

Characterization of $\text{La}_2\text{Ce}_2\text{O}_7$ and $\text{Y}_2\text{Zr}_2\text{O}_7$ using polarization effects via Kelvin Probe Force Microscopy



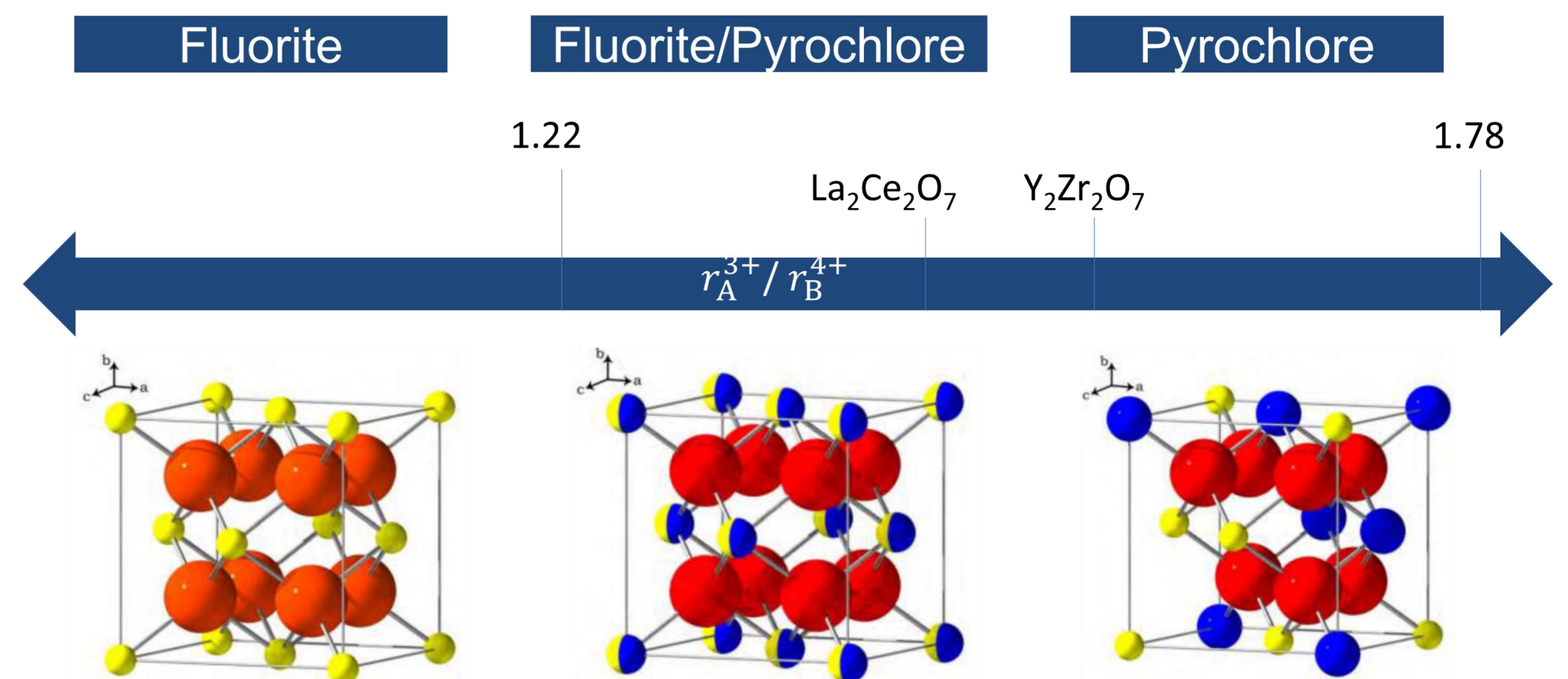
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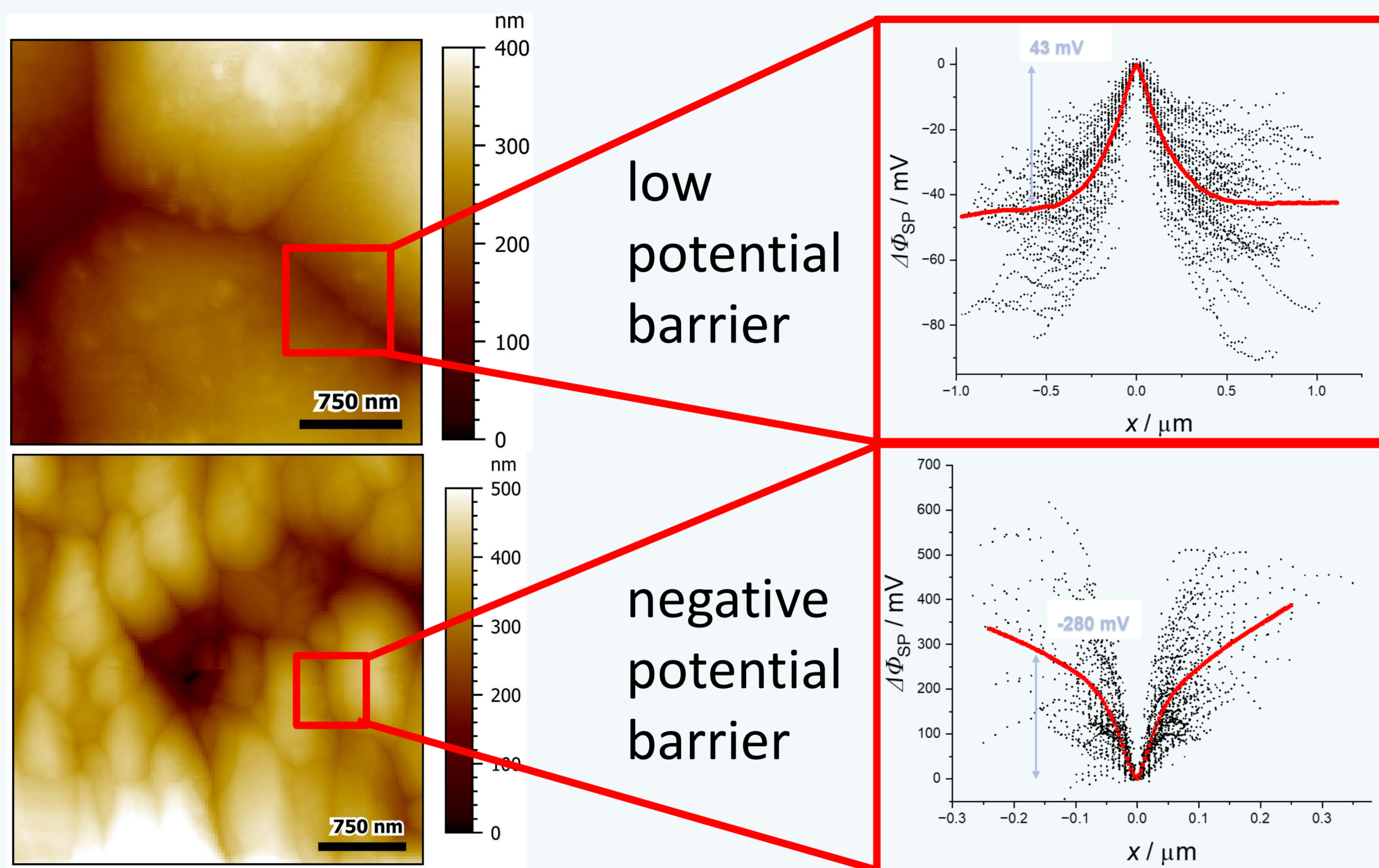
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Ion Conductivity in Pyrochlores

