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The influence of ferric ion impurities on a proton exchange membrane electrolyzer operated at varying temperature and current density conditions

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Introduction

A water purification system is typically used in PEM water electrolysis systems, but over time the quality of the circulating water may deteriorate due to metallic impurities originating from the piping system, catalyst layers and other components degradation. These impurities lead to a progressive increase of the cell voltage [1].

In this work, the influence of 5 ppm Fe^{3+} contamination on cell performance of PEM water electrolysis has been investigated, and the temperature and current density effects on cell performance in the presence of Fe^{3+} were also studied.

Experimental setup

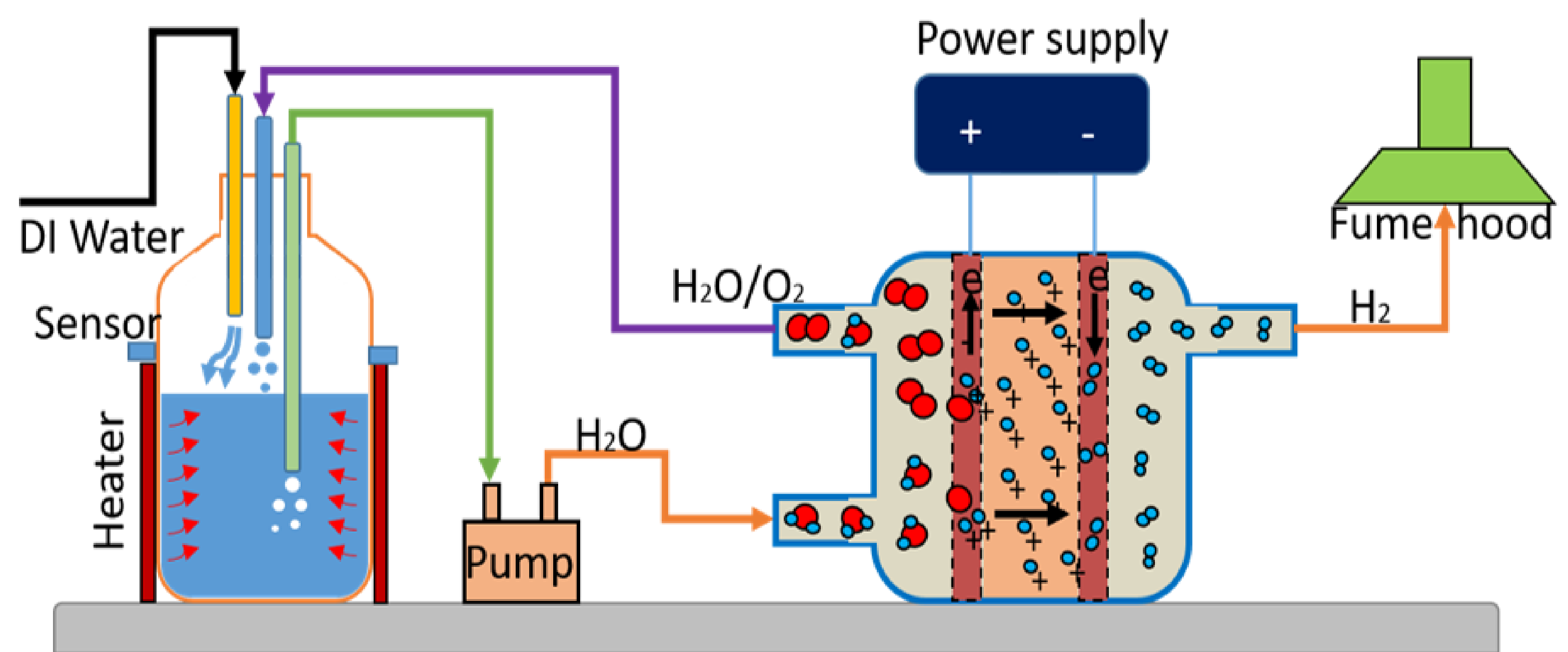


Fig. 1: Schematic of the experimental setup

Results and discussion

The Electrochemical impedance spectroscopy (EIS) and polarization results showed that cell performance decreased severely when 5 ppm of Fe^{3+} solution in water was tested in an electrolyzer cell.

