Effects of Metal Sulfate Impurities on the Vanadium Redox Flow Battery

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Introduction

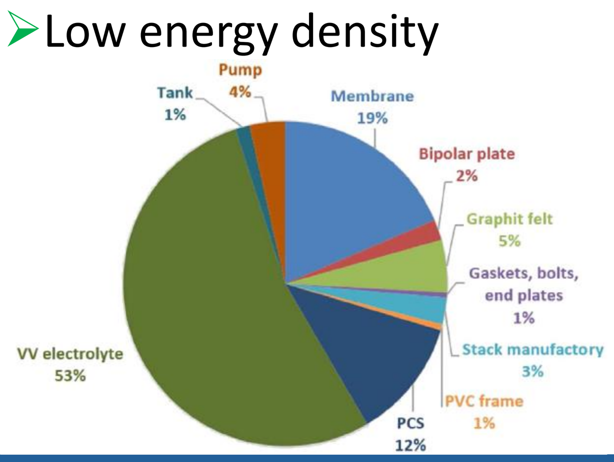
Vanadium Redox Flow Battery (VRFB)

Advantage:

- Single element
- Cheap solvent (water)

Disadvantage:

- Vanadium cost
- Low energy density



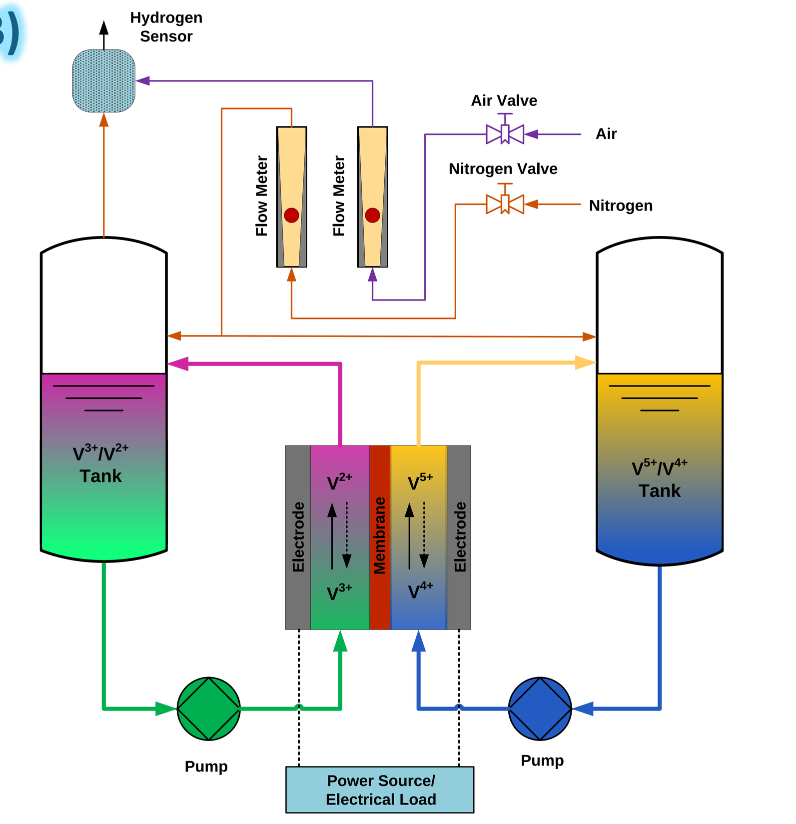


Fig. 1. Schematic illustration of the VRFB charge-discharge cell.