- High temperature proton conductivity combined with oxygen ion conductivity in pyrochlores with the formula $\text{A}_2^{3+}\text{B}_2^{4+}\text{O}_7$
- Depending on cation ionic radii ratio, sintering temperature, and synthesis method these materials may adopt different fluorite-derived structures
- These structures affect ionic transport properties.
- Limited information on ion conductivity below 400°C



$\text{La}_2\text{Ce}_2\text{O}_7$



$\text{Y}_2\text{Zr}_2\text{O}_7$

KPFM

- Technique that measures the local contact potential difference between the metal-coated AFM tip and the sample
- Surface potential (SP) of ceramics is strongly dependent on local defect concentration
- conducting ions must overcome potential barrier between grains
- Average SP taken from over 80 grain pairs at room temperature

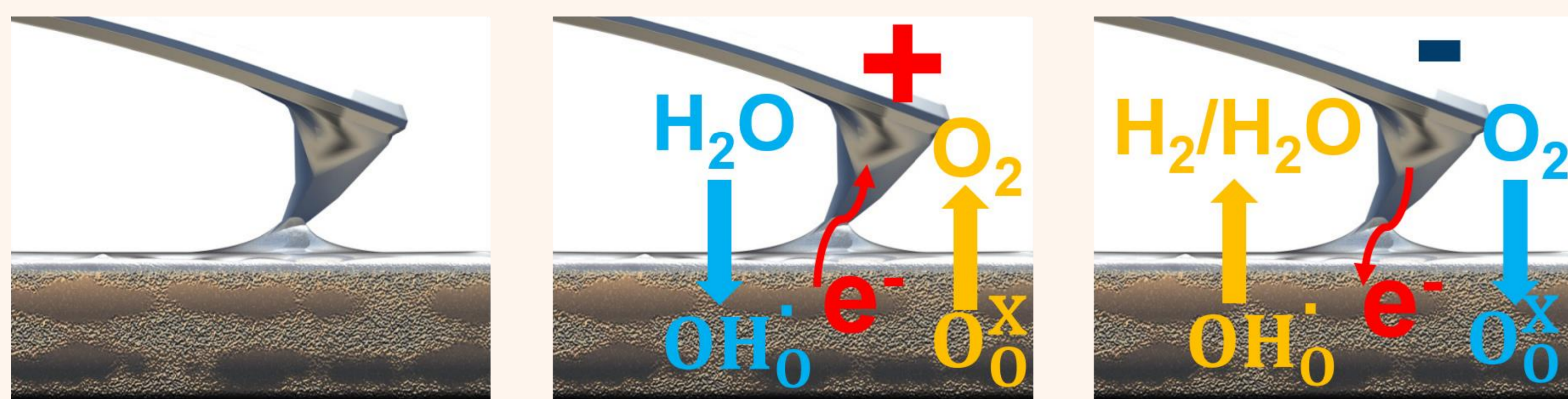
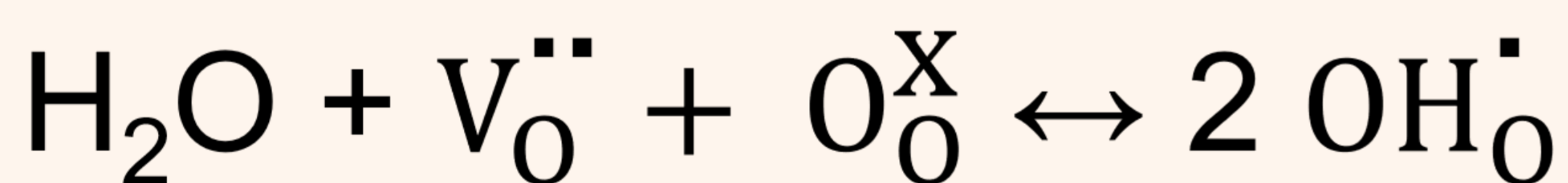
Polarization-Relaxation

- Determination of chemical diffusion coefficient D
- Measure SP before and after polarization at the polarization point every 120 s until plateau is reached.
- Polarization duration: 300 s, Voltage: +3 V & -3 V
- $\tau_{fit} = \Delta\phi_{SP}^0 \cdot e^{-1}$

