Evaluation of Corrosion Resistance of 316L stainless steel with or without SiC additions produced via Directed Energy Deposition

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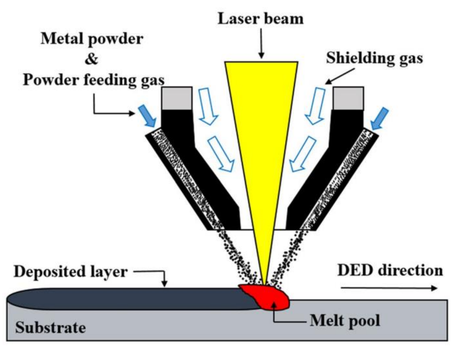
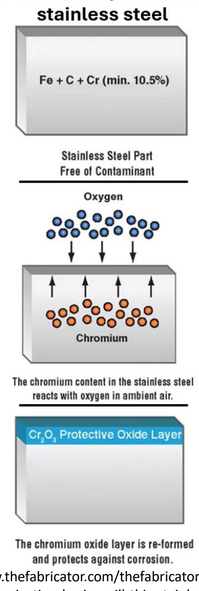
Background

Direct Energy Deposition (DED)



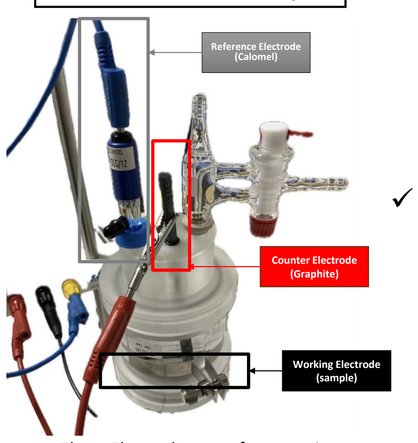
[Lim (2021)]

Passivation process of stainless steel



[https://www.thefabricator.com/thefabricator/article/testingmeasuring/passivation-basics-will-this-stainless-steel-rust-]

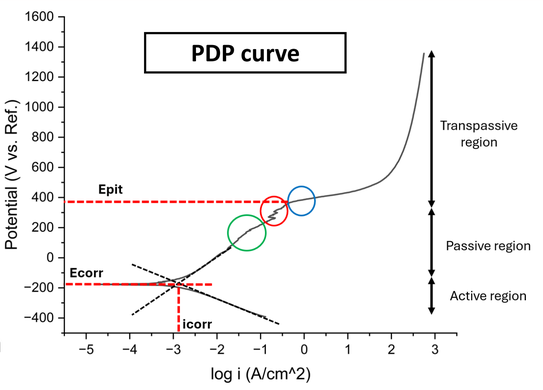
Corrosion tests setup



Three Electrode setup for corrosion tests on flat samples.

Tests performed in **0.5M NaCl** (aq) solution at room temperature

- ✓ Open Circuit Polarization **(OCP)** ~ 15h → For system stabilization
- ✓ Electrochemical Impedance Spectroscopy **(EIS)** → Bode and Nyquist plots for **general corrosion** evaluation
- ✓ Potentiodynamic Polarization **(PDP)** → PDP curve for **pitting corrosion**

