# „Development and characterization of additives for multi-wire processes"

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As a chemist and scientist,

- who is considering the waterborne sawing processes

- who want to understand what is behind the way of action

some questions about the process are coming up

➢ **It seems to be clear - environmental friendly water soluble coolant acts both - as coolant and lubricant – but what is behind this action?**

> **We found wetting (soaps, glycols and other alcoholic components, paraffin's) as well as particle stabilization and corrosion inhibition agent.**

➢ **It is not completely clear what is the "best state of the art" for additives that are still on the market for waterborne sawing processes, because the commercial additives in use differ in their properties**

> **We found solid contents of additives for coolants on the market differing from 2 wt.% to almost 25 wt.% with suggested usage levels also differing from low percentage range to more than 20 wt.%**

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➢ **The remaining question is - what are the dominating properties that should be provided by additives in waterborne multi-wire sawing processes**

**The wetting and elastic/viscose/plastic properties, to pick-off the friction energy as a lubricant is highly desirable.**

**We found that it is the CORROSION the SMALL SILICON PARTICLES, created in the sawing process that extremely changes the waterborne coolant properties over time and in respect to electrolyte content and pH-value, making the process difficult be understood.**

➢ **Additives should therefore provide a powerful corrosion protection for the silicon particles created in the sawing process**

➢ **There is a need for characterizing and understanding the corrosion properties of silicon particles created in the waterborne sawing processes.**

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# SEM / EDX analyses of corroded silicon obtained in waterborne wire processes
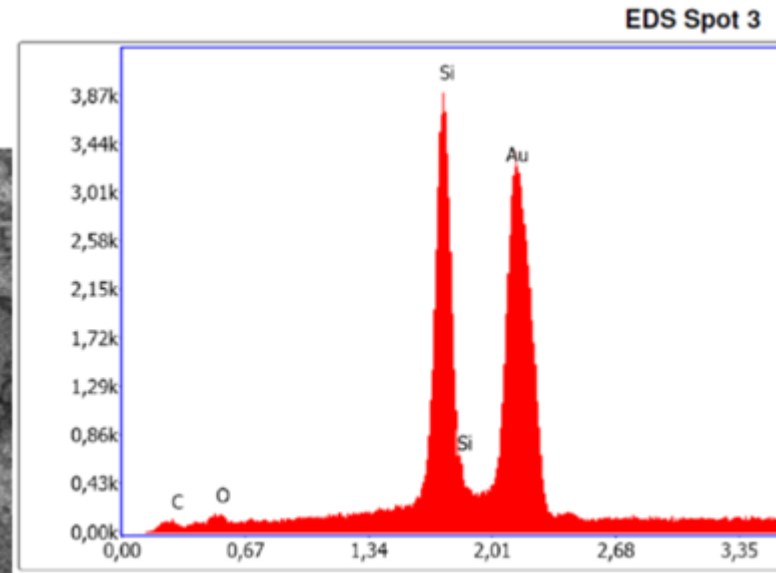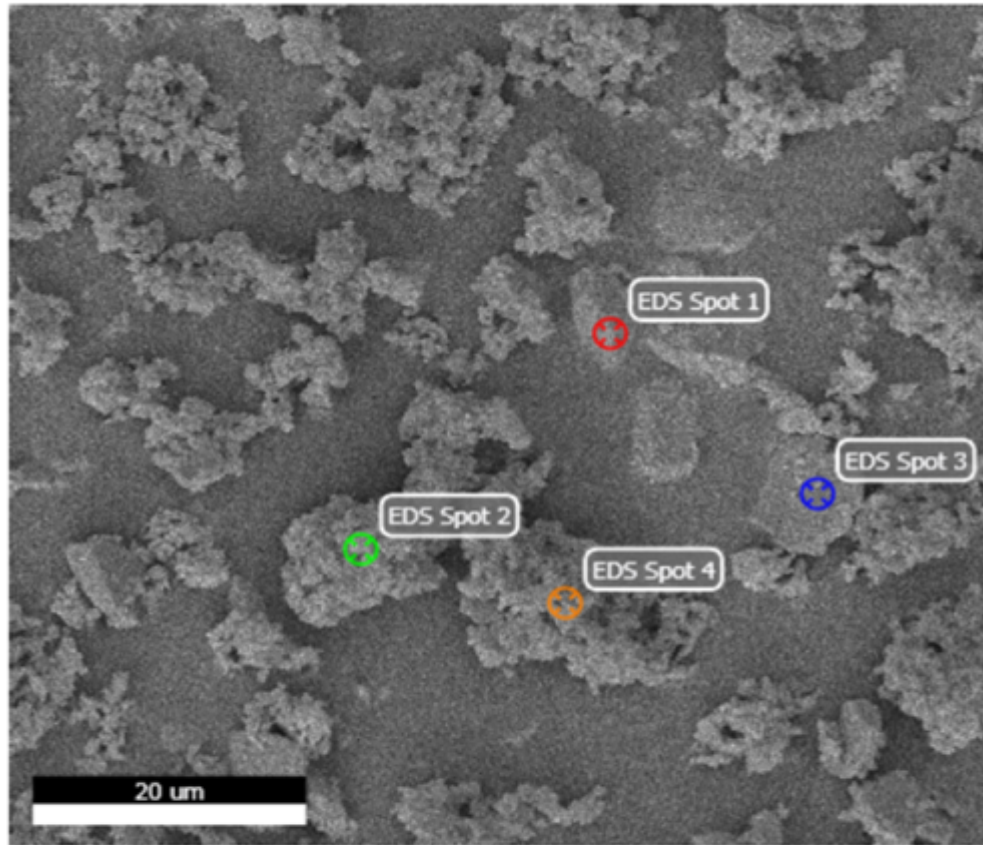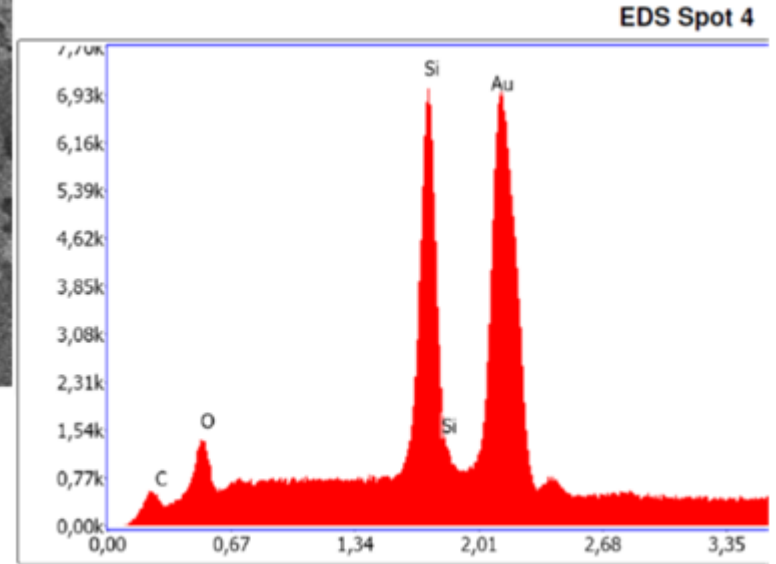


