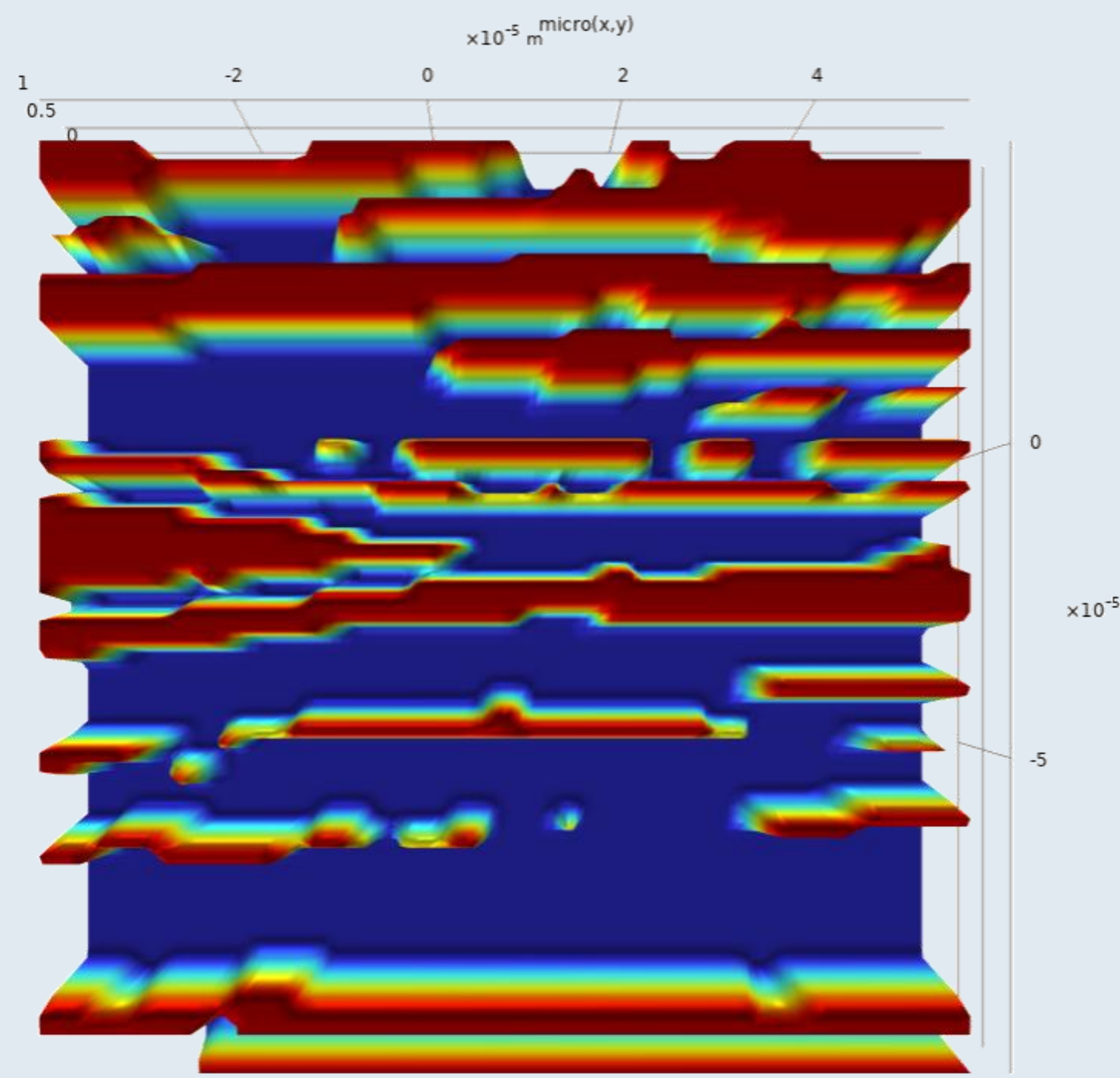




Experimental and Numerical Study of the Selective Dissolution Mechanism of a Super Duplex Stainless Steel

By combining experimental electrochemical measurements and microstructure-based phase-field simulations, this project explores the mechanisms governing selective dissolution in a super duplex stainless steel in sour environment.

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Introduction

Duplex stainless steels are commonly used in oil and gas production due to their high mechanical properties and good resistance to stress corrosion cracking. In particular, URTM 2507 (EN 1.4410) exhibits good resistance to stress corrosion cracking in an acidic environment containing chlorides at low partial pressures of hydrogen sulfide (H₂S). At high H₂S partial pressures, samples do not exhibit cracking, but the selective dissolution of a phase is visible on the sample surface [1]. Even if no cracking occurs,

surface dissolution is sufficient to conclude that the stress corrosion cracking resistance is not suitable for this environment [2]. Therefore, a deeper understanding of the dissolution mechanism is necessary to further expand the application range of the grade. The phase field model will help to capture first order parameters in the mechanism.