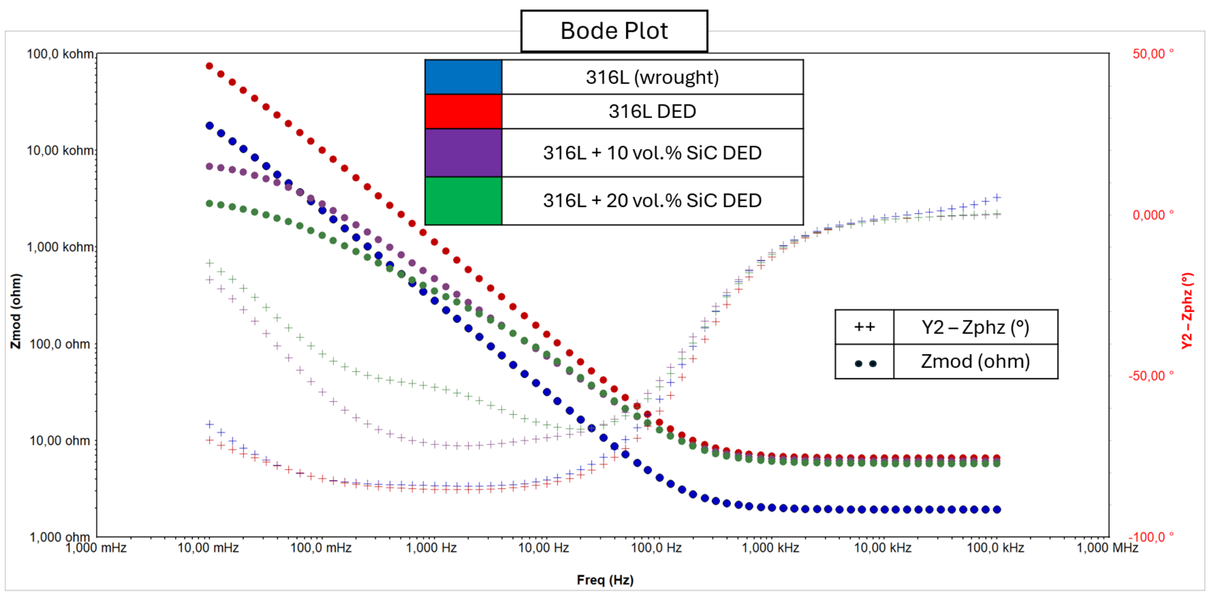


The pitting is characterized by 3 steps:

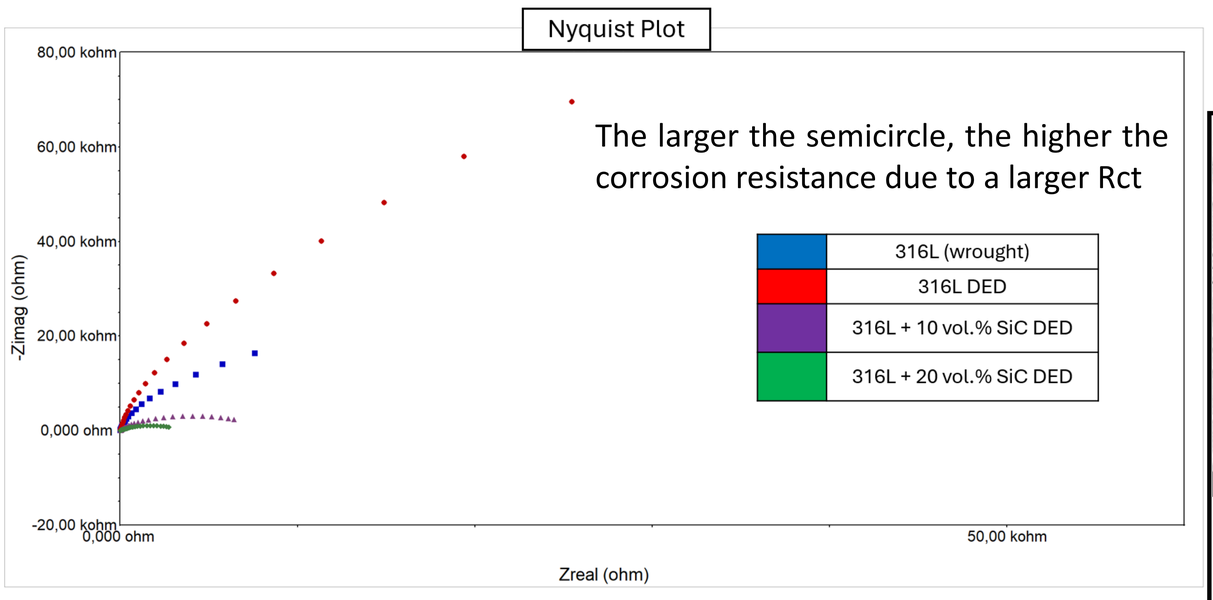
- Pitting initiation [1]
- Metastable pitting growth [2]
- Stable pitting growth [3] [Al Saadi (2016)]

Results

EIS



- The higher the magnitude of impedance at lower frequencies, the higher the corrosion resistance due to the decrease of kinetics of the charge transfer.
- The lower the phase angle plot, the higher the capacitance, thus the better the corrosion resistance.