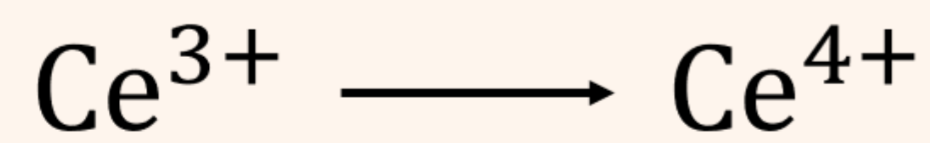
$$D = \frac{L^2}{\pi^2 \tau_{fit}}$$

Diffusion length (taken from image) \rightarrow L

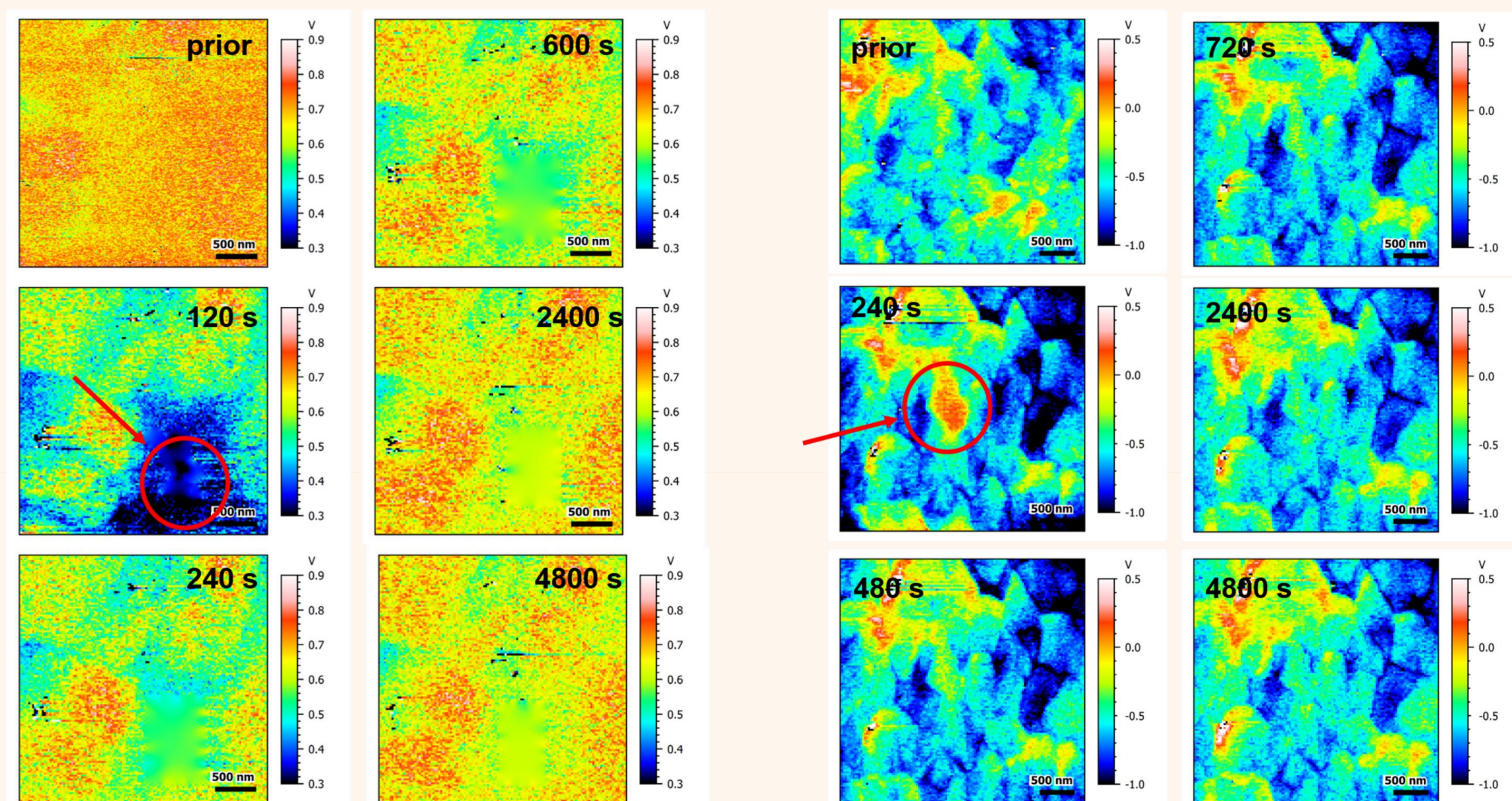
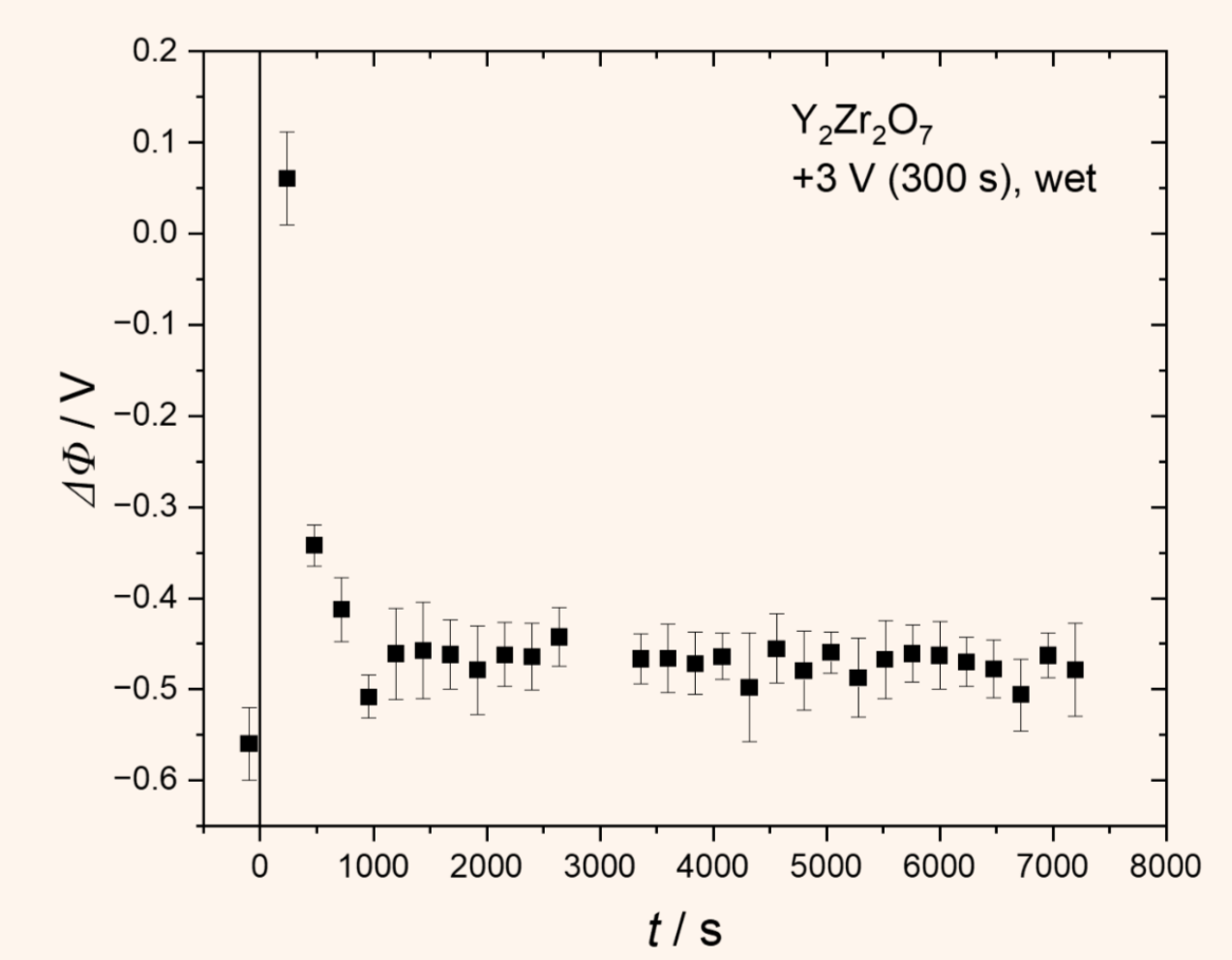
