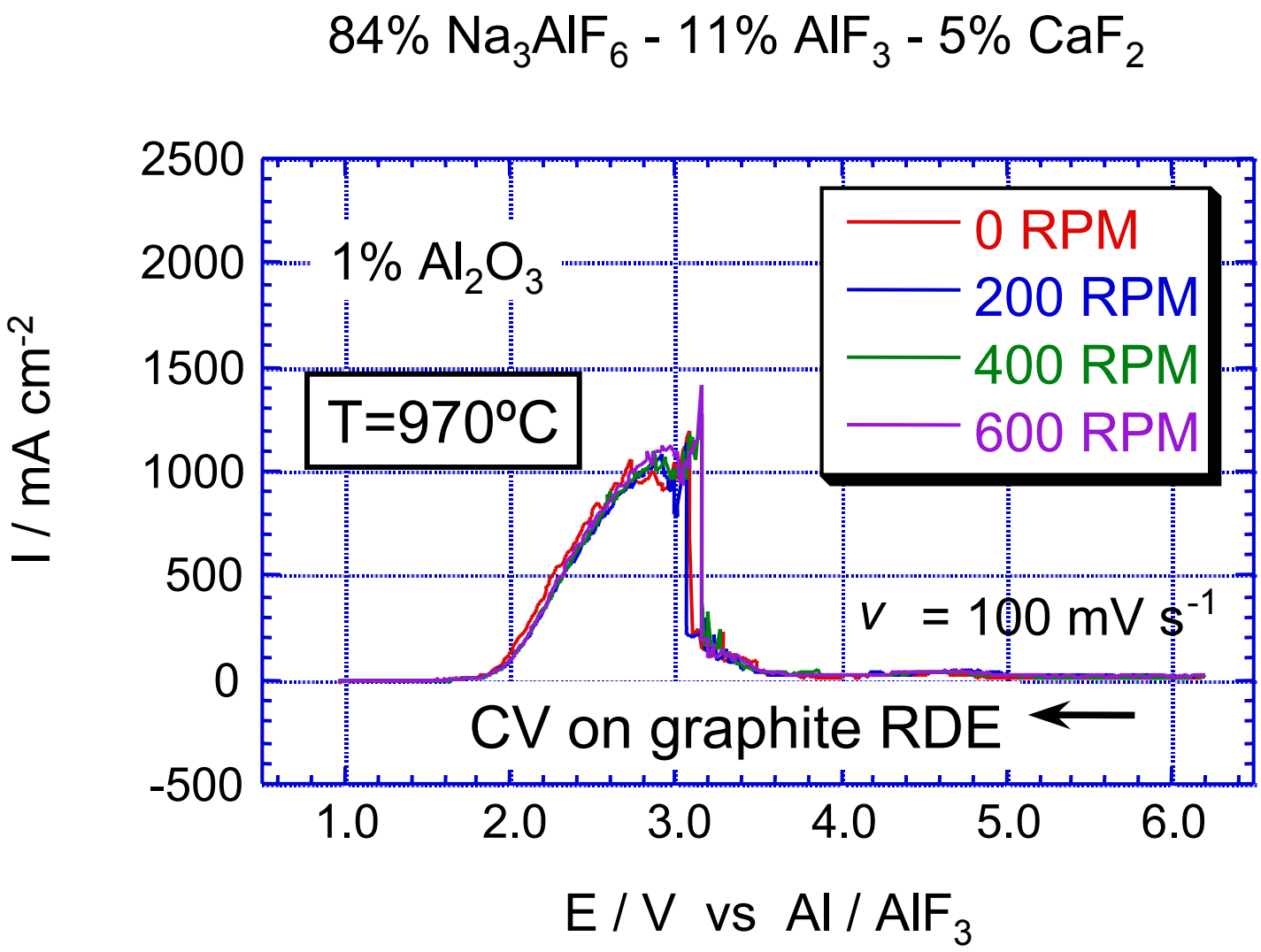

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