Electrochemical Characterization

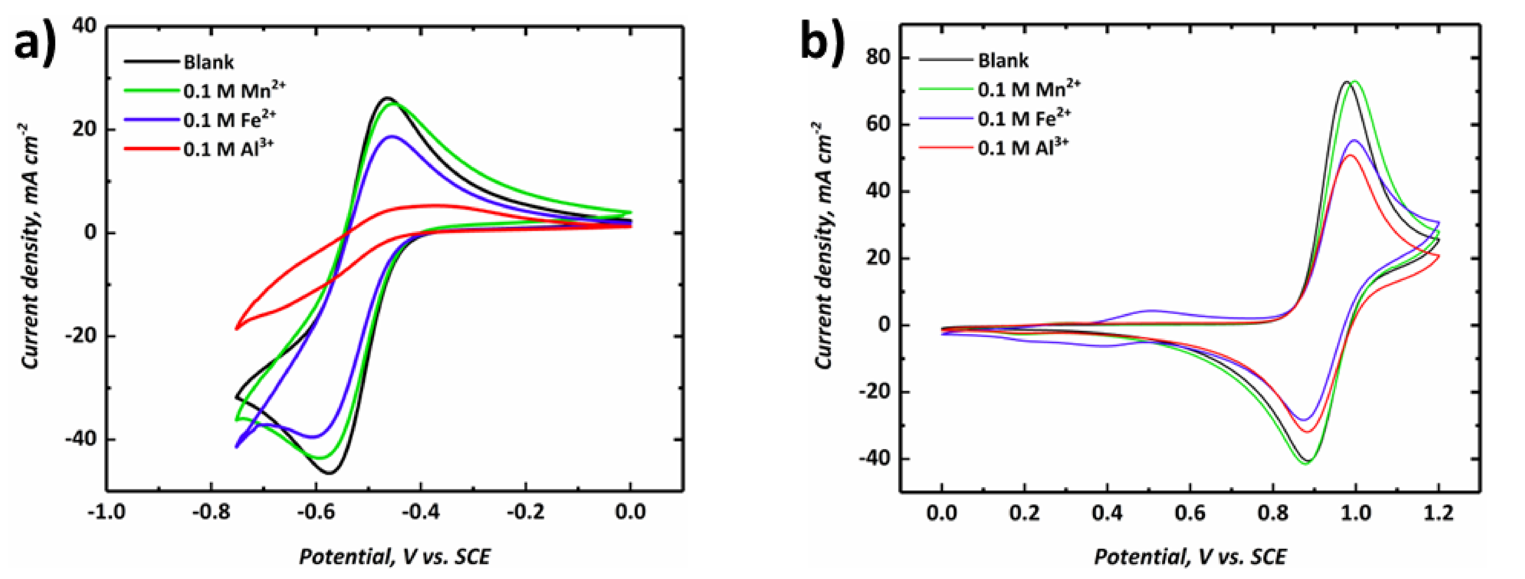


Fig. 2. Cyclic voltammetry comparison of 0.1 M of $MnSO_4$, $FeSO_4$, and $Al_2(SO_4)_3$ (a) in 1.6 M $VOSO_4$, 3 H_2SO_4 for V^{2+}/V^{3+} redox reaction, and (b) in 1.6 M $V_2(SO_4)_3$, 3 M H_2SO_4 solutions for VO^{2+}/VO_2^+ redox reaction with scan rate of 10 mVs^{-1}.

