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THESIS OUTLINE

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Thesis Outline

Solid oxide cells (SOCs) are attractive electrochemical energy conversion devices that can potentially provide sustainable future energy economy, which would be heavily reliant on intermittent renewable energy, by operating reversibly in solid oxide electrolysis cell (SOEC) and solid oxide fuel cell (SOFC) modes. Electrical energy and chemical energy of fuel can be reversibly converted in the SOEC and SOFC manners through series of electrochemical reactions occurred at electrodes of SOC. The performance of the electrode is thus of fundamental importance to improve overall performance of SOC. In this thesis, we examine a way to instantly enhance catalytic properties of electrodes and investigate the electrochemical behaviour of porous SOC cathodes, where significant reduction reactions occur at the double- and/or triple - phase boundary inside their complex microstructures, through methods of electrical reduction and oxygen-18 labelling. Advance in technique as well as precise understanding of electrochemical behaviour of the electrodes are one of the key issues required to develop and design electrode structures that are capable of delivering high performance and stability while ensuring cost- and time-efficient manufacture. The chapters of this thesis are organised as follows:

Chapter 2 (*Electrical reduction for in situ preparing perovskite electrodes with exsolved nanoparticles*) examines the appeal of potential reduction for preparation of high performance SOC electrodes decorated with *in-situ* exsolved nanoparticles under carbon dioxide electrolysis condition. Characterizations of resulting exsolved nanoparticles and electrochemical performances of the cells based on the prepared electrodes are also analysed and presented.

Chapter 3 (*Visualization of oxygen incorporation in porous mixed-conducting cathode I: Effects of applied current density*) describes important characteristics of oxygen incorporation for the cathodic reduction reaction at a porous mixed-conducting LSC cathode through visualization using a technique of oxygen isotope (^{18}O) labelling combining with rapid cooling. Correlations between oxygen incorporation in the LSC

cathode and applied current density, including associated transfer phenomena of oxygen incorporated into the GDC interlayer and the YSZ electrolyte are presented and discussed.

Chapter 4 (*Visualization of oxygen incorporation in porous mixed-conducting cathode II: Effects of operating temperature*) explores and describes different characteristics of the oxygen incorporation reaction and the electrochemical reaction site distribution in the porous cathode at low operating temperature of 500 °C. Comparisons between the results obtained at 500 °C in this chapter and 600 °C in Chapter 3 are presented and described as well.

Chapter 5 (*Carbon dioxide electrolysis in solid oxide electrolysis cell: Active site visualization in Ni-YSZ cathode*) presents an overview and brief discussion of phenomenon discovered from applying the technique of ^{18}O labelling coupled with subsequent quenching to carbon dioxide electrolysis experiment for the first time. Important findings and outlook are provided at the end of the chapter.

Chapter 6 (*Conclusions*) summarises the main findings of this thesis.