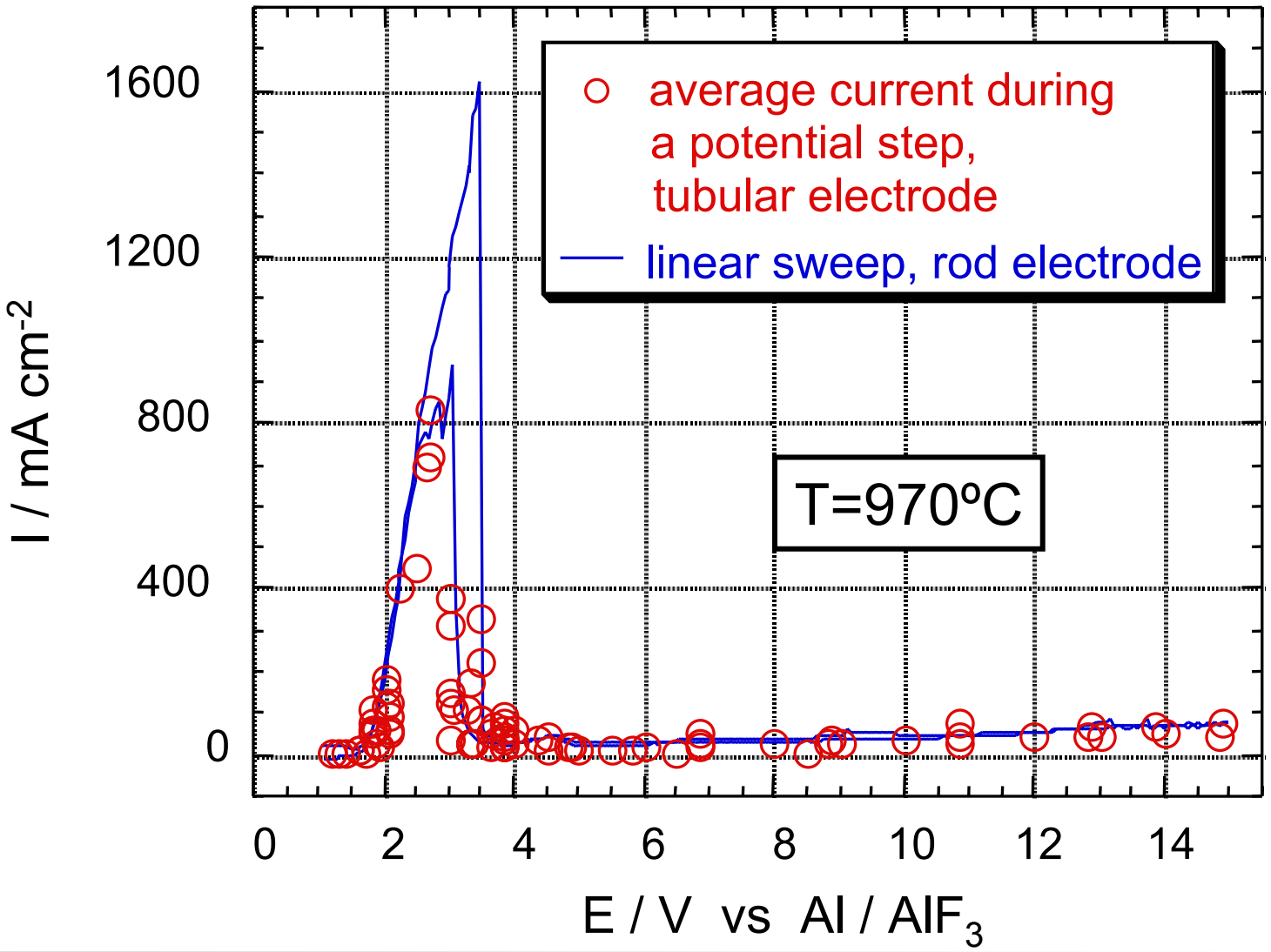
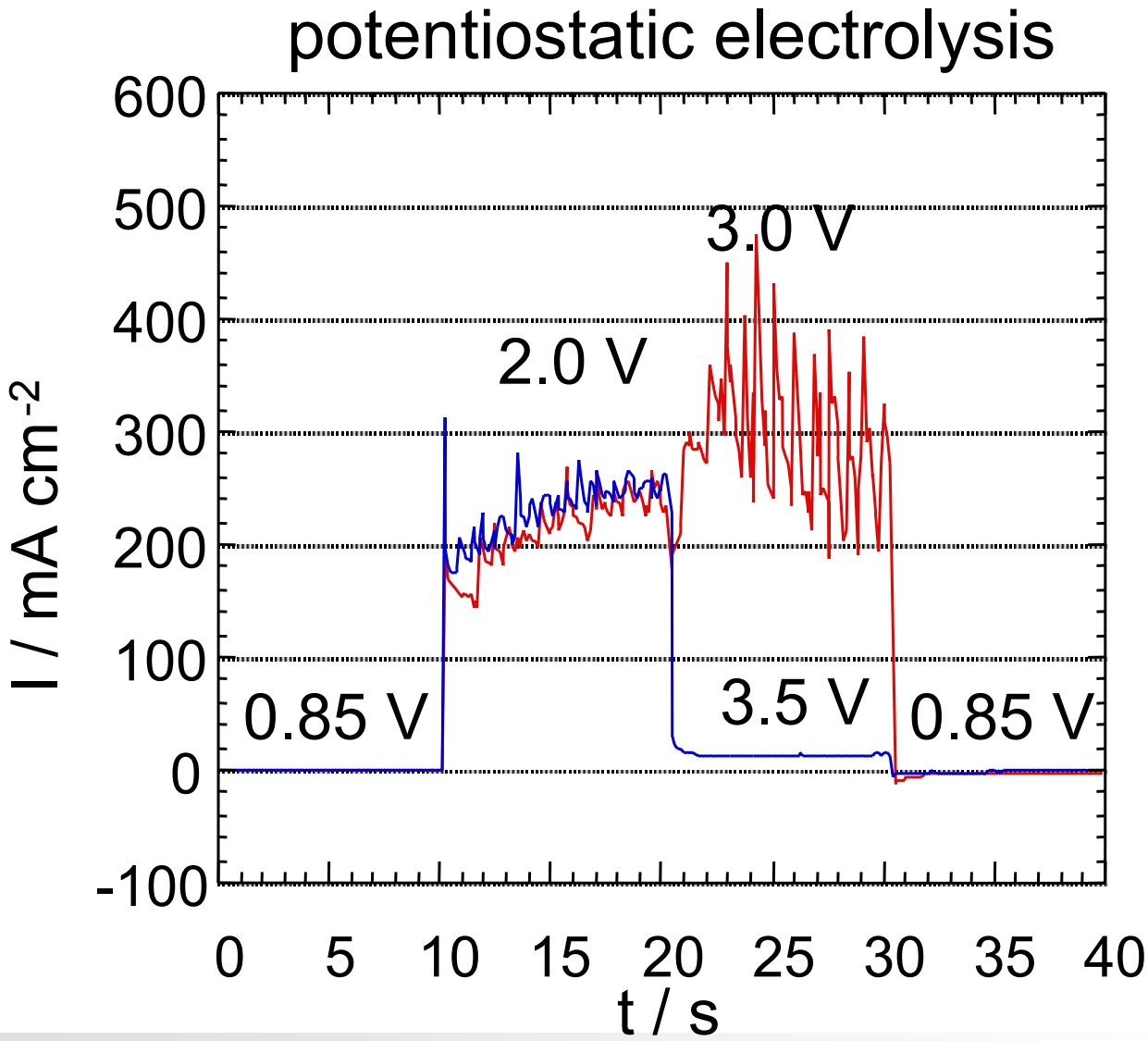


