EXPERIMENTAL RESULTS OF $LA_{0.8}SR_{0.2}CRO_3$ / $SRTIO_3$(100) HETEROSTRUCTURE USED FOR A HIGHTEMPERATURE PHOTOVOLTAIC CELL

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Abstract

The absorption of light by semiconducting materials results in a partial conversion of the radiative energy into electrical energy, a process of great importance and interest in energy technology. The solar spectrum can be classified into a high energetic part (short wave length) and a lower energetic part (long wave length). Both can be used by the special type of high temperature photovoltaic cell (HT-PV) under consideration, which consists of solid oxide materials, especially perovskite oxides with the general formula *ABO_3*. In fact, strontium doped lanthanum chromium oxide ($La_{1-x}Sr_xCrO_3$) and strontium titanate ($SrTiO_3$) are not only attractive candidates as semiconducting oxide materials for a HT-PV cell, but also for driving an electrochemical reaction used in a *Solid Oxide Photo-Electrochemical Cell* (SOPEC).

Material Characterisation

This paper shows the results of investigating the heterostructure $La_{0.8}Sr_{0.2}CrO_3$/$SrTiO_3$(100) under ultra-violet (UV) radiation at temperatures from 400°C up to 500°C. The HT-PV cell consists of a $SrTiO_3$ (STO) single crystal in the orientation 100 with a $La_{0.8}Sr_{0.2}CrO_3$ thin-film deposited by *pulsed laser deposition* (PLD). Both perovskites are large band gap (*Eg*) semiconducting metal oxides. It is well known that the *Eg* of STO is about 3.2 eV. Furthermore, optical measurements of 20% doped strontium $LaCrO_3$ ($La_{0.8}Sr_{0.2}CrO_3$) have shown that its *Eg* should be around 2.8 – 3.1 eV. For the excitation of electron-hole charge carriers (*e*-, *h*+) photons in wave-length *v* equal to or larger than around 385 nm are necessary. Any photon's energy that is higher or lower than *Eg* is converted into heat. Given the high *Eg* of the $La_{0.8}Sr_{0.2}CrO_3$/ $SrTiO_3$(100)-system, electrons (*e*-) can be excited from the valence band (VB) to the conduction band (CB) at temperatures up to 600°C. In contrast, *e*become thermally excited at relatively low temperatures when using low-band gap materials such as Si-based semiconductors (~1.1eV).

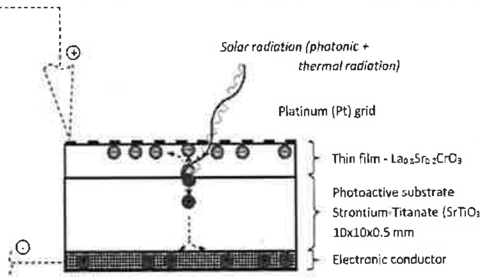

Fig. 1: Scheme of the heterostructure $La_{0.8}Sr_{0.2}CrO_3$/ $SrTiO_3$(100) single crystal used as HT-PV cell

Research Process and Results

In a first step, the HT-PV cells were characterized by measuring current-voltage (I-V) curves. The I-V measurement was performed depending on a) temperature, b) light intensity and c) wave-length. For this test series, HT-PV cells with the dimension of 10x10x0.5 mm

were used. The results of open-circuit voltage and (*Uoc*) short-circuit (*Isc*) current are shown in Fig. 2a and 2b.

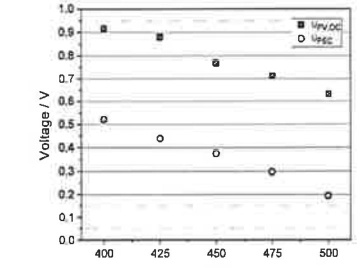

Fig. 2a: DC measurement of photo voltage on HT-PV and PEC cell at 400, 425, 450, 475 and 500°C under illumination with LED 10W/365 nm

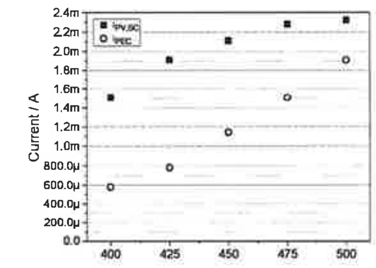

Fig. 2b: DC measurement of photo current on HT-PV and PEC cell at 400, 425, 450, 475 and 500°C under illumination with LED 10W/365 nm

The measurements have shown that $U_{PV,OC}$ is decreasing with rising temperature, whereas $I_{PV,SC}$ is increasing. In that context, it is interesting that the voltage at the HT-PV cell η_{PV} remains more or less stable over temperature. In the next step, the HT-PV cell was packed on top of an electrolyte supported cell (ESC) consisting of a polycrystalline 3 mol% yttria-stabilised zirconia (YSZ) substrate (Ø20x0.3 mm) coated on both sides with porous strontium doped lanthanum cobaltite (LSC) as electrode material for oxygen reaction. Voltage and current in the operation point (U_{PEC}, I_{PEC}) of the cell shown in Fig. 3 were measured at different temperatures. The measurements have shown that U_{PEC} decreases dramatically with rising temperature (Fig. 2a), whereas I_{PEC} increases (Fig. 2b).

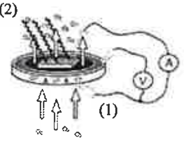

Fig. 3: Sketch of HT-PV on top of an ESC

Further on, the cell in Fig. 3 has been implemented in an experimental setup with gas-tight chambers and light-coupling by a quartz bar. When the light (LED 10W/365 nm) is switched on, oxygen is incorporated (Eq.1) at the cathode (1) due to the applied current and voltage from the HT-PV cell. Oxygen ions going through the YSZ following *Kröger–Vink* nomenclature (Eq. 2) and leaves the cell at the anode (2), Eq. 3.

$$½O_2 + 2e' \rightleftharpoons O^{2-} \qquad \text{Eq. 1}$$

$$½O_2 + 2V_O^{\bullet\bullet} \rightleftharpoons O_O^{x} + 2h^{\bullet} \qquad \text{Eq. 2}$$

$$O^{2-} \rightleftharpoons ½O_2 + 2e' \qquad \text{Eq. 3}$$

In a sequence of light off-and-on, voltage, current, and oxygen concentration have been measured at a temperature of 450°C, as shown in Fig. 4.

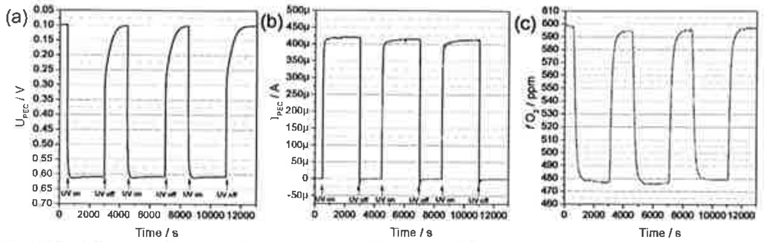

Fig. 4: Diagrams of a) voltage curve b) current curve and c) oxygen profile at 400°C

The voltage in the operation point under illumination has reached its maximum at nearly 0.5 V (Fig. 4.a). That has led to an electrical current of more than 0.8 mA (Fig. 4.b). Finally, the oxygen concentration has been shifted from 640 to 400 ppm O_2 (Fig. 4.c).). Overall, it could be shown that the $La_{0.8}Sr_{0.2}CrO_3$ / $SrTiO_3(100)$ heterostructure is a promising material system for photo-electrochemical energy conversion.

Acknowledgement
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