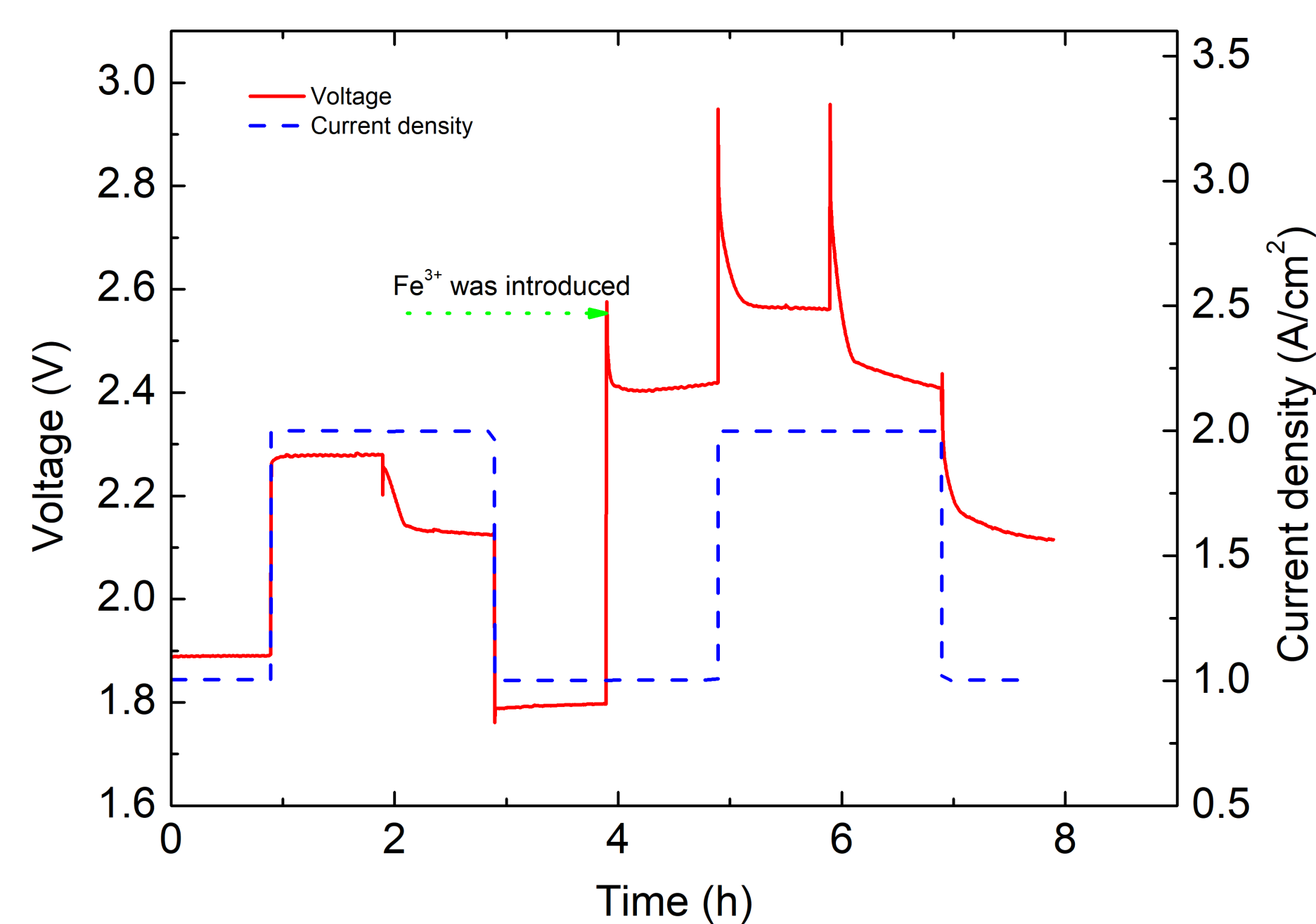


Fig. 2: voltage profile of the entire test period

In Fig. 2, where the voltage profile of the entire test period is given, it can be seen that the voltage of the cell increases significantly compared to DI water operation, after introducing Fe^{3+} ions from the 4th hour of the testing on-wards. Consequently, the IV curve slopes became significantly steeper after Fe^{3+} ions are introduced, showing the increase in the overall resistance, as can be seen in Fig. 3.

