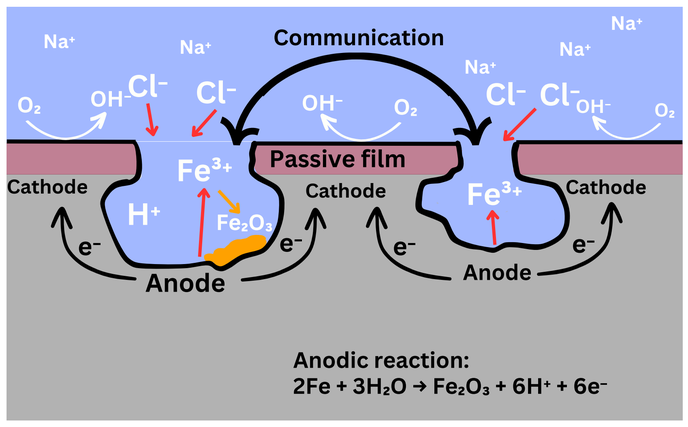
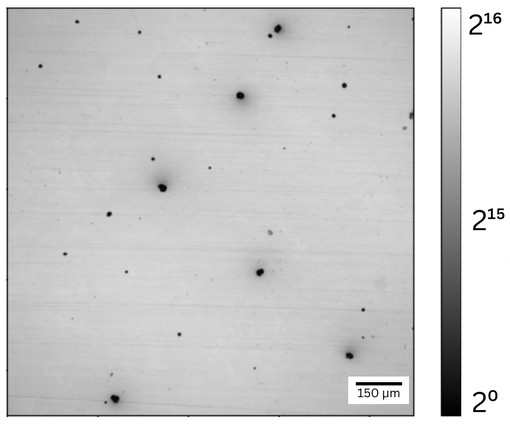
Chemical Communications in Pitting Formation: A Multi-Faceted Study on Pitting Corrosion in Steel using Optical Microscopy, Machine Learning, and Physical Modeling

Aleksei Makogon, Frédéric Kanoufi, Viacheslav Shkirskiy
aleksei.makogon@cnrs.fr
Université Paris Cité, ITODYS, CNRS-UMR 7086

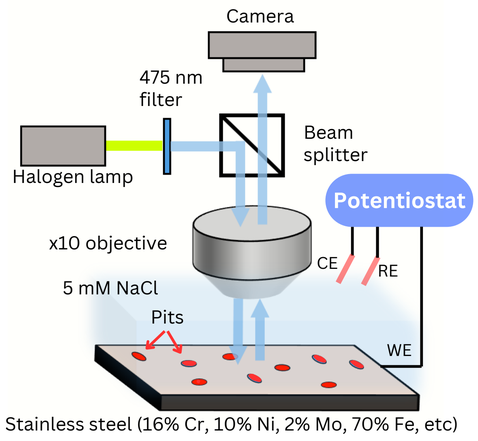
Synchronized degradation: multimodal approach to pitting communication studies



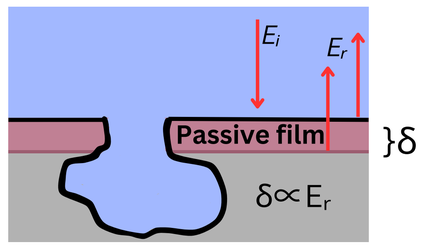
Scheme of pits growth and communication



Optical microscopy view of pitting corrosion on a steel surface during the experiment



Scheme of the setup [2]



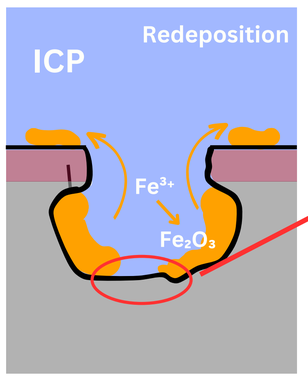
$$\frac{\partial}{\partial t}\left(1+\frac{\Delta R}{R}\right) \sim i$$