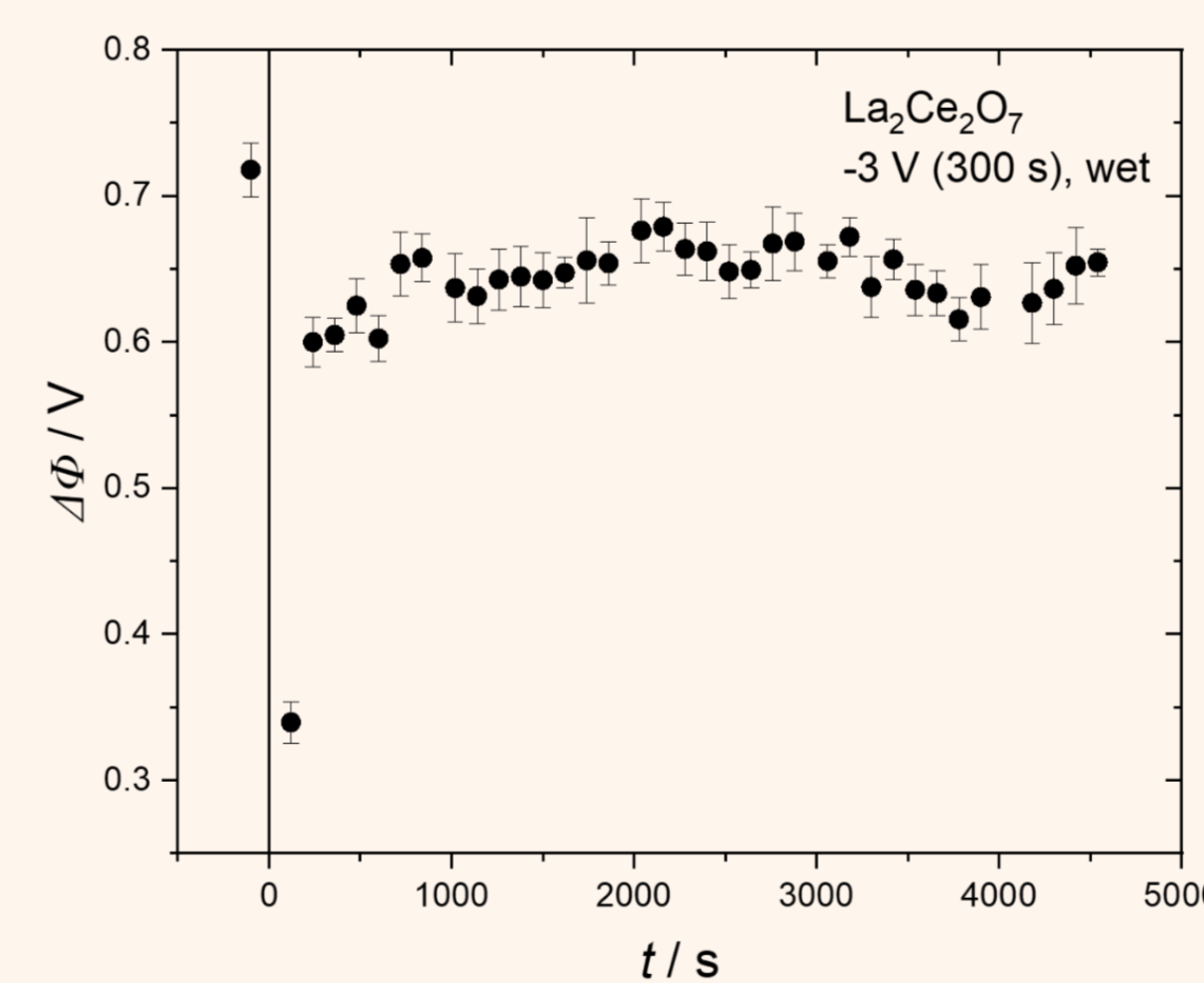
time constant of the relaxation curve \rightarrow τ_{fit}



