Experiments Confirm Solvated Electron Penetration Depth Scaling in a Plasma-Liquid System

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INTRODUCTION

- Total Internal Reflection Spectroscopy (TIRAS) is used to observe and measure solvated electrons at the plasma-liquid interface (Fig. 1).[1]

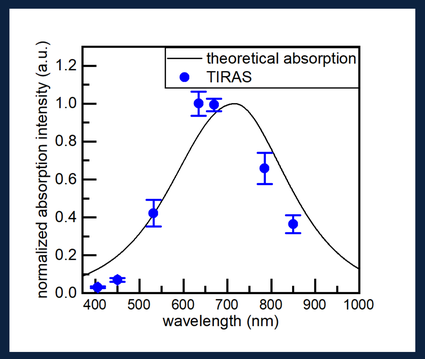

Figure 1. TIRAS measured solvated electron absorption spectrum, compared with known theoretical spectrum. Error bars correspond to a 95% confidence interval.

- Theoretical model predicts exponential scaling of TIRAS intensity with plasma current density.[2]

EXPERIMENTAL SETUP AND THEORY

- Plasma current is modulated between states (i_{on} and i_{off}) at frequency (ω), and a lock-in amplifier is used to reduce noise.
- TIRAS intensity is a function of the current density (j) in the plasma and the modulation frequency.
- Plasma current density is a function of the ionic strength of the electrolyte solution.[3] Ionic strength is varied to observe TIRAS intensity as a function of current density.

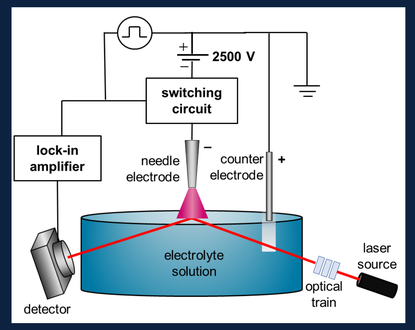

Figure 2. Diagram of the TIRAS experimental setup.

$$n_o = j\left(\frac{D^2}{(kn_0)^2+\omega^2}\right)^{\frac{1}{4}},\ l = \left(\frac{D^2}{(kn_0)^2+\omega^2}\right)^{\frac{1}{4}}$$

$$\frac{\Delta I}{I_0} \propto n_0 l$$

$$kn_0 \ll \omega \longrightarrow \frac{\Delta I}{I_0} \propto j$$

$$kn_0 \gg \omega \longrightarrow \frac{\Delta I}{I_0} \propto j^{\frac{1}{3}}$$

RESULTS AND CONCLUSIONS

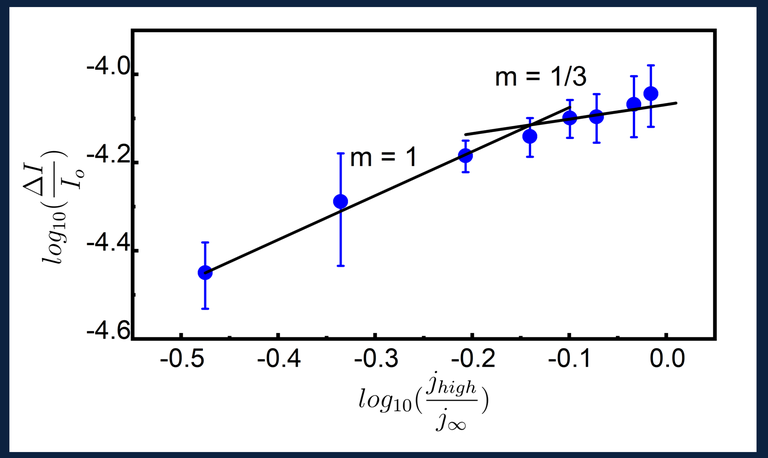

Figure 3. Logarithmic plot of TIRAS intensity vs plasma current density. Error bars correspond to a 95% confidence interval.

- Results are **in agreement with the model** (Fig. 3).
- This validated model can predict **upper limits** for:
  - solvated electron penetration depth, ~100 nm.
  - interfacial concentration ~0.1 mM.

References:
[1] Rumbach et al., *Nat. Commun.*, 6 (2015) 7248.
[2] Rumbach et al., *Plasma Sources Sci. Technol.*, 27 (2018) 115013.
[3] Rumbach et al., *Phys. Rev. E.*, 95 (2017) 053203.

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