evidence of film formation



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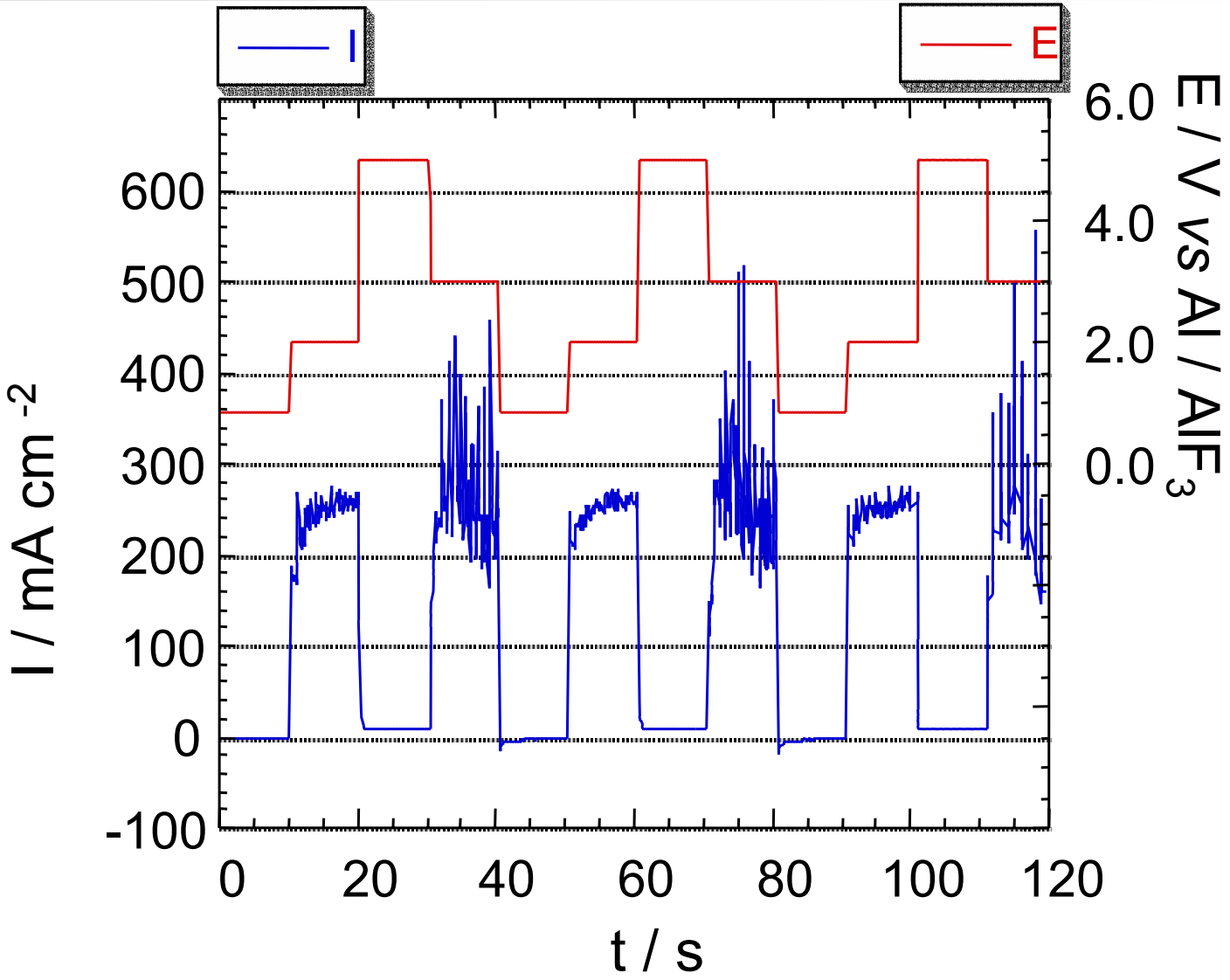