Change in reflected light intensity is proportional to the electrical current

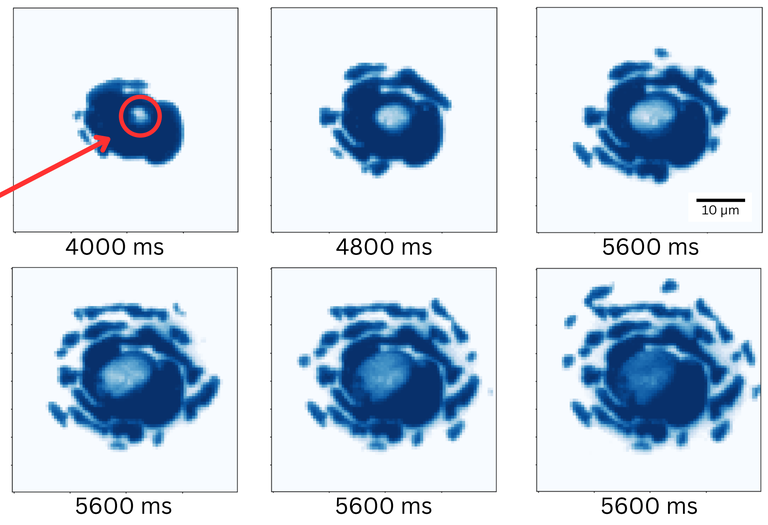
Reflective microscopy was coupled with chronoamperometry (1.6 V (vs Ag/AgCl))

Goal: Investigate communication between pits using optical microscopy reinforced by computer vision and data science

Single Pit Dynamics: Redeposition Insights

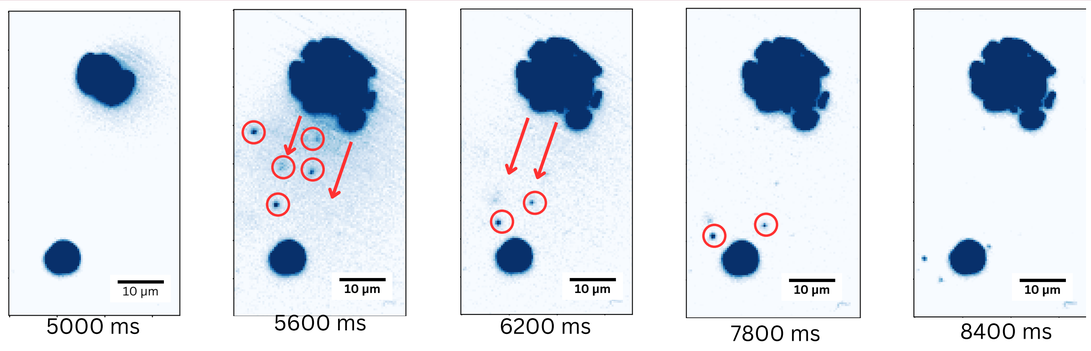


Scheme of Insoluble Corrosion Products Redeposition inside single pit

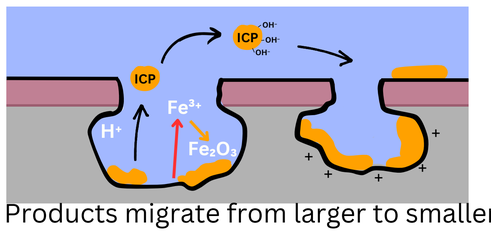


Sequential images of a corrosion pit: from the bright appearance of pure metal, darkening with passivation, to the surrounding deposition of corrosion products.

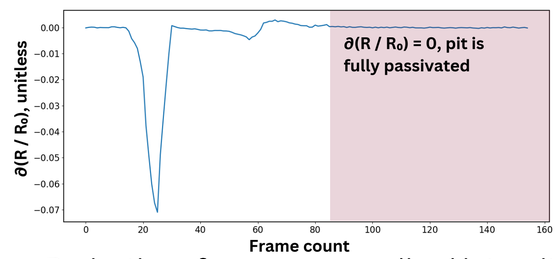
Adjacent Pits: A Dance of Decay



Sequential images showcasing two active pits. Corrosion products are observed migrating from the larger pit towards the smaller one, evidencing the dynamic interplay of pit interactions

