Electrochemical Corrosion Measurements of MEA aqueous solutions at elevated temperatures

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Abstract

Background
For post combustion carbon capture (PCC), the conventional solvent is monoethanolamine (MEA). One of the operational difficulties is degradation of solvent and associated increase in corrosivity. Evaluation of corrosivity has traditionally been performed as monitoring of weight loss coupons in media of interest. Alternatively, electrochemical methods are applied. These may be performed in industrial scale (e.g. LPR), or laboratory scale (e.g. Tafel-plots from measurements in glass apparatus) in water solutions. In laboratory scale, the use of standard glass apparatus and water solutions effectively limits the experimental conditions to less than 100 °C and atmospheric pressure. As monitoring of weight loss coupons can be time consuming, especially for low corrosion rates, it is of great benefit to enable electrochemical methods for small-scale studies also at elevated temperatures and pressures. The use of pressure-resistant glass equipment at moderate pressure has the benefit of visual inspection.

Previous work
"An Assembly for Electrochemical Corrosion Studies in Aqueous Environments at High Temperature and Pressure" has been presented by Wilde[1] using a 1 L steel autoclave studying high purity water as well as sodium chloride solutions at about 300 °C. He found a very short Tafel region for the cathodic polarization of Type 304 steel, probably due to high resistance polarization at high currents in high purity water.
Tanaporn Tanupabrungsun and co-workers[2, 3] have studied "Effect of pH on CO2 Corrosion of Mild Steel at Elevated Temperatures" using 2 L and 4 L autoclaves at 80 to 200 °C. The pH-range was pH = 4 and 6. They found iron carbonate to be the dominant corrosion product below 150 °C, and mixed with iron oxide at higher temperatures. Solutions containing dissolved CO2 and Fe^{2+} showed less effect on pH upon changing temperature due to presence of precipitated iron carbonate. Corrosion rates decreased with higher temperature as a protective layer of iron carbonate was formed.
Veawab and co-workers[4] at University of Regina have studied corrosivity of mild steel in MEA at temperatures 40 to 80 °C and observed corrosivity to increase upon both temperature and CO2-loading increase.

Experimental setup
Laboratory scale equipment has been designed in order to extend the previous glassware limits and still allow for work in small scale. That is, a glass autoclave (Büchi Ecoclave) of 1 L volume, see Figure 1, is used allowing 6 barg maximum pressure. This allows for temperatures of water solutions extending to ca 160 °C (dependent on other volatiles or salts in the water solution), and thus comparable to process conditions of the desorber section in a MEA-based PCC-unit.

The glass autoclave has been equipped with sensors for temperature, pressure and pH as well as working electrode (WE), reference electrode (RE) and counter electrode (CE) for the electrochemical measurements. All items must be compatible with the designed pressure range and temperature range. Due to the limited space available in a 1 L volume setup, a custom sample holder for working and counter electrodes had to be designed and manufactured.
The potentiostat Reference 600+ from Gamry with software was used to control the electrochemical methods and measurements. Counter electrode was a 10×25 mm platinum sheet. Working electrode was mild steel or stainless steel 10×25 mm sheet. An Ag/AgCl reference electrode from Cormet was used. The CE and WE sample holder and pressure compatible wire connection were custom made by Cormet.
The glass pH probe was delivered by Büchi. Calibration and temperature correction of pH measurements was performed by a Mettler FiveEasyPlus FP20 pH-meter.

Figure 1: Büchi Ecoclave glass autoclave

Temperature sensor used was a Bola Pt100 P 1792-20 made from PTFE, and the autoclave temperature was controlled by a Thermo AC200-S3 heated bath circulator from Thermo Fischer Scientific.

Results

The corrosivity of mild steel and stainless steel in water and MEA-solutions are measured in the temperature range from 25 to above 100 °C and variation of pH within the alkaline region. The corrosivities are interpreted from electrochemical methods: Tafel-plot and linear polarization.

Acknowledgement

The work is part of the ALIGN-CCUS project[1] to answer the open questions regarding the MEA losses by interconnecting the factors flue gas quality, plant operation and the special operational conditions to the chemistry of solvent degradation including corrosivity.

References

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[1] ACT ALIGN CCUS Project No 271501 (*www.alignccus.eu*)

This project has received funding from RVO (NL), FZJ/PtJ(DE), Gassnova(NO), UEFISCDI (RO), BEIS (UK) and is co-funded by the European Commission under the Horizon 2020 programme ACT, Grant Agreement No 691712.