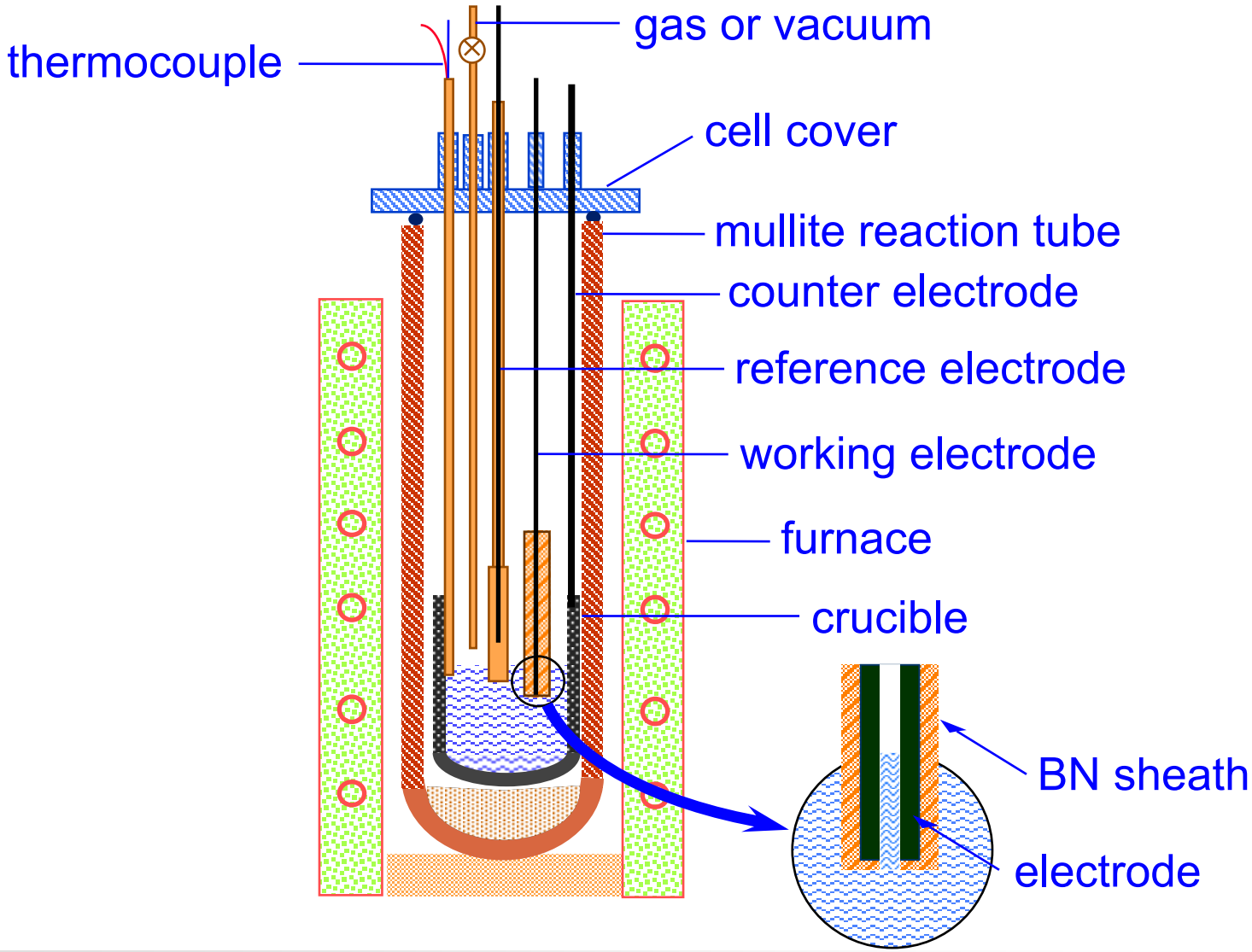
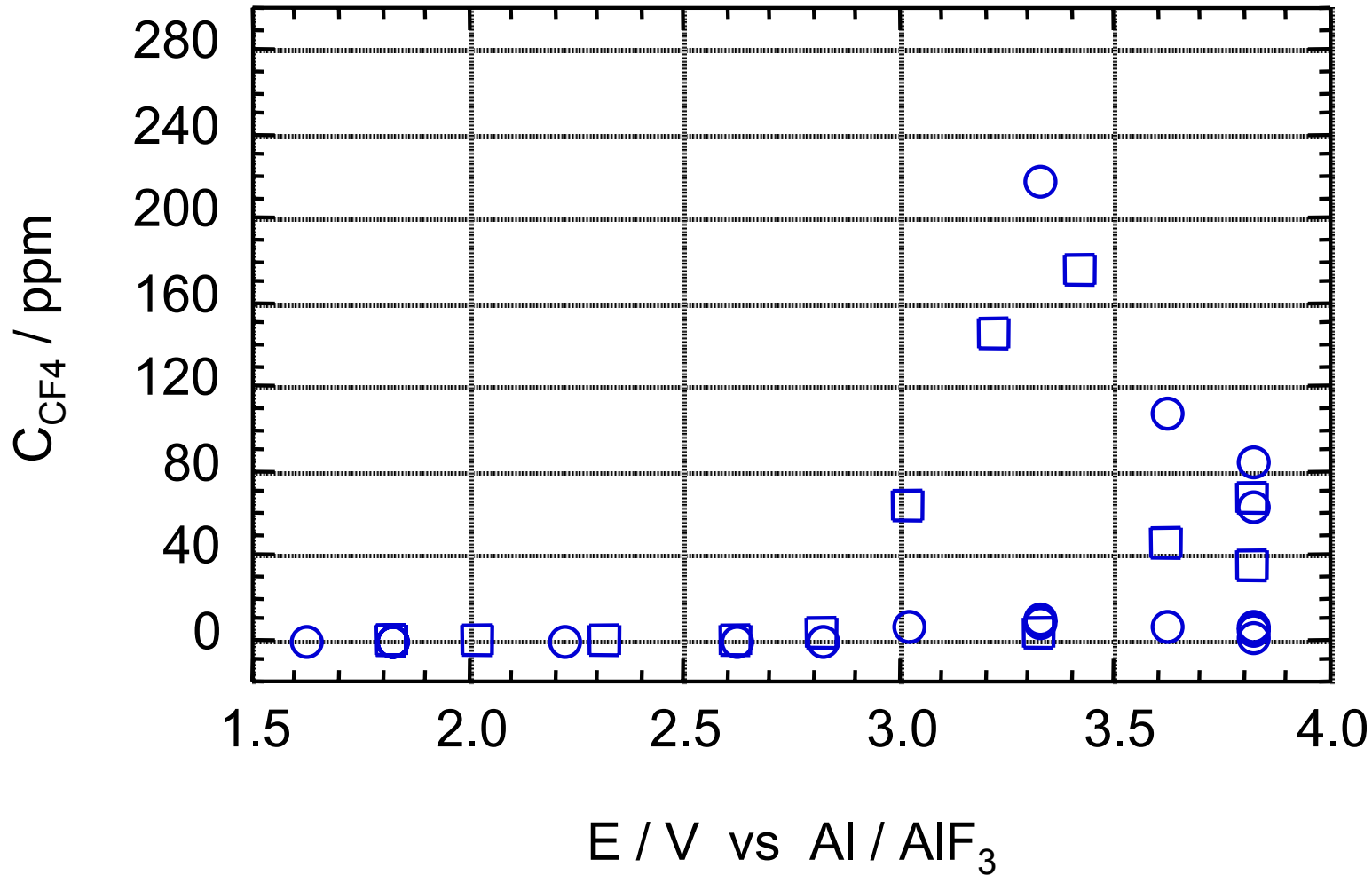