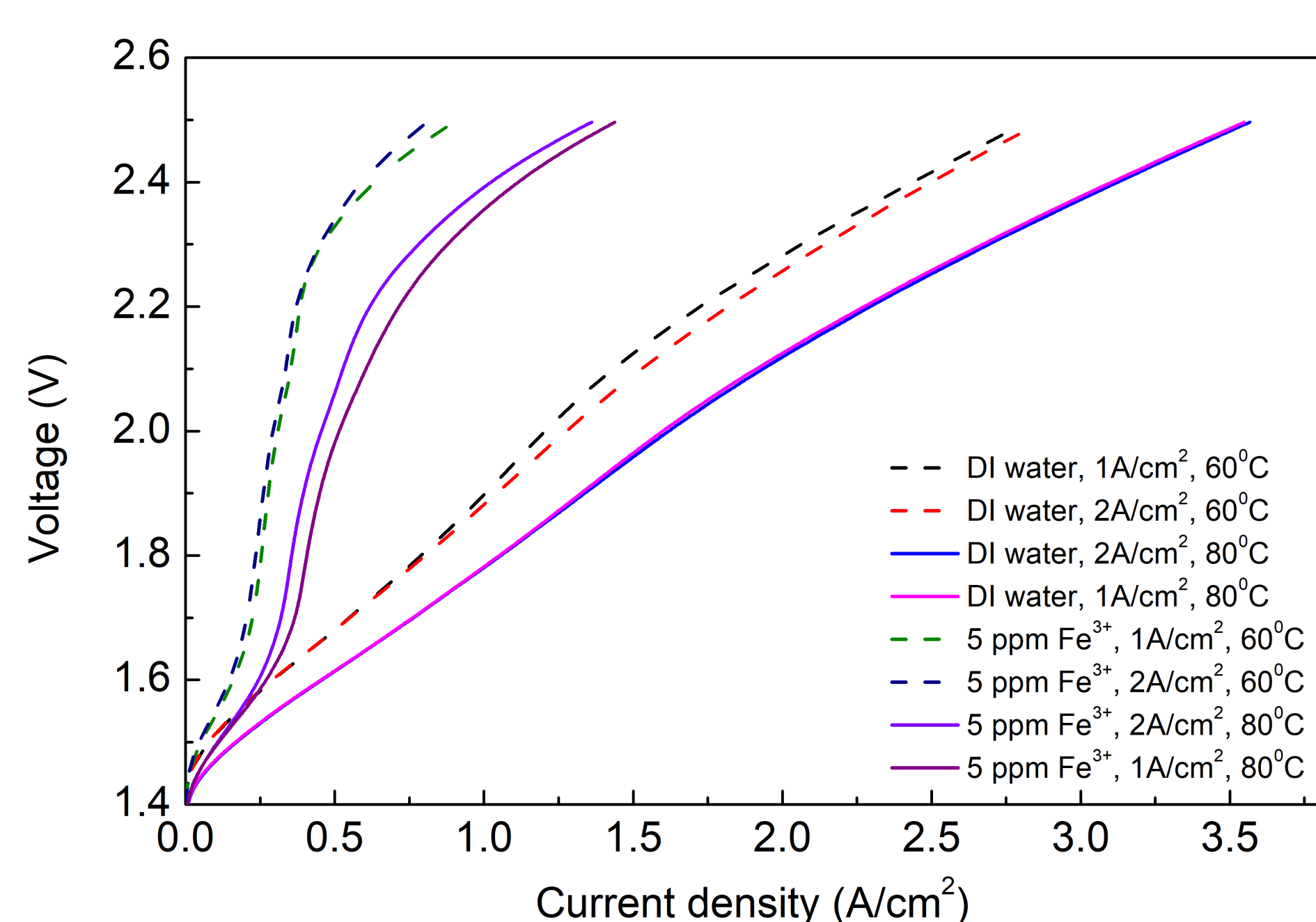


Fig. 3: polarization curves at different test conditions

As shown in Fig. 4 for DI water operation, both high temperature and low current density can improve the cell performance, where the ohmic resistance decreased clearly.

In the case of contaminated feed solution, the cell performance decreases progressively, even at higher temperature and lower current density, as can be seen in Fig. 5.