$\text{La}_2\text{Ce}_2\text{O}_7$



$\text{Y}_2\text{Zr}_2\text{O}_7$



Conclusion & Outlook

Using KPFM-based polarization-relaxation measurements, diffusion coefficients were successfully determined in dry and wet environment by applying positive or negative polarization.

- Highest D for $\text{La}_2\text{Ce}_2\text{O}_7$ with $7.70 \cdot 10^{-13} \pm 8.11 \cdot 10^{-14} \text{ cm}^2/\text{s}$ under wet cond. & neg. applied potentials
- Higher overall conductivity for $\text{La}_2\text{Ce}_2\text{O}_7$ compared to $\text{Y}_2\text{Zr}_2\text{O}_7$, due to bigger grains and lower pot. difference between bulk and grain boundaries

Acknowledgements

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[1] K. Neuhaus, H. D. Wiemhöfer, Solid State Ionics. 371 (2021) 115771.

[2] M.A. Subramanian, G. Aravamudan, G.V.s. Rao, Prog. Solid State Chem. 15 (1983) (2) 55-143.

[3] K. Neuhaus, C. Schmidt, L. Fischer, W. A. Meulenber, K. Ran, J. Mayer, S. Baumann, Beilstein J. Nanotechnology. (2021) (12) 1380-1391.