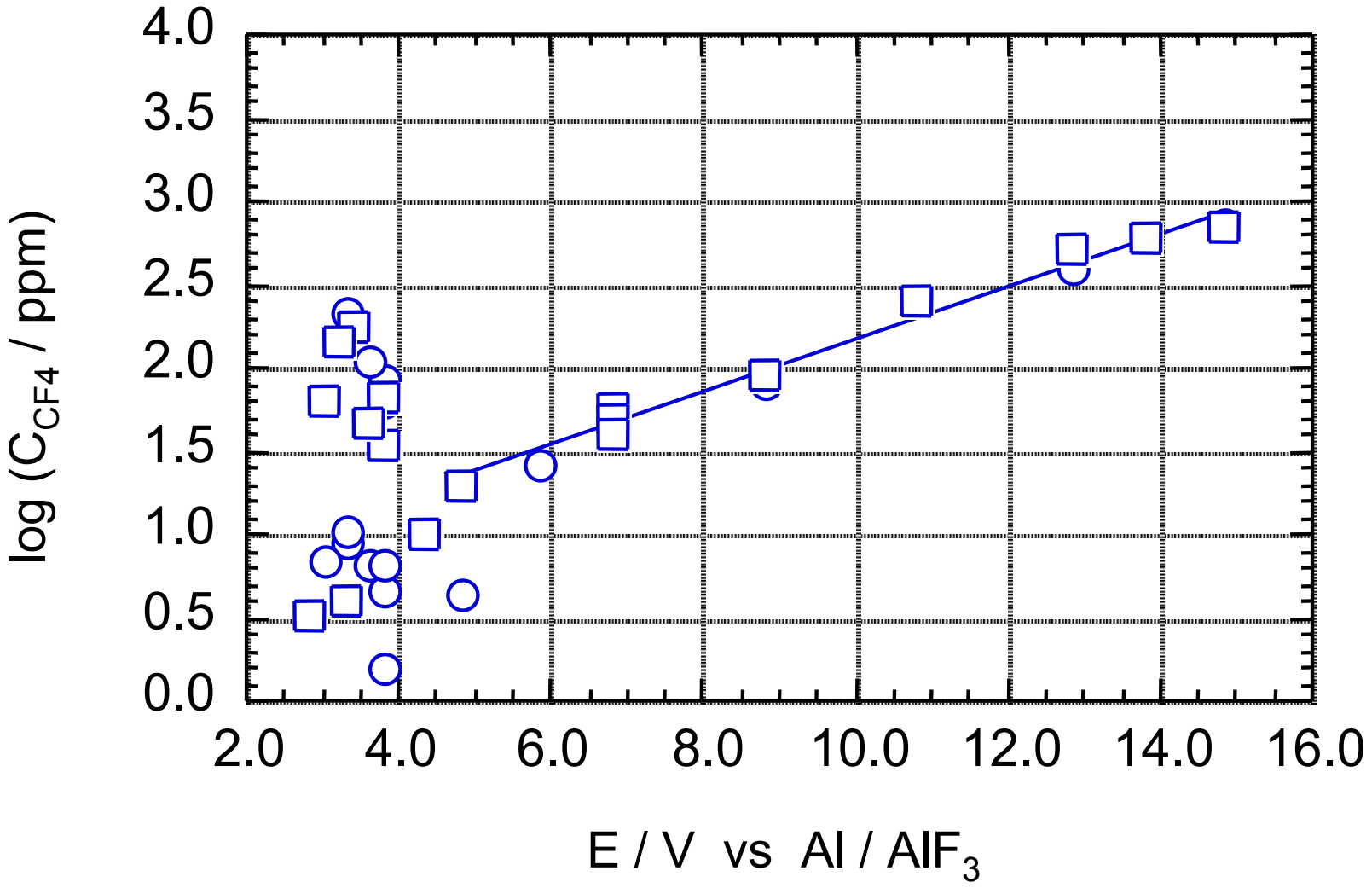
cell for analysis of anode gas



controlled-potential electrolysis



controlled-potential electrolysis



controlled-potential electrolysis

in the high-voltage regime

$$ln\ \boldsymbol{c} = \alpha + \beta\ \boldsymbol{E},$$

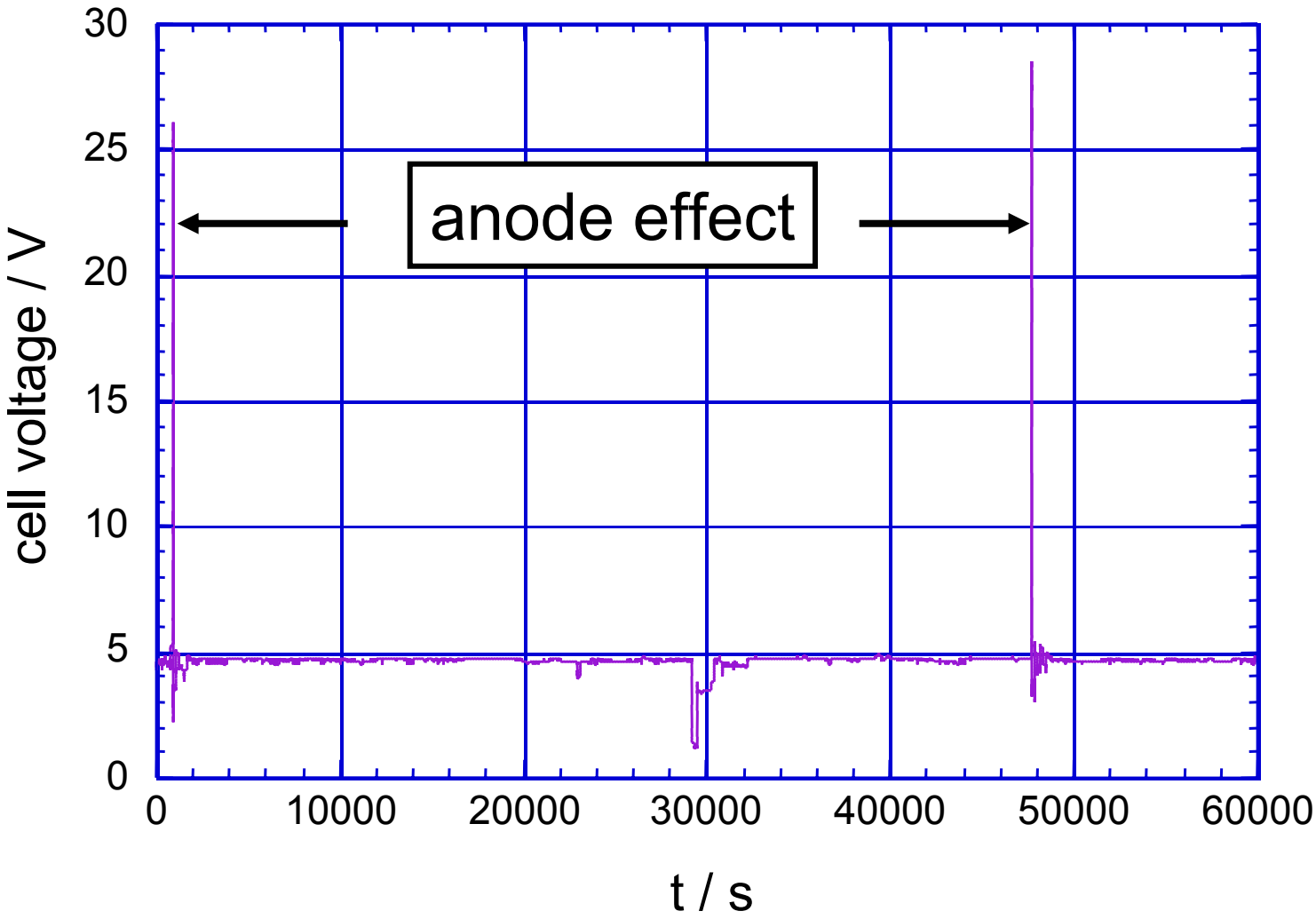
where β = 0.325 V^{-1}

c.f. Nissen & Sadoway (1997)

