Manganese-Ion Based Tailored Waterflooding Processes for Carbonates

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Abstract. In this experimental study, we explored the wettability alteration capability of divalent foreign metal constituents, such as manganese ions, in the injection water for enhanced oil recovery (EOR) in carbonates. The wettability alteration capability of manganese ions is first evaluated by measuring zeta-potentials at calcite/brine and crude oil/brine interfaces. These measurements were then extended to carbonate rocks and reservoir cores by performing contact angle and spontaneous imbibition tests at reservoir conditions.

The zeta potential results indicated that the addition of 100-1,000 ppm of manganese ions to the high salinity injection water (57,670 ppm TDS) can favorably alter the wettability towards water-wet conditions in carbonates. These wetting transitions were confirmed by the resulting increased values of same polarity negative surface charges measured at both oil/brine and calcite/brine interfaces. Such interesting trend of enhanced negative zeta potentials observed with manganese ions at the calcite/brine interface can be attributed to the selective incorporation of foreign metal ion into the calcite crystal structure to modify its surface chemistry. The contact angle data demonstrated good agreement with zeta potential results. Manganese ions were able to drastically decrease the contact angles from 156° to 88° to confirm the favorable wettability alteration from oil-wet to intermediate/water-wet conditions. The results from spontaneous imbibition experiments showed about 10% increase in oil recoveries due to enhanced imbibition of manganese containing injection water into the carbonate cores at the reservoir temperature. These consistent trends obtained from micro-macro-core scale experiments thereby revealed the promising potential of manganese ion based tailored water flooding processes for enhanced oil recovery in carbonates.

This work for the first time highlighted the beneficial effects of including manganese ions in the waterflooding injection water to enhance the wetting transition in carbonates. The presented novel findings have also identified manganese ions as cheap and sustainable wettability modifiers for advanced waterflooding applications in carbonate reservoirs.