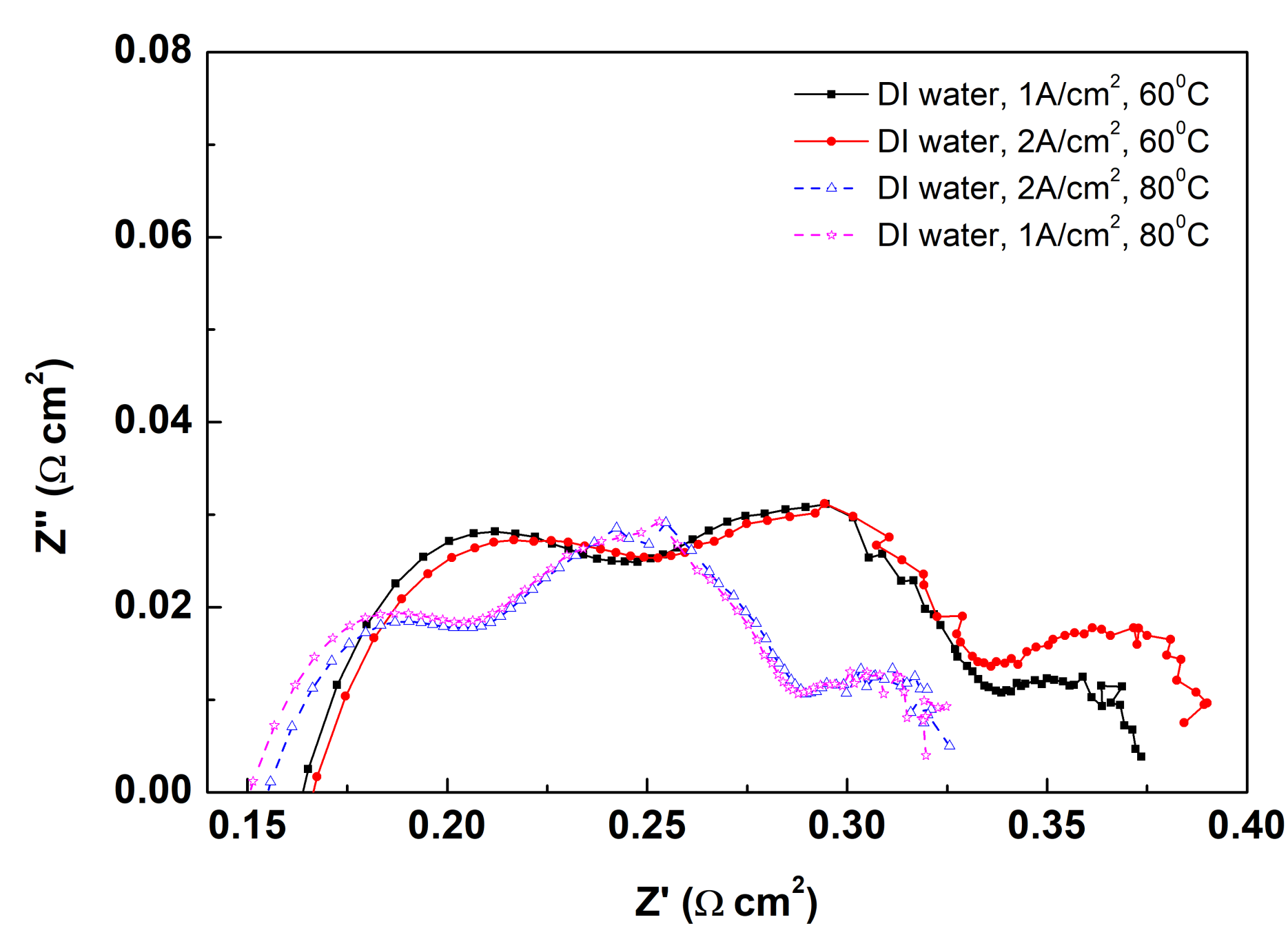


Fig. 4: EIS spectra at different operating conditions with DI water feed

Higher temperature (80 °C) reduces the ohmic resistance, both for DI water and contaminated solution operation. Whereas, higher current density (2 A/cm²) seems detrimental at lower temperatures in the presence of Fe^{3+} ions, but can contribute to reduced mass transfer resistance at higher temperature.