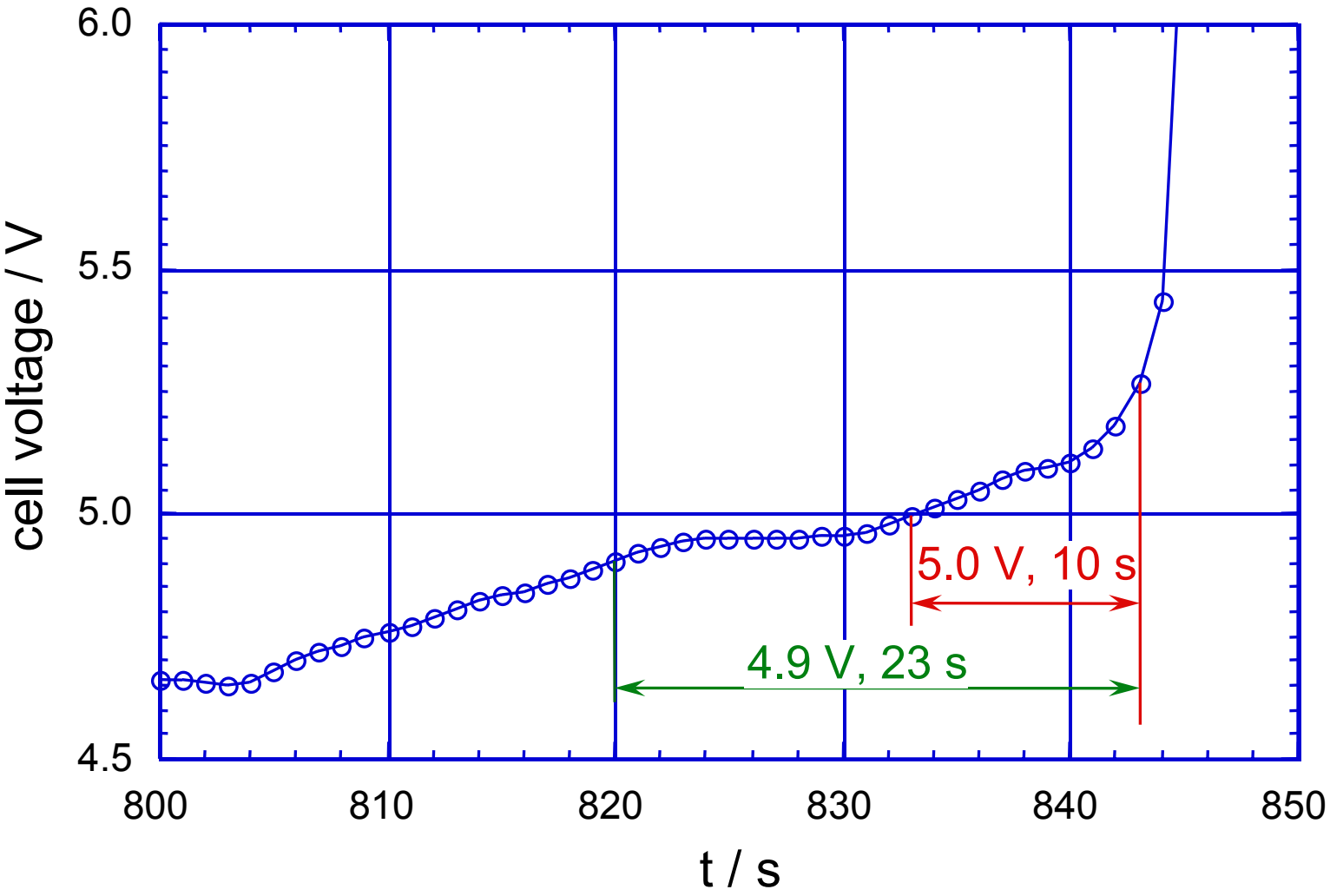
$$r_{CF4} = a\ exp\ (b\ E\ ),$$

where b = 0.331 V^{-1}

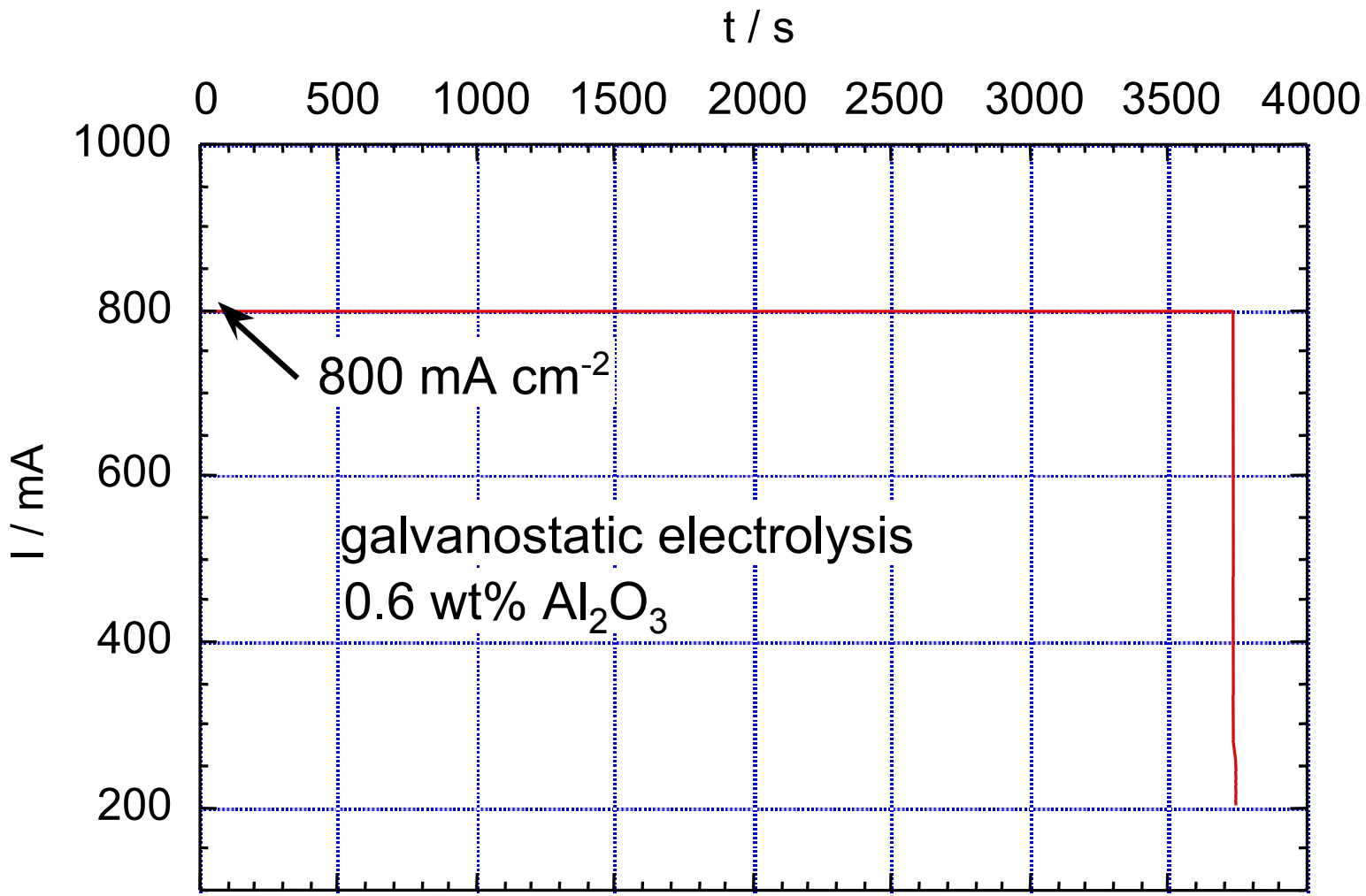
data from an industrial cell



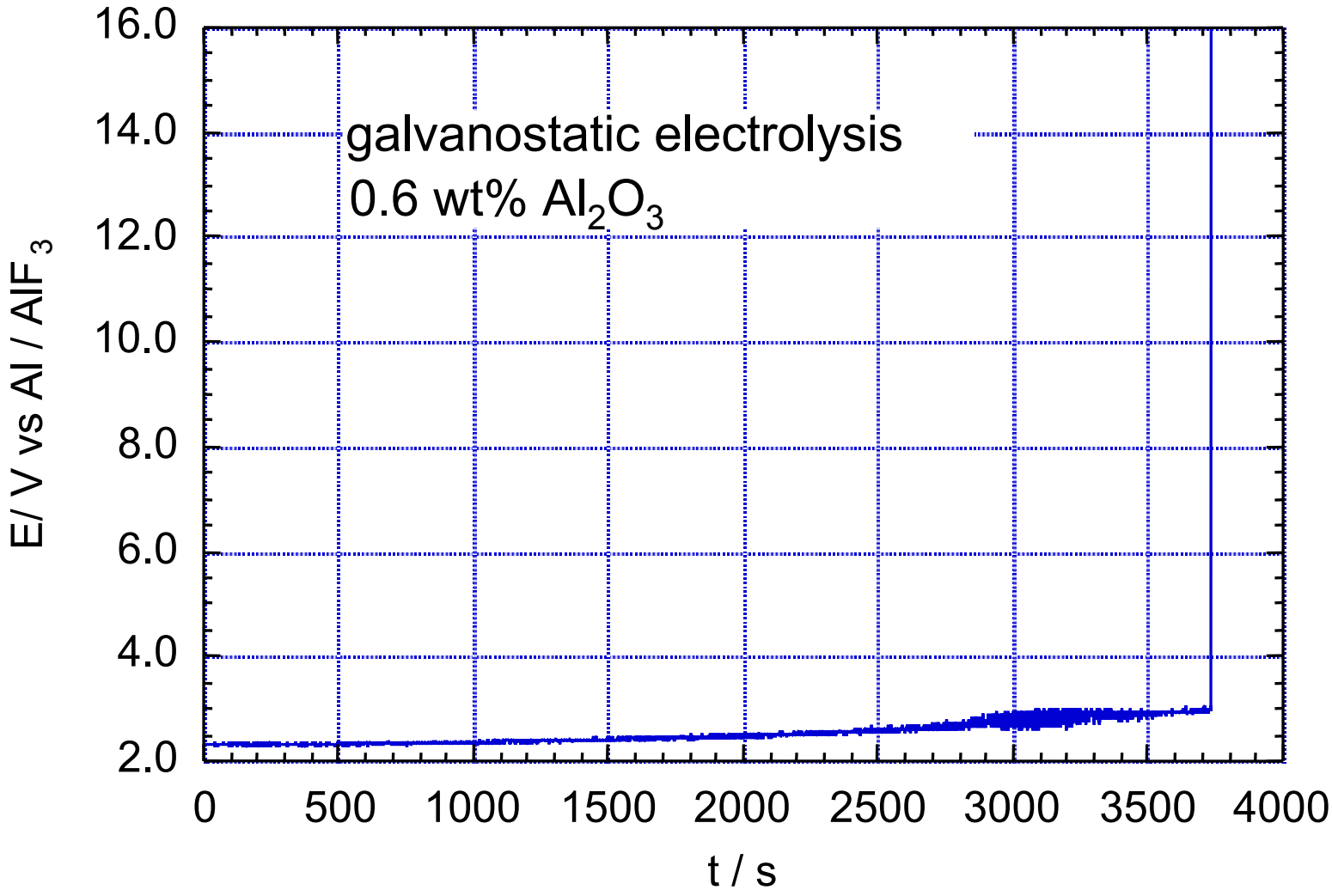
a closer look at an anode effect



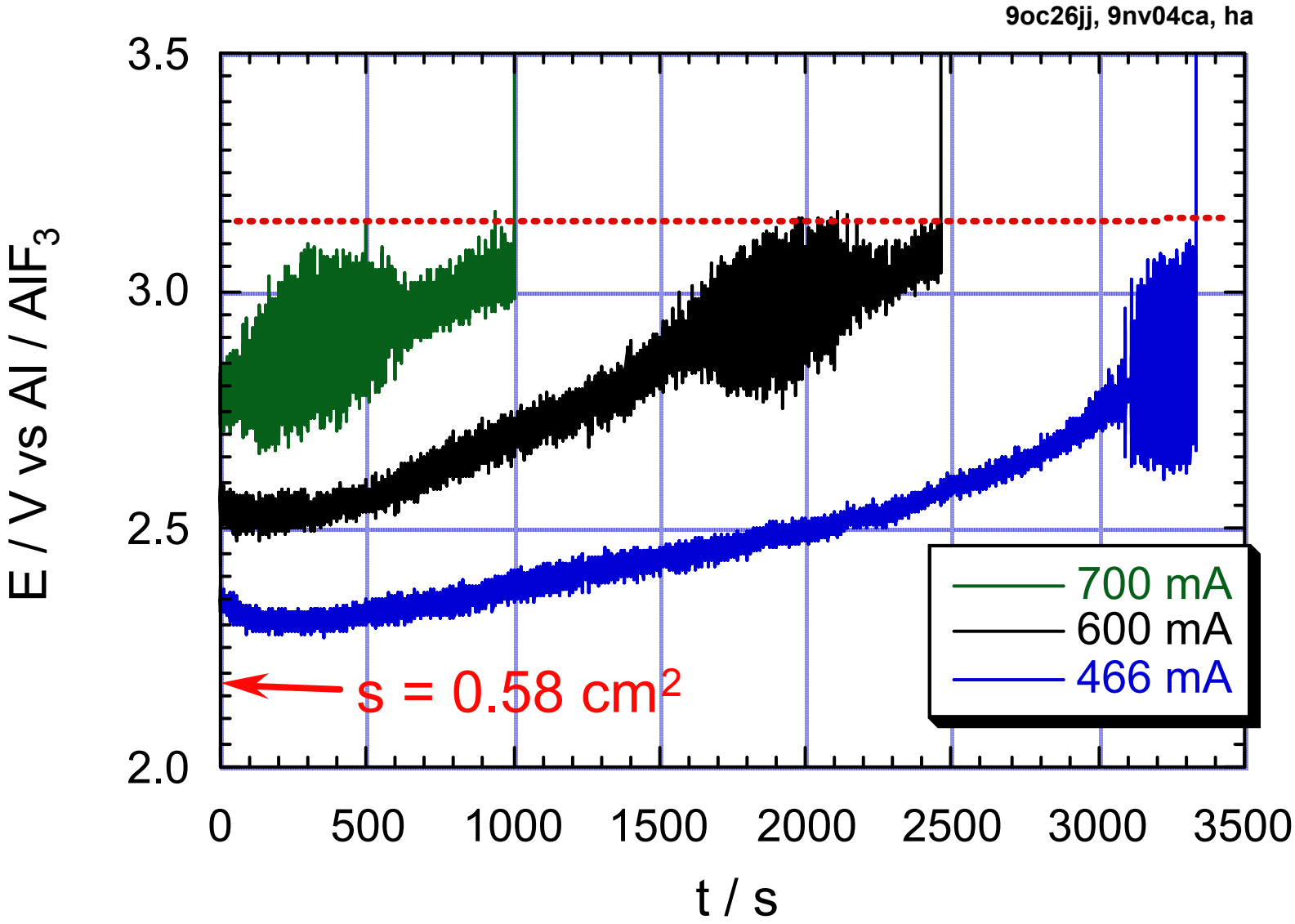
data from a laboratory cell



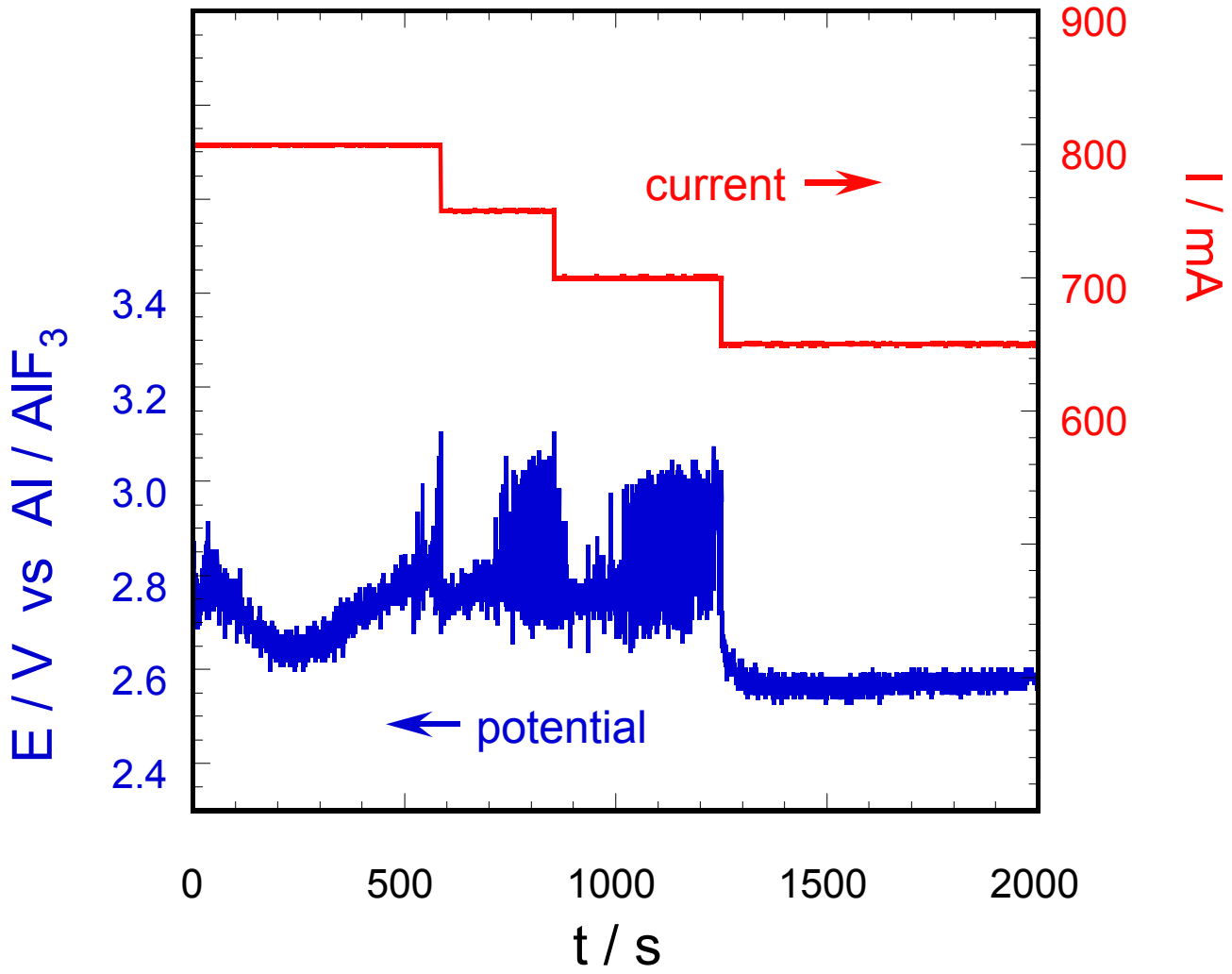
data from a laboratory cell