Battery Performance Results

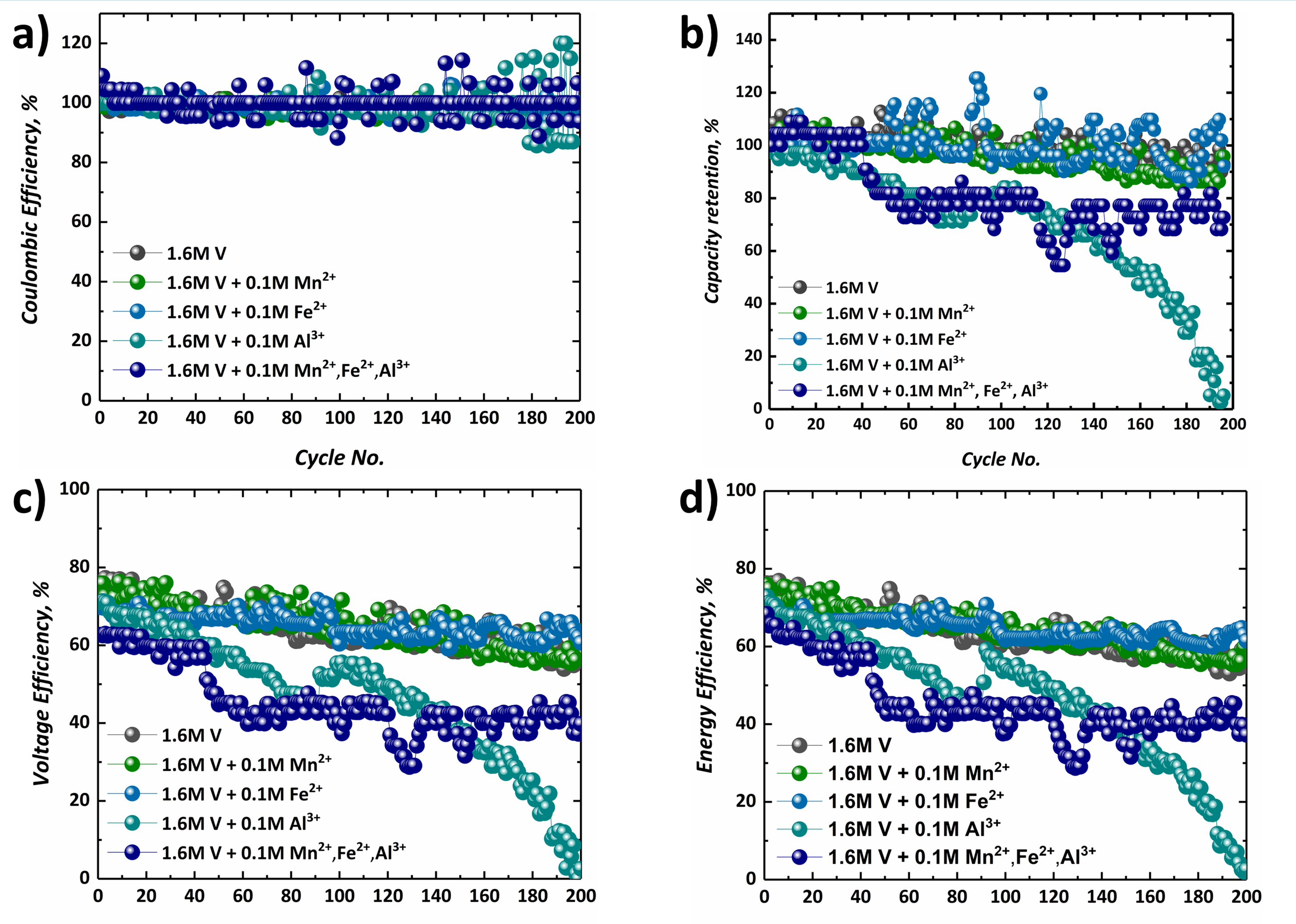


Fig. 3. a) Coulombic, b) capacity retention, c) voltage , d) energy efficiency over 200 cycles of VRFB operation in the absence and presence of 0.1 M of Mn^{2+}, Fe^{2+}, and Al^{3+} and their combination in the electrolytes.

