High Temperature characterization of redox systems for thermochical energy storage

INTRODUCTION

Efficient energy storage systems are critical to the large-scale development of intermittent energy sources such as solar and wind power. Thermochemical energy storage technologies can be promising if they achieve both low material cost and high energy density targets. These are the objectives for which technologies based on redox chemistry are being developed, with a focus on the characterization of the considered redox systems.
Thermogravimetric analysis is a useful technique from that point of view as it can measure the oxygen stoichiometry – or M/O ratio – of materials. The present example concerns the magnesium manganese mixed oxide redox system.

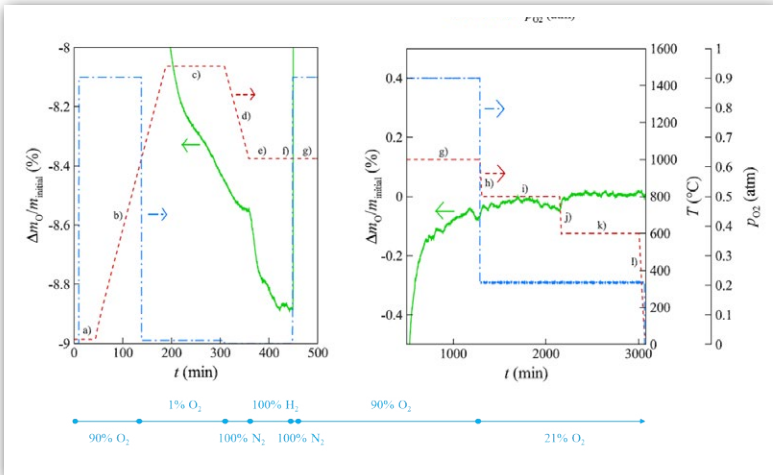

Figure 1 – Mass change, temperature and oxygen partial pressure vs. time for the tested $MgMnO_{2+y}$ sample.

EXPERIMENT

• Instrument: THEMYS TGA
• Sample: Cylindrical pellets of magnesium and manganese mixed oxide ($MgMnO_{2+y}$), about 50mg
• Atmosphere: oxygen/nitrogen blend with varying oxygen partial pressures, pure hydrogen, or pure nitrogen (to avoid direct contact of oxygen and hydrogen at high temperature).
• Temperature profile:
1. Heating to 1500°C at 10 °C/min,
2. A dwell time of 2 h at 1500 °C,
3. Cooling down to 1000 °C at 10 °C/min,
4. A 15h hold time at 1000 °C,
5. A stepwise temperature decrease to room temperature.

RESULTS AND CONCLUSION

For $MgMnO_{2+y}$, the theoretical most reduced state is $MgMnO_2$, i.e. y = 0. The theoretical maximum oxidized composition is $MgMnO_3$, i.e. y = 1.
The TGA experiment procedure applied allows measuring the mass change during the full oxidation and reduction of the sample at the tested temperatures. The practical minimum and maximum M/O ratios can thus be measured. They respectively range from $MgMnO_{2.109}$ (1500 °C, pO2 = 0.01 atm) and $MgMnO_{2.672}$ (1000 °C, pO2 = 0.9 atm).

Reference : A. Bo, K. Randhir, N. Rahmatian et al., Chemical equilibrium of the magnesium manganese oxide redox system for thermochemical energy storage, Chemical Engineering Science 259 (2022) 117750.

INSTRUMENT

THEMYS TGA

HIGH ACCURACY & VERSATILITY
hang-down symmetrical beam balance, specifically designed for TGA applications

ULTRA-HIGH TEMPERATURE CAPABILITY
to 2400°C with a single furnace.

MODULAR ADAPTIONS ALLOWING
TGA only, DTA only, TG-DTA, and TMA up to 2400°C, DSC only and TG-DSC up to 1600°C all in one instrument.

EXTERNAL COUPLING CAPABILITY
designed for evolved gas analyzers (FTIR, MS, GCMS, MSFTIR, or FTIR-GCMS)