Experimental investigation of $La_{0.8}Sr_{0.2}CrO_3/SrTiO_3(100)$ heterostructure used for a high-temperature photovoltaic cell

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Preparation and Measurement

Pulsed laser deposition

material: $La_{0.8}Sr_{0.2}CrO_3$
substrate: STO (100) single crystal
size: a) 5x5x0.5mm
b) 10x10x0.5mm
temperature: 700°C
partial pressure: $1.5x10^{-2}$ mbar O_2
film thickness: ~ 300 nm
energy: 400 mJ

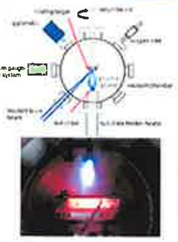


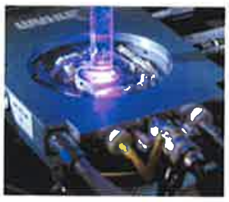
Fig. 1: Sketch of the PLD

The current collector was prepared by using photolithography and subsequent platinum sputtering

^Fig. 2: Electrically contacted high-temperature PV cell (HT-PV) illuminated by 10W LED/365nm

Measurement setup

- homogeneous temperature through a hot heating stage
- temperature up to 550 C
- I-V- measurement in air
- used light LED sources:
  - 10W/365nm,
  - 10W/405nm,
  - 10W/460nm
- light coupling by a temperature-resistant conductor (quartz rod)



< Fig. 3: Set-up of heating device and light coupling

Strontium doped lanthanum chromium oxide ($La_{1-x}Sr_xCrO_3$) and strontium titanate ($SrTiO_3$) are attractive candidates as semiconducting oxide materials for a HT-PV cell. The heterostructure $La_{0.8}