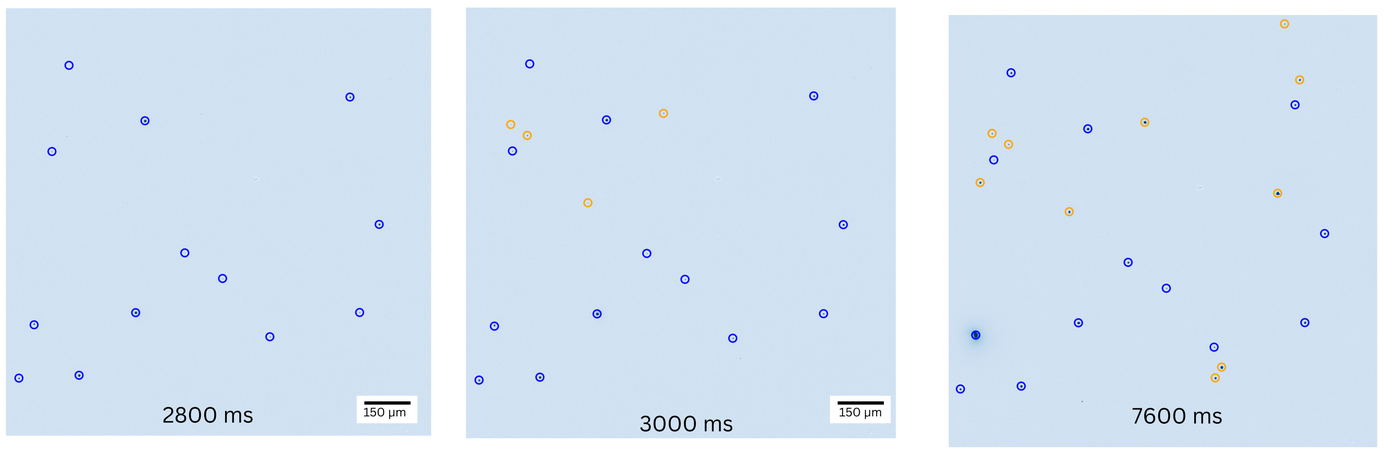


Products migrate from larger to smaller pits, influenced by pH and charge dynamics, leading to pit passivation.

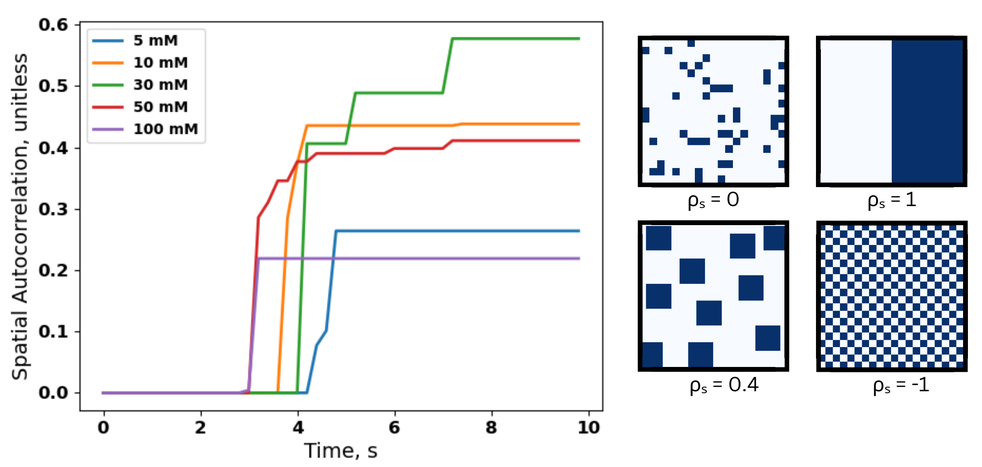


Derivative of average normalized intensity of the small pit

Proximity Matters: Understanding the Spatial Distribution of Corrosion Pits



At 2800ms, initial pits highlighted in blue. At 3000ms, original pits in blue with emerging pits in orange. (Bottom) At 7600ms, further development of older (blue) and newer pits (orange). The evolution indicates a trend of new pits emerging closer to pre-existing ones, underscoring an increase in spatial autocorrelation.



Temporal progression of spatial autocorrelation (SA). SA consistently increases over time, the values remain unaffected by the salt concentration.

A novel approach to investigate pit communication during steel pitting corrosion was established, utilizing optical microscopy and machine learning

Pit communication significantly influences overall reactivity, underscoring its practical relevance and the need for developing respective physical models

This work was partially financially supported by the Agence Nationale de la Recherche 33 (ANR) Jeunes chercheuses, jeunes chercheurs, ANR JCJC, program (OCTAWA project, ANR-34 15 22-CE29-0010-01).
In collaboration with Université Libre de Bruxelles

[1] http://impact.nace.org/economic-impact.aspx
[2] Godeffroy L, Makogon A, Derouich S, Kanoufi F, Shkirskiy V. ChemRxiv. Cambridge: Cambridge Open Engage; 2023;
[3] George R. Engelhardt and Digby D. Macdonald 2020 J. Electrochem. Soc. 167 013540
[4] Rebecca S. Marshall et al 2022 J. Electrochem. Soc. 169 021506