In-situ hydrogen evolution during VRFB operation

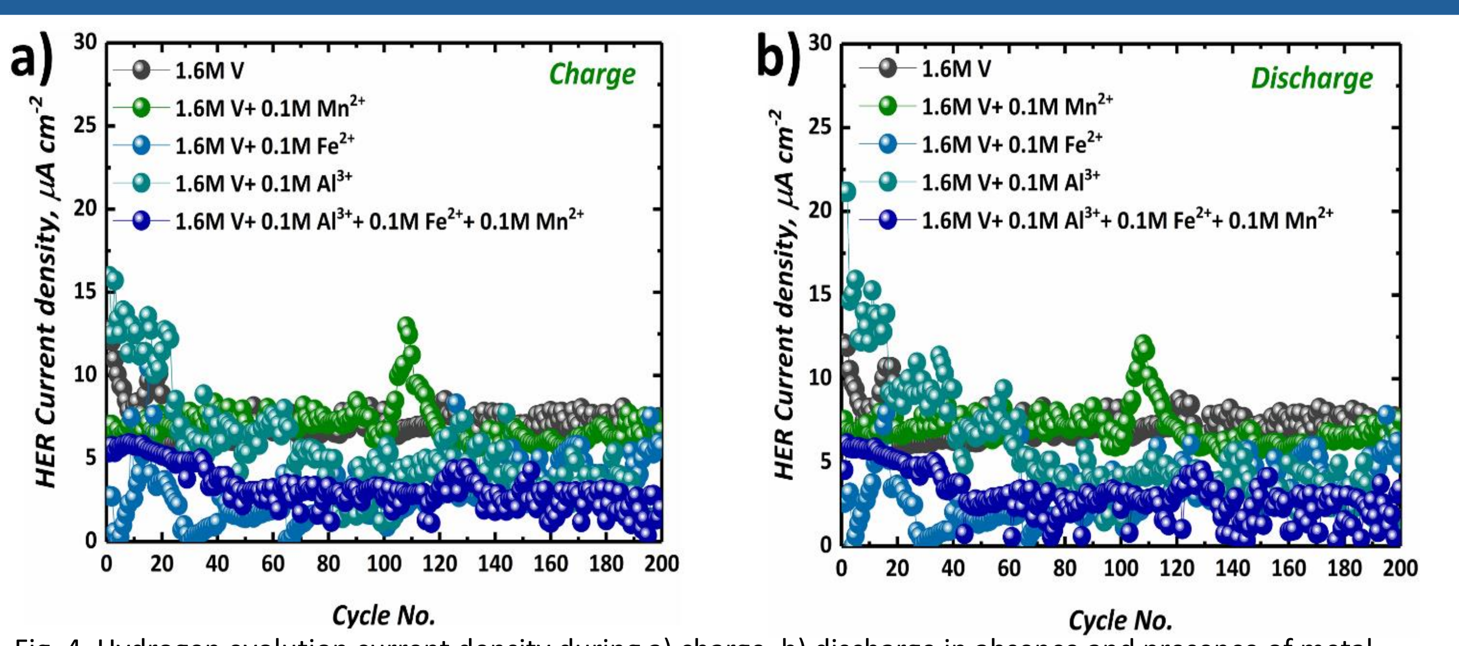


Fig. 4. Hydrogen evolution current density during a) charge, b) discharge in absence and presence of metal sulfate in the electrolytes during 200 cycles of VRFB operation at 80 mA cm^{-2}.