**The result: colloidal silicon oxides are formed**

# In general – corrosion stability and reactions of silicon



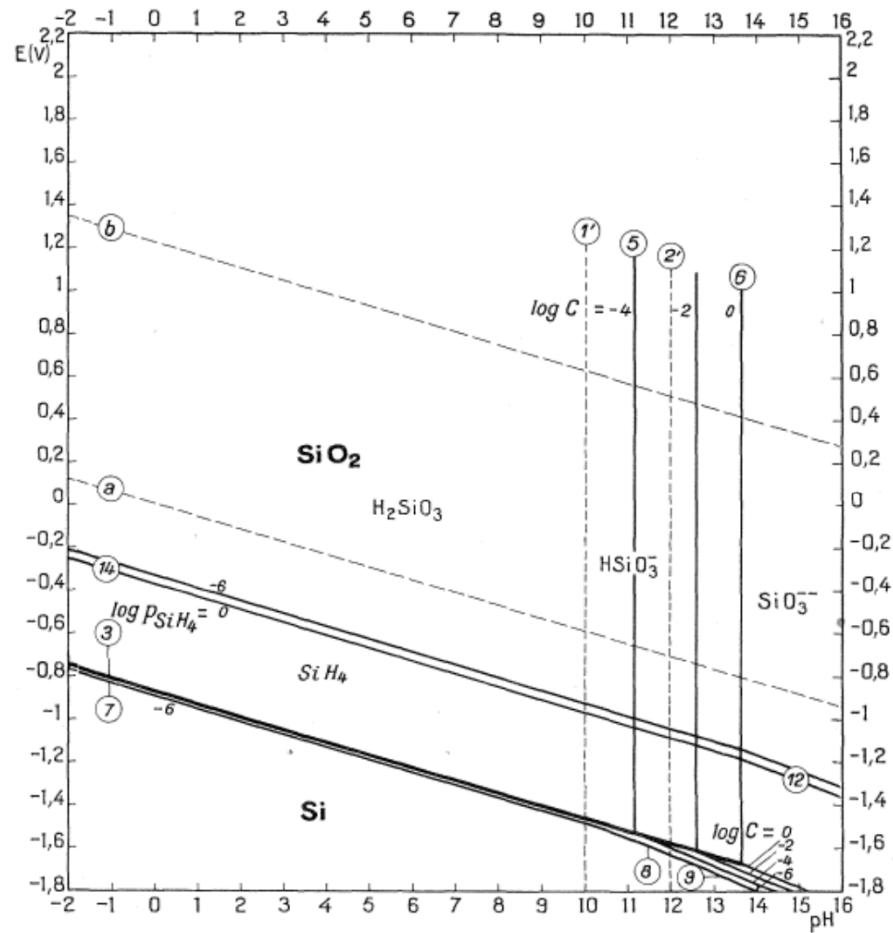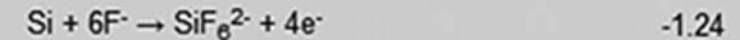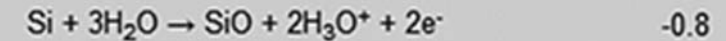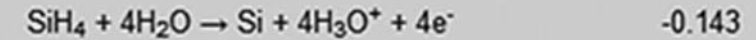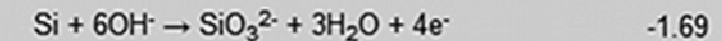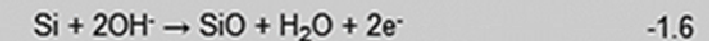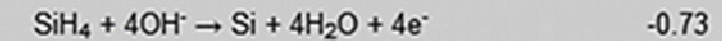FIG. 1. Potential–pH equilibrium diagram for the system silicon–water, at 25°C. (Considering $SiO_2$ in the form of quartz. Approximate diagram.)