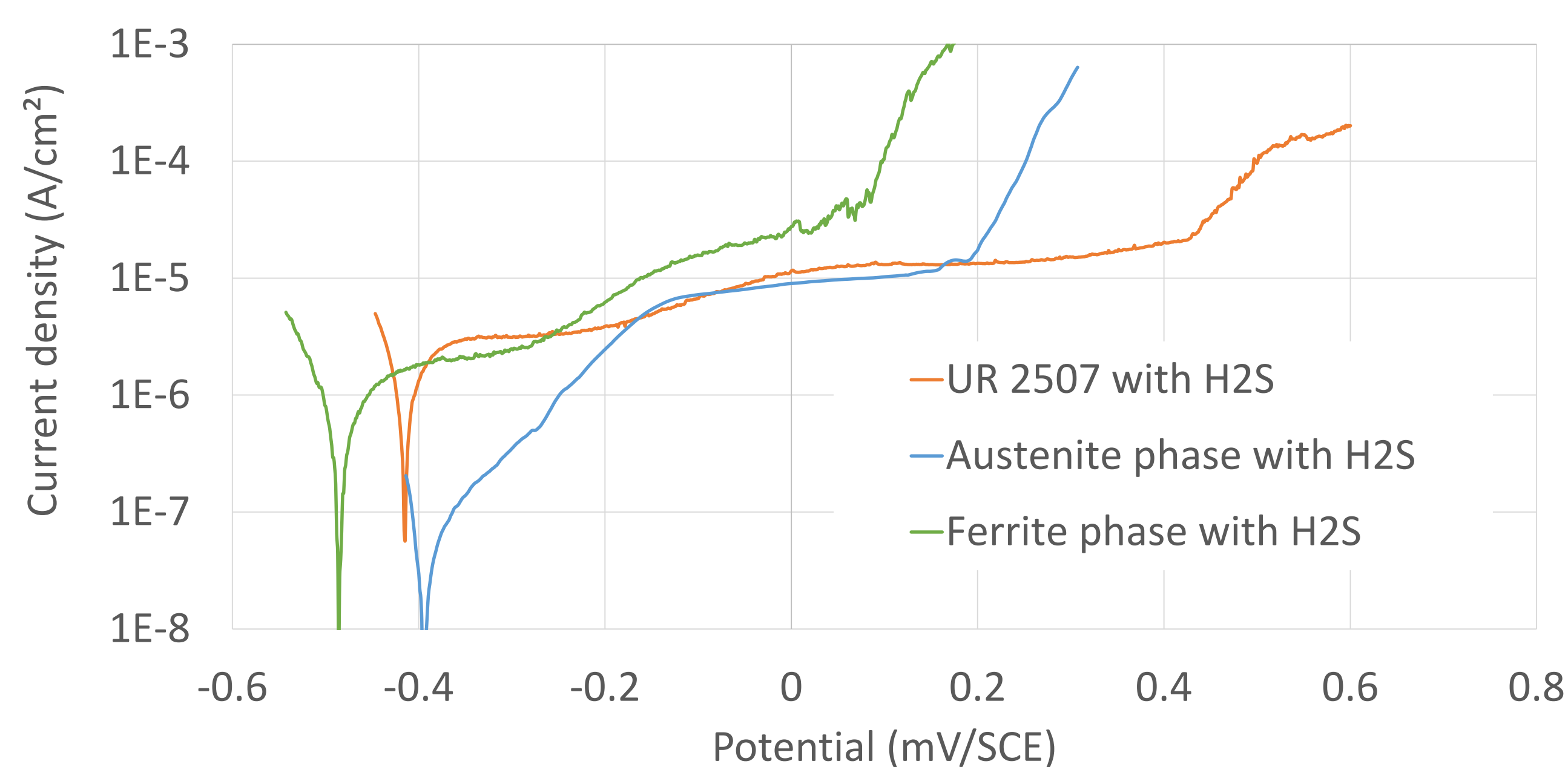


Figure 1. Right. Polarization curves of URTM 2507 and its separate phase in H₂S environment

Methodology

The duplex stainless steel microstructure was incorporated into the model following image-processing techniques used to distinguish the ferrite and austenite phases. A phase-field variable was introduced to account for the specific dissolution behavior of each phase.

The electrochemical behavior of each phase was then experimentally characterized using laboratory-produced model alloys reproducing the respective chemical compositions of ferrite and austenite.

Corrosion rate is defined from electrochemical curves :

$$\begin{cases} i_{ferrite} = f(\varphi_s - \varphi_L) * (1 - micro(x, y)) \\ i_{austenite} = f(\varphi_s - \varphi_L) * micro(x, y) \\ i_{loc} = i_{ferrite} + i_{austenite} \end{cases}$$

Results

The phase-field simulations accurately reproduce the experimentally observed dissolution pathways. Ferrite undergoes rapid dissolution, while austenite acts as an effective physical barrier that impedes dissolution propagation.