Material Characterization

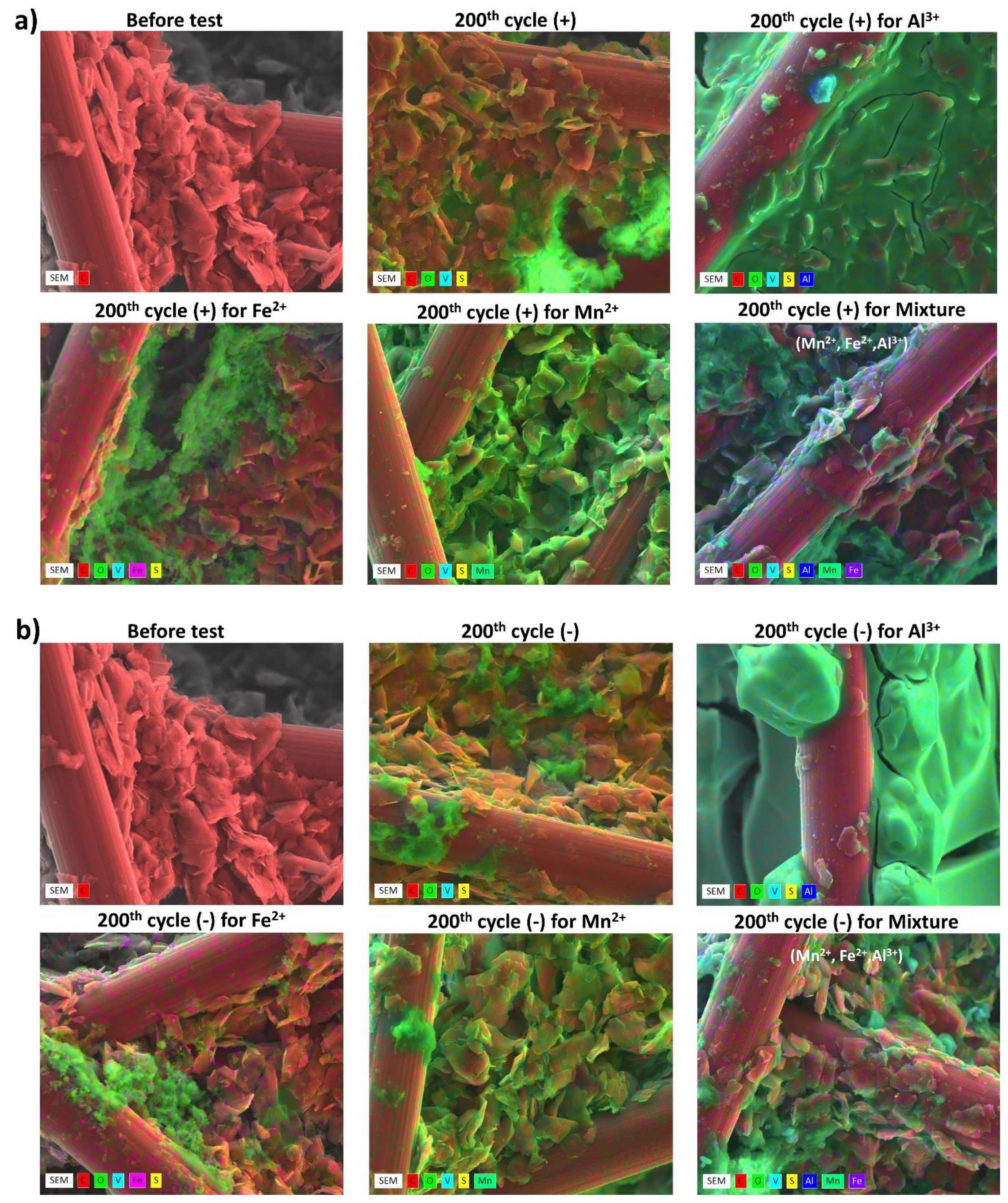


Fig. 5. a) EDS mapping of the positive carbon paper electrodes before and after cycles, and b) EDS mapping of the negative carbon paper electrodes before and after cycles.