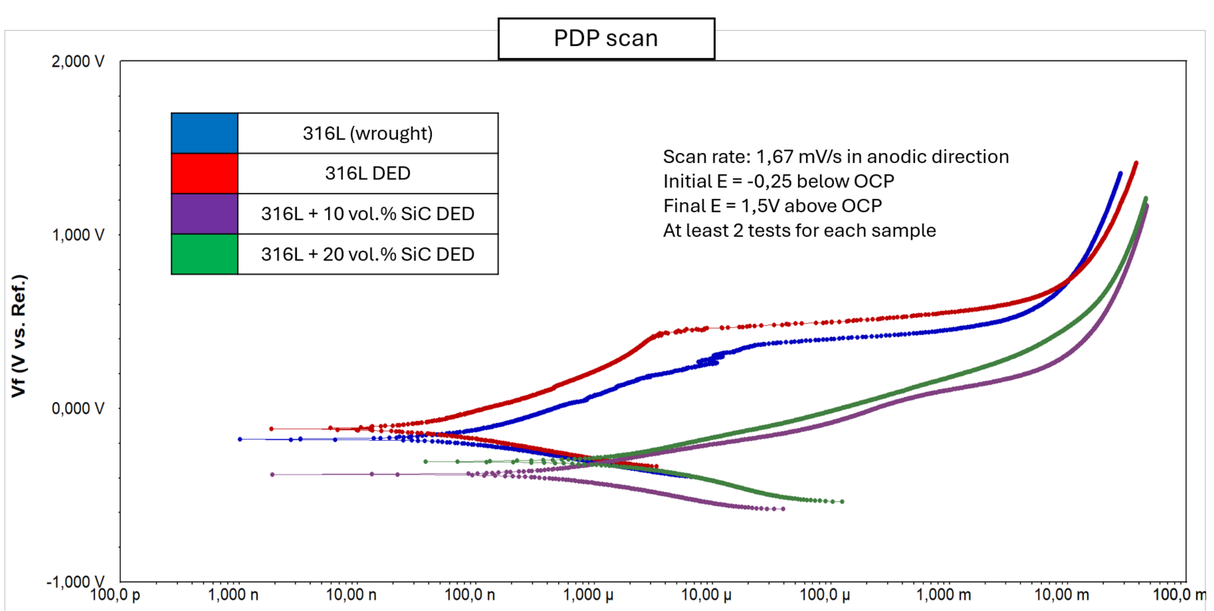


The Nyquist plot is in the shape of a semicircle, and the diameter of the plot gives the charge transfer resistance of the samples.

Materials	Charge transfer resistance Rct or Rp (Ωcm²)	Goodness of fit
316L (wrought)	**9,8e+05**	5,8e-04
DED 316L	**1,1e+06**	7,6e-04
DED 316L+10 vol.% SiC	**3,9e+02**	7,7e-04
DED 316L+20 vol.% SiC	**1,5e+02**	1,3e-02

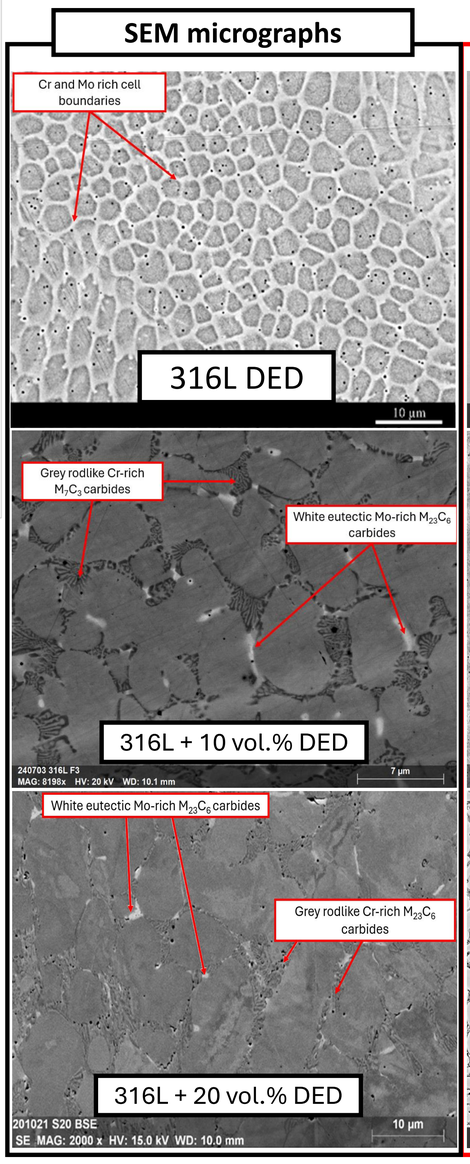
- **EIS** is an AC technique while **PDP** is a DC technique, leading to a difference in resistance values when the surface is not completely homogeneous.
- The higher the resistance of the sample, the more the corrosion rate is reduced. The lower the value of icorr and the higher the Rp, the higher the corrosion resistance.