data from a laboratory cell



AE averted by current stepping



major findings:

- ☑ onset of anode effect is potential dependent
- ☑ AE can be averted by reducing current so as to prevent voltage from exceeding a critical value

in an industrial cell

enabling technologies:

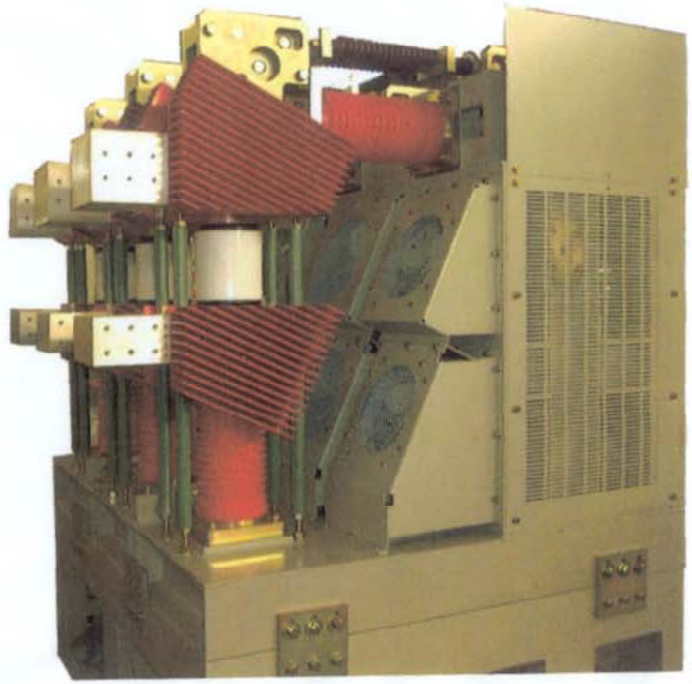
☑ accurate voltage sensing

☑ control circuit

☑ robust current shunting

vacuum current breaker

12kV-12000A 大電流通電器



our proposal

☑ shunting ≈1% cell current drops cell voltage for ≈1 min

∴ 300 kA cell ⇨ 3 kA/min

$$\Rightarrow \quad \frac{di}{dt} = 50\, A\, s^{-1}$$

\+ **NO ANODE EFFECT!!!**

☑ no AE ⇨ no PFCs

acknowledgments

The Aluminum Association

U.S. Environmental Protection Agency,
Climate Protection Division