acid conditions – potentials in $V_0$

| | |
|---|---|
| $SiH_4 + 4H_2O \rightarrow Si + 4H_3O^+ + 4e^-$ | -0.143 |
| $Si + 3H_2O \rightarrow SiO + 2H_3O^+ + 2e^-$ | -0.8 |
| $Si + 6H_2O \rightarrow SiO_2 + 4H_3O^+ + 4e^-$ | -0.909 |
| $Si + 6F^- \rightarrow SiF_6^{2-} + 4e^-$ | -1.24 |
| $SiO + 3H_2O \rightarrow SiO_2 + 2H_3O^+ + 2e^-$ | -1.018 |

alkaline conditions – potentials in $V_0$

| | |
|---|---|
| $SiH_4 + 4OH^- \rightarrow Si + 4H_2O + 4e^-$ | -0.73 |
| $Si + 2OH^- \rightarrow SiO + H_2O + 2e^-$ | -1.6 |
| $Si + 6OH^- \rightarrow SiO_3^{2-} + 3H_2O + 4e^-$ | -1.69 |

➢ *at differed potentials and pH – also differed species and derivates of silicon are stable*
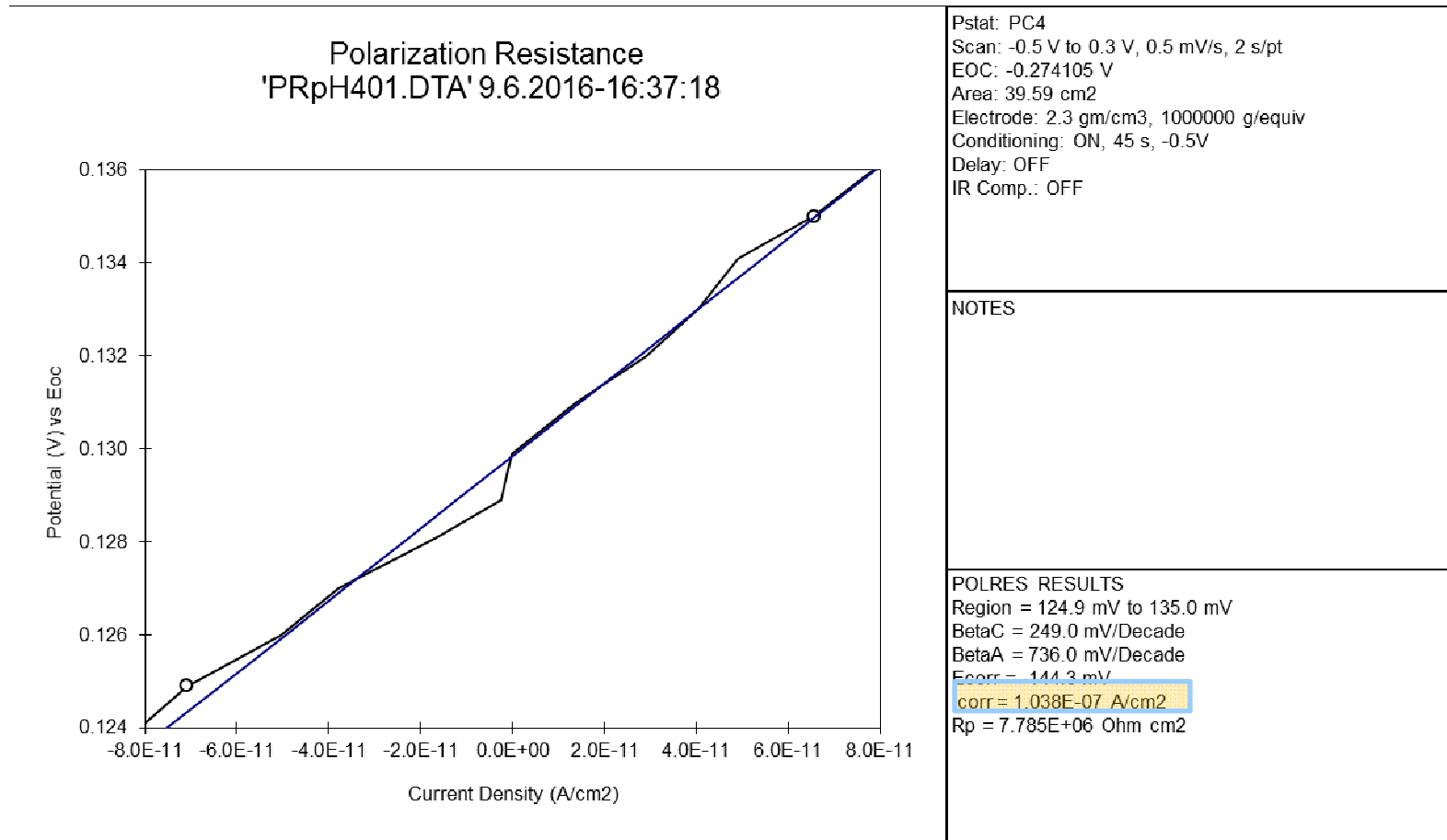
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# 1st method of determination of corrosion current Ic of silicon in Na-electrolyte buffer at a certain pH using the Tafel-experiment
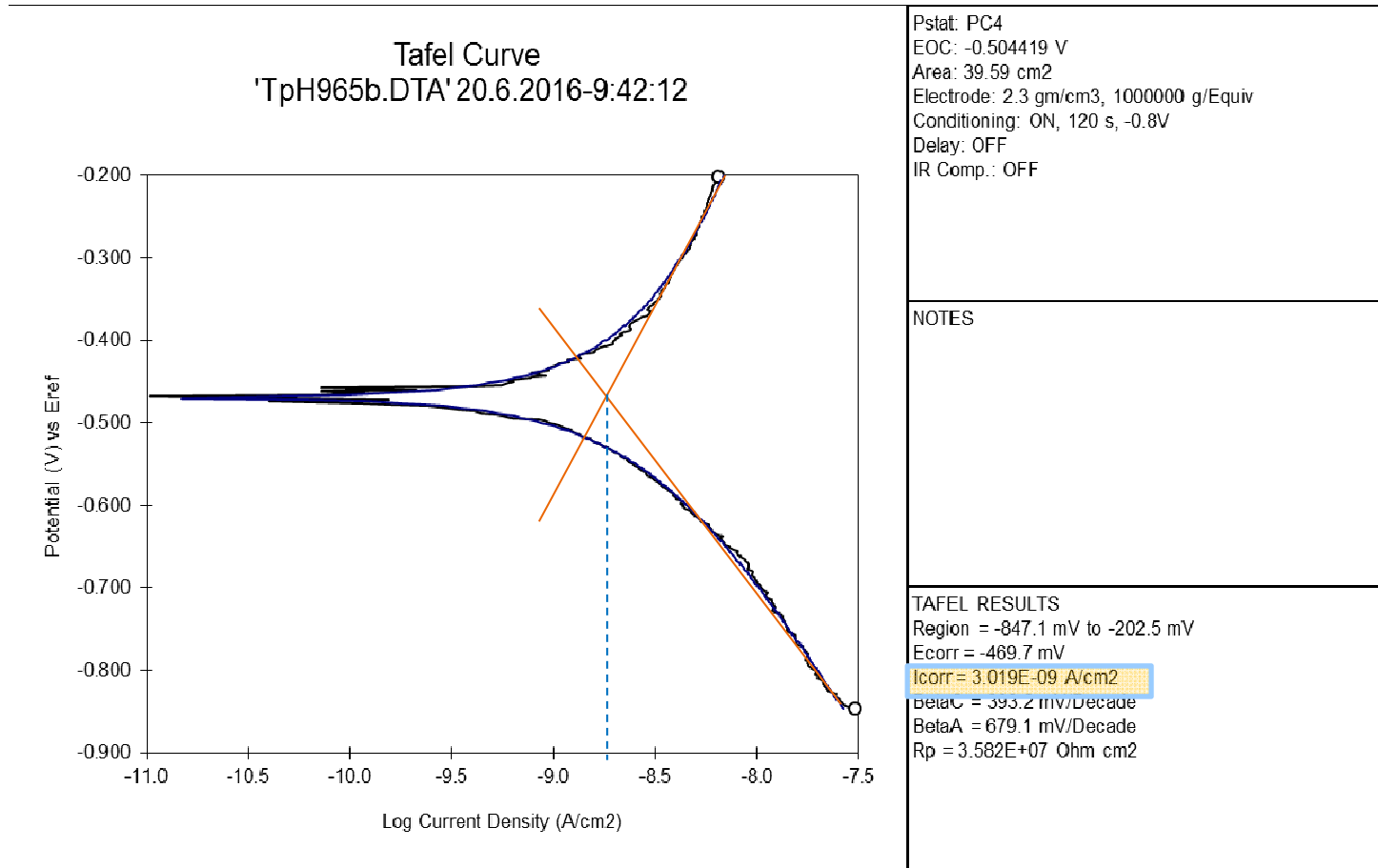