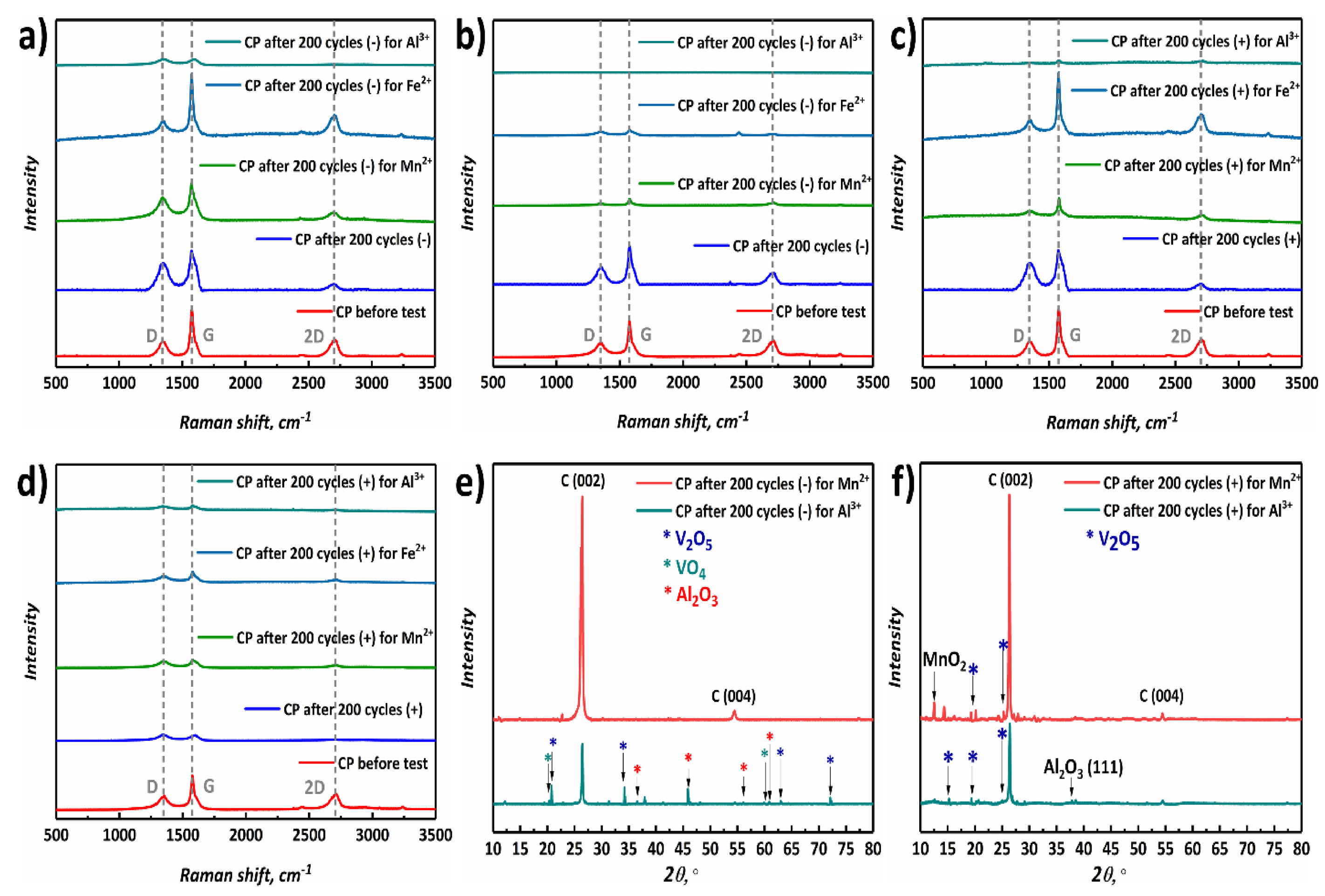


Fig 6. Raman spectra and XRD patterns obtained on carbon paper electrodes before and after 200 VRFB cycles, in the absence and presence of impurities. Raman spectra collected from: a) flake sites on the negative electrode; b) fiber sites on the negative electrode; c) flake sites on the positive electrode; and d) fiber sites on the positive electrode. XRD patterns for the e) negative and g) positive carbon paper electrode in the presence of Mn^{2+} and Al^{3+} impurities.

Summary

- Impurities affect the V^{2+}/V^{3+} reaction more than VO^{2+}/VO^{2+} redox reaction
- Mn^{2+} electrolyte impurity did not affect VRFB performance.
- VRFB capacity decreased by 36% in presence of 0.1 M Fe^{2+}.
- Capacity of VRFB dropped rapidly when Al^{3+} was present.
- Al^{3+} led to precipitation of Al and V oxides on the electrodes.

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