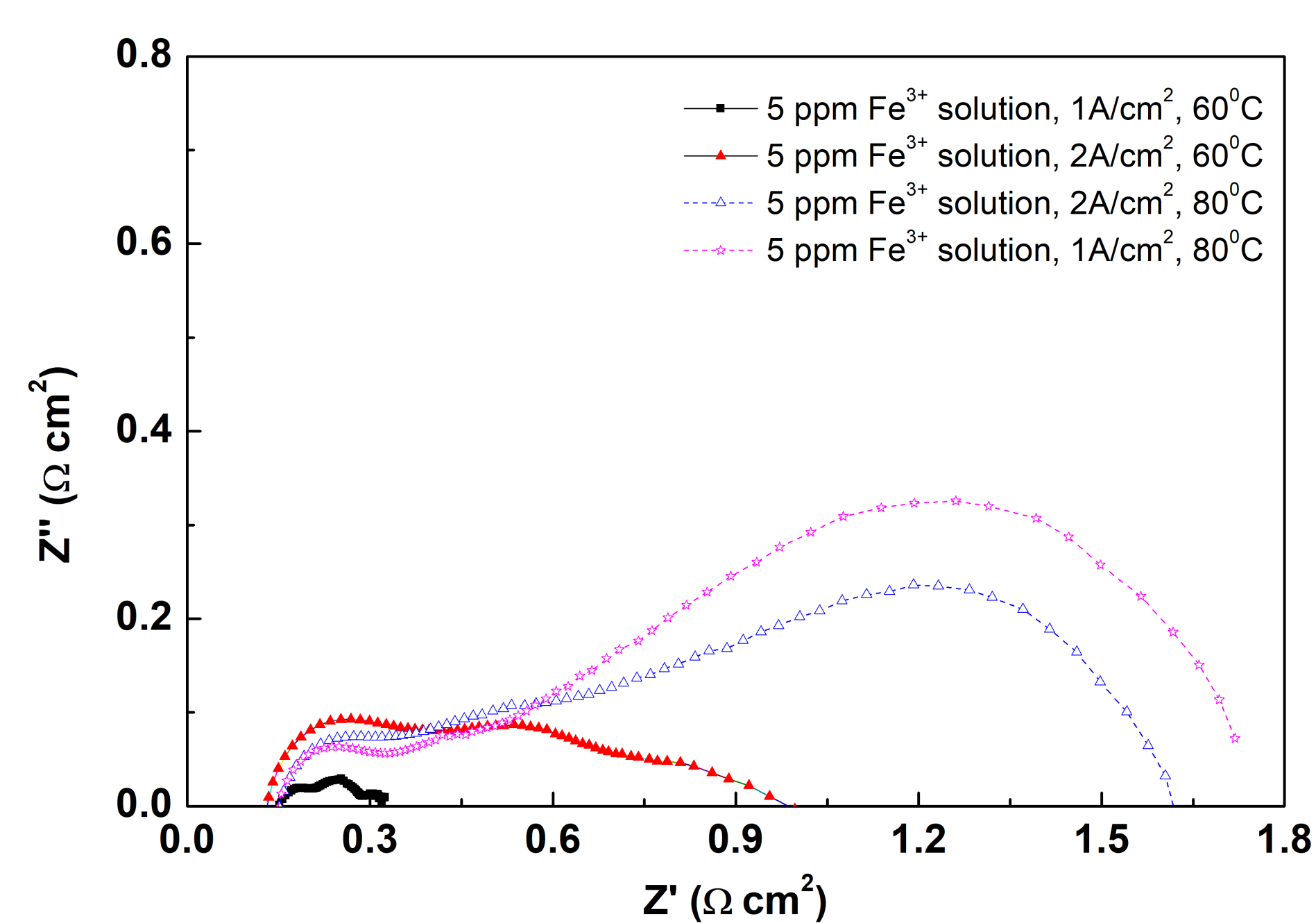


Fig. 5: EIS spectra at different operating conditions with contaminated solution

A strong effect of ionic contamination is seen throughout the tested frequency spectrum. This can be explained by the higher affinity of Fe^{3+} ions than protons for the sulfonic acid group sites, which could substitute protons in normal ion exchange processes [2] and by membrane degradation through radical attack promoted by the metallic ions [3].

Conclusions

It has been shown that the cell performance degrades severely with Fe^{3+} in feed water. The Fe^{3+} ions adsorbed on Nafion membrane and catalyst layers, resulting in the increase of membrane ohmic resistance and charge transfer resistance on both electrodes. Furthermore, some metallic impurities may promote the generation of hydroxide radicals from hydrogen peroxide and hence degrade the membrane severely by the caused Fenton mechanism [3, 4]. High temperature operation can contribute to improve cell performance at the tested Fe^{3+} concentration.

References

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