The maximum dissolution depth was found to be sensitive to the sampling orientation, and a good correlation was obtained between experimental observations and numerical predictions.

Microstructural optimization studies indicate that decreasing the spacing between austenite regions may reduce the maximum dissolution depth. Future investigations will focus on the detailed characterization of corrosion products to quantify the potential hydrogen uptake associated with the dissolution process.

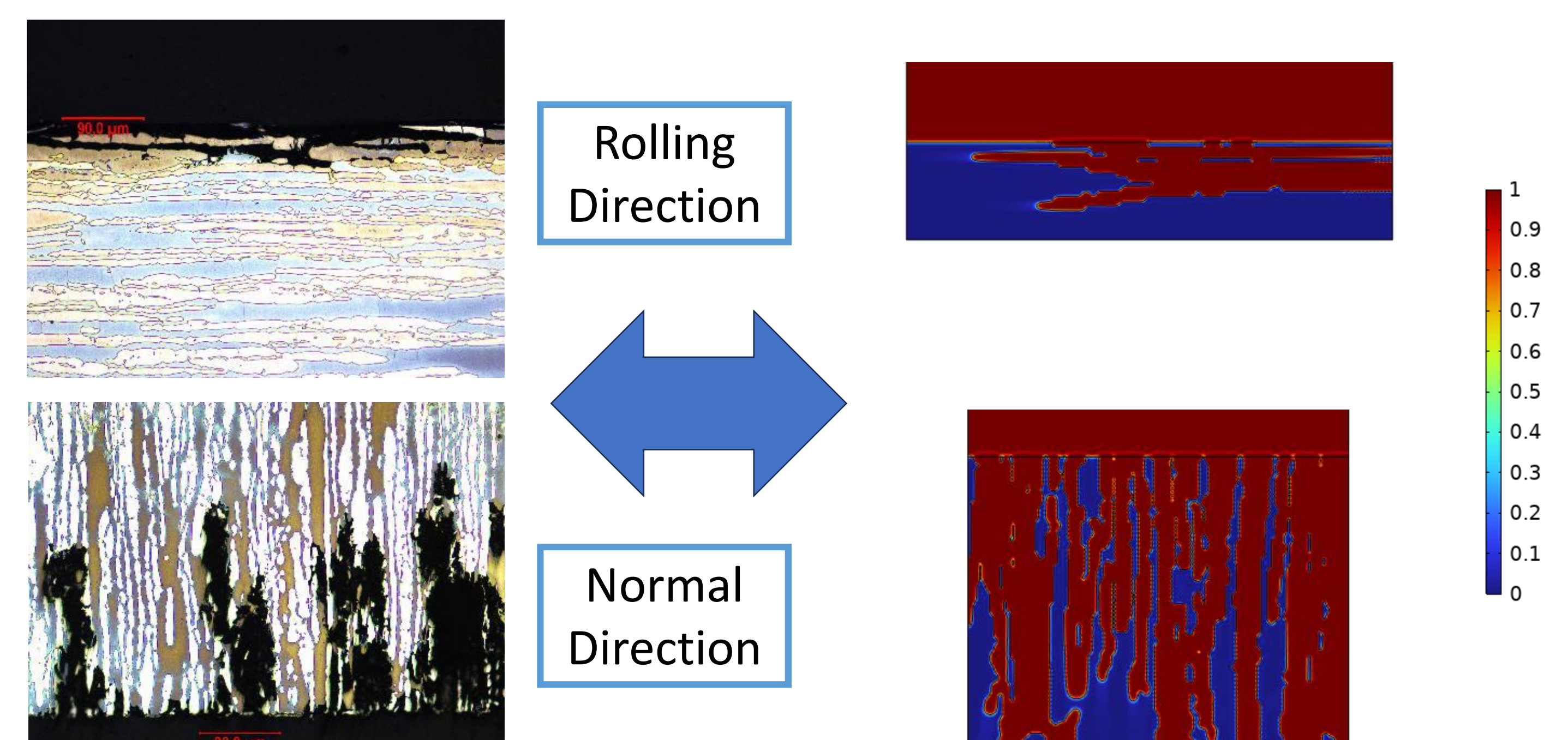


Figure 2. Comparison of experimental dissolution front with results obtained with phase field model

REFERENCES

[1] R. Oltra and al., "The stress corrosion cracking of duplex stainless steels in environments containing chlorides and H₂S. Study of the ferrite phase behaviour", Corrosion Science, Volume 27, Issues 10–11, 1987, Pages 1251-1269

[2] F. Zanotto, « Stress-Corrosion Cracking Behaviour of Lean-Duplex Stainless Steels in Chloride/Thiosulphate Environments », Metals 2018, 8(4), 237

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