> cathodic and anodic polarization leads to Ic as cutting point between both tangents at Ecorr resting potential of the measured system

## 2<sup>nd</sup> method of determination of corrosion current Ic of silicon in Na-electrolyte buffer at a certain pH using the polarization method-LPR-experiment



Polarization Resistance
'PRpH401.DTA' 9.6.2016-16:37:18

Pstat: PC4
Scan: -0.5 V to 0.3 V, 0.5 mV/s, 2 s/pt
EOC: -0.274105 V
Area: 39.59 cm2
Electrode: 2.3 gm/cm3, 1000000 g/equiv
Conditioning: ON, 45 s, -0.5V
Delay: OFF
IR Comp.: OFF

NOTES

POLRES RESULTS
Region = 124.9 mV to 135.0 mV
BetaC = 249.0 mV/Decade
BetaA = 736.0 mV/Decade
Ecorr = 144.3 mV
corr = 1.038E-07 A/cm2
Rp = 7.785E+06 Ohm cm2

➢ diagonal bluish theoretical curve and black the curve of the linear polarization measurement resulting in calculation of Ic as shown above 8
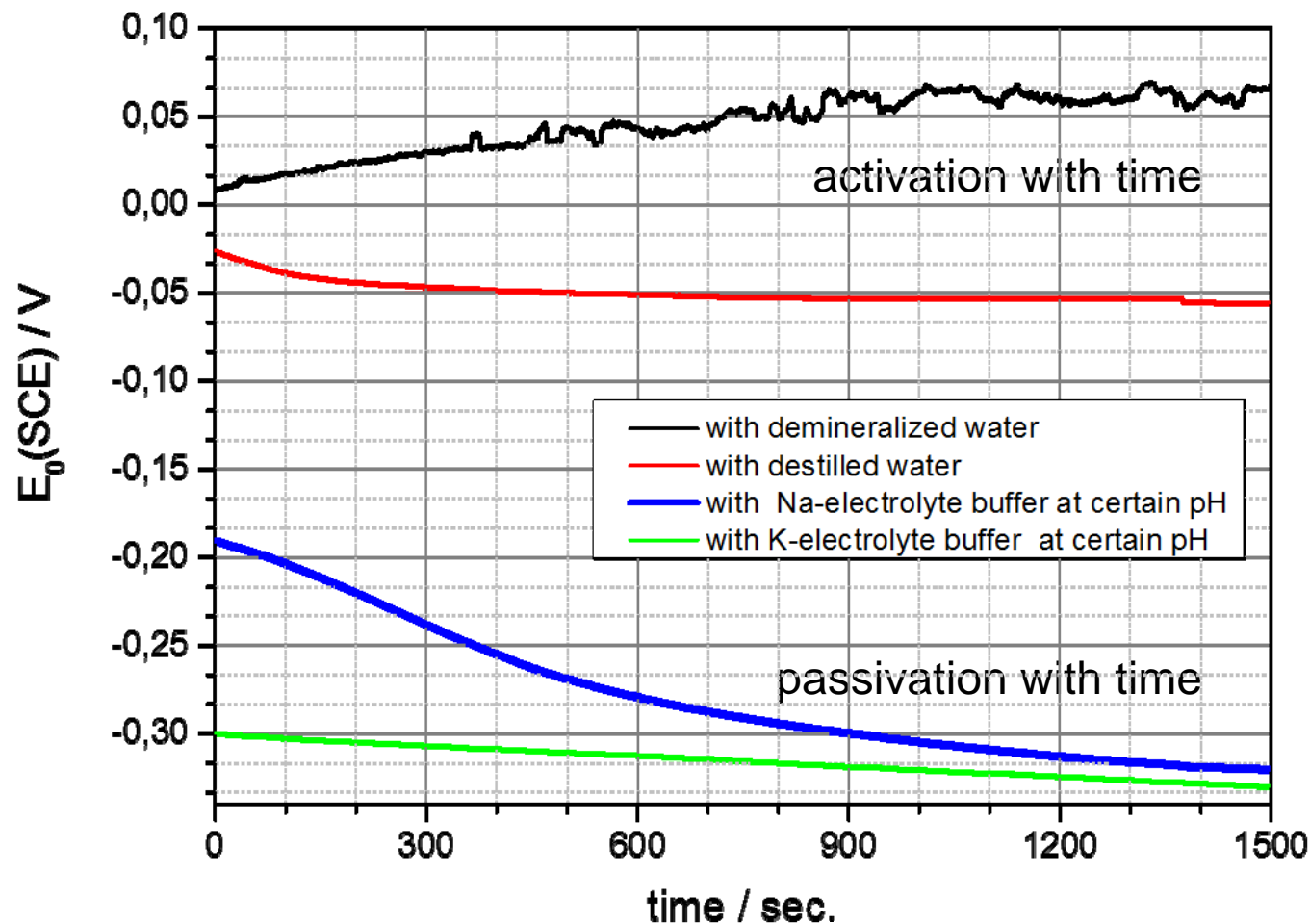
# Comparison of 1st and 2nd method of determination of corrosion current Ic of silicon in Na-electrolyte buffer at different pH
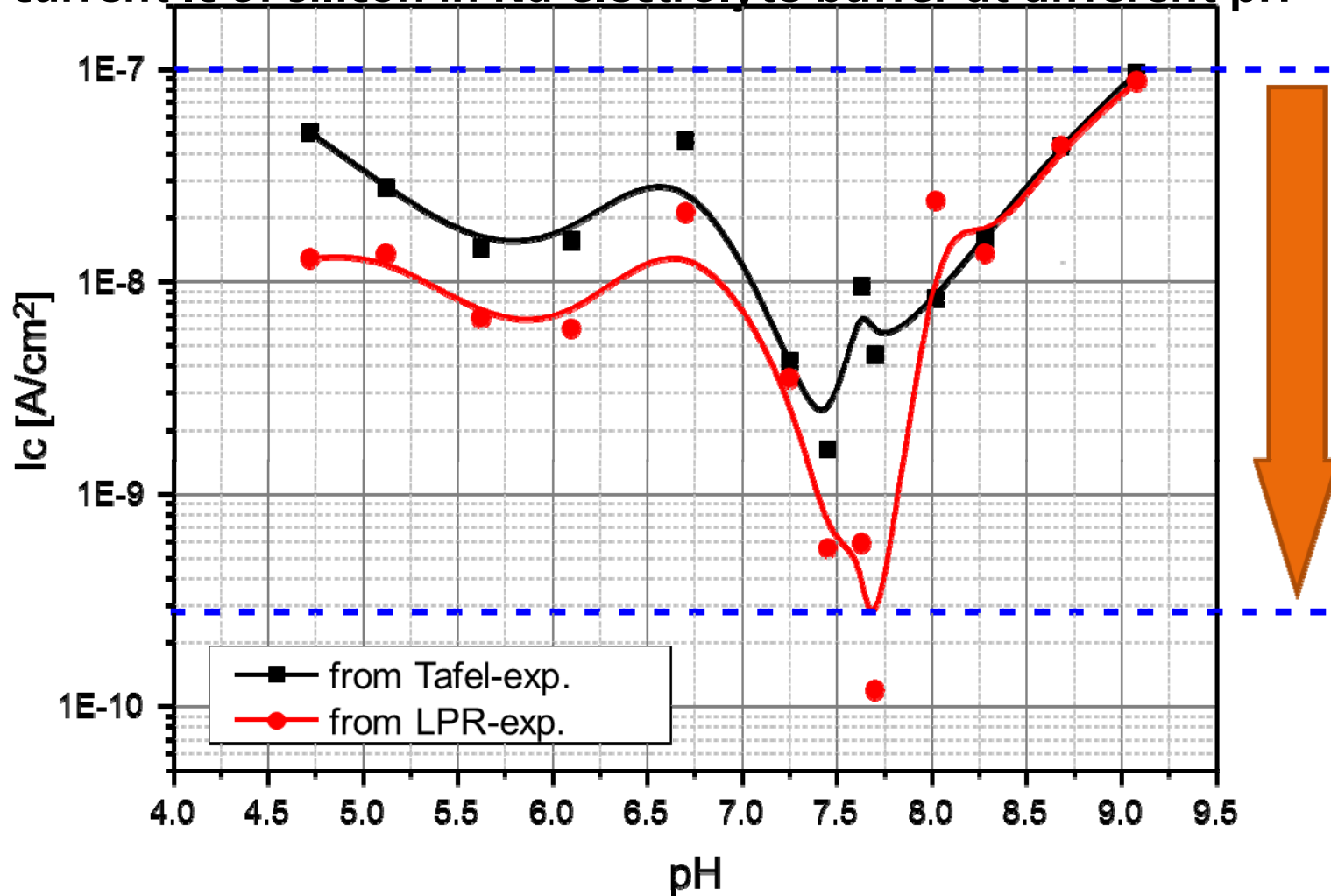