Potentiodynamic polarization (PDP)

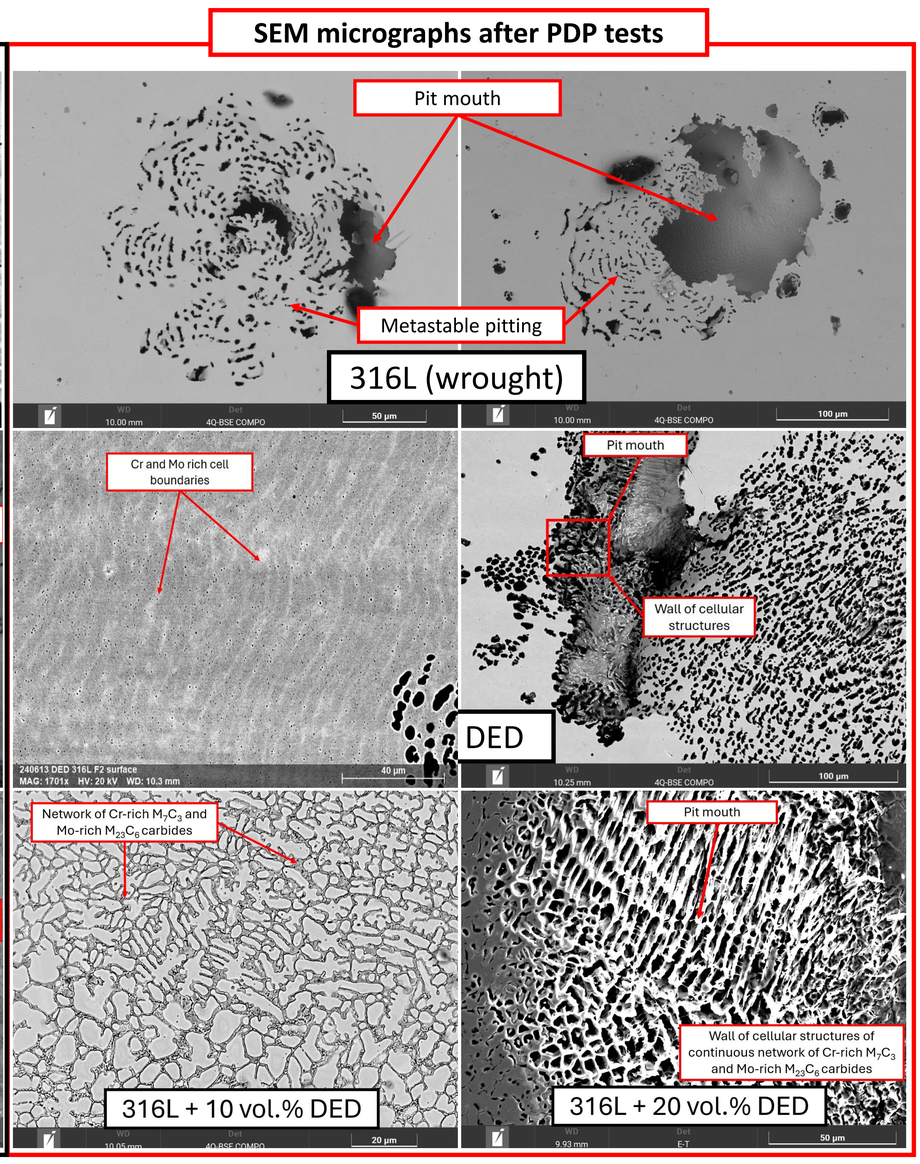


Materials	Ecorr (mV)	icorr (nA/cm²)	Epit (mV)	Epit – Ecorr (Range of passivity)
316L (wrought)	-158,3 ± 15,3	42,4 ± 14,3	344,90 ± 20,5	508,6
DED 316L	-123,5 ± 6,4	23,3 ± 19	533,55 ± 19,6	657,1

SEM micrographs



SEM micrographs after PDP tests



Conclusions

- ➢ High cooling rates lead to the solidification of out-of-equilibrium microstructures and of supersaturated solid solution.
- ➢ SiC additions in DED SS 316L lead to the formation of Cr- and Mo-rich carbides either as discontinuous (10 vol.% SiC) or continuous (20 vol.% SiC) network at cell boundaries.
- ➢ DED 316L showed a larger passivity than wrought 316L due to the subgrain structure richer in Cr and Mo.
- ➢ The 316L + 10 vol.% SiC surface does not appear affected by pitting although passivation is not observed on the PDP curve.
- ➢ In 316L + 20 vol.% SiC, cell boundaries seem to act as barrier with respect to corrosion, similarly to Cr-and Mo-rich cell boundaries in DED 316L.

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