➤ Only by choosing the best. pH for the system, Ic can be reduced by a factor of approx. 250

# Resting potentials – corrosion behavior of silicon in different electrolytes



➤ As more negative the potential gets over time as more passivation will be possible, leading to less corrosion

# Resting potentials – corrosion behavior of silicon with different corrosion inhibition agents in Na-electrolyte buffer at a certain pH
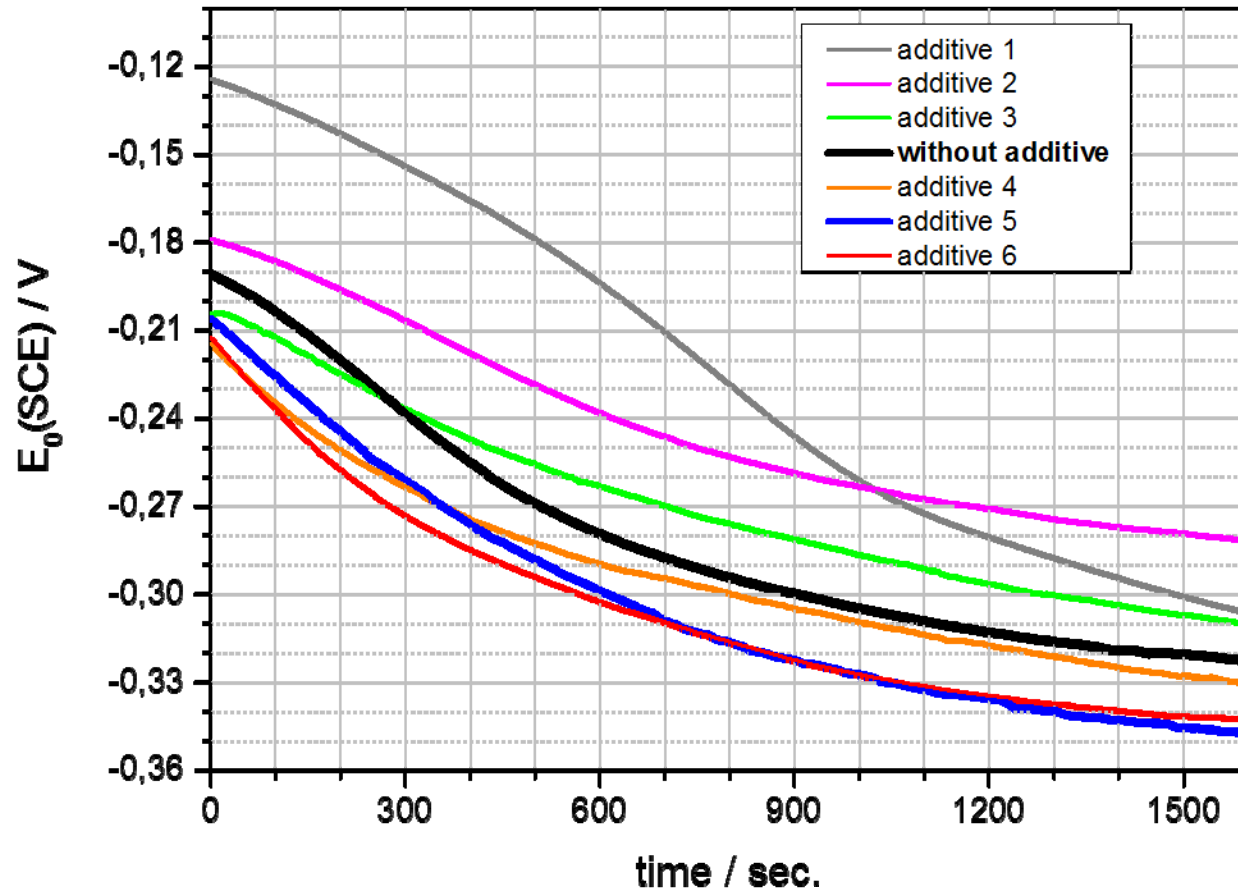


➤ It can be seen that the used corrosion inhibition additives strongly influences the passivation and corrosion stability of silicon.

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# Resting potentials – corrosion behavior of silicon with different corrosion inhibition agents in Na-and K-electrolyte buffer at a certain pH



silicon in Na-electrolyte buffer at a certain pH

silicon in Na-electrolyte buffer at a certain pH
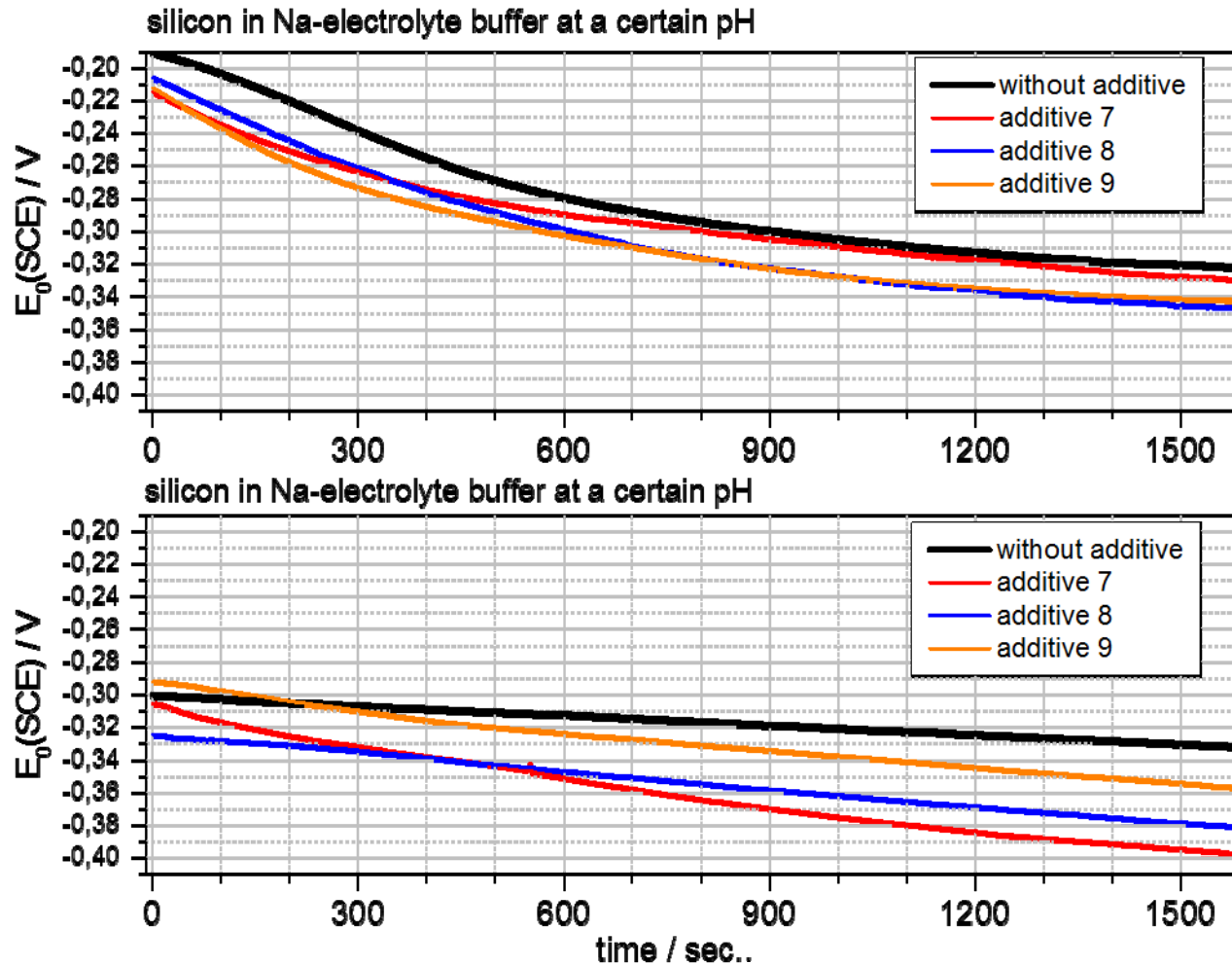
➤ It can be seen that different corrosion inhibition additives in different electrolytes, differently influence the passivation and corrosion stability of silicon.

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# General summary and conclusions

➢ **The corrosion reaction of the silicon particles can dominate the waterborne sawing processes. Therefore they should be characterized and understood.**

➢ **The corrosion of silicon particles is of a complex matter, because it depend on overlapping effects of particle size, pH-value and electrolyte contents, kind of electrolyte impurities and well as on the temperatures created by the waterborne sawing process.**

➢ **Electrochemical measurements can be used to characterize the main corrosion processes of silicon particles, but it is necessary to establish as similar measurement conditions in respect to the sawing processes as possible.**

## Summary and conclusions in detail:

➢ At diffured potentials and pH – also diffured species and derivates of silicon are stable

➢ Ic under certain conditions (pH, temperature, electrolytes..) can be determined by cathodic / anodic polarization (Table-exp.) as well as linear polarization (LPR-exp.).

➢ Only by choosing the best. pH for the system, Ic can be reduced by a factor of approx. 200

➢ Through resting potential measurements over time passivation or activation of the silicon can be determined:

   -As more negative the potential gets over time as more passivation will be possible, leading to less corrosion

   -It can be seen that the used corrosion inhibition additive, strongly influences the passivation and corrosion stability of silicon.

   -It can also be seen that different corrosion inhibition additives in different electrolytes, differently influence the passivation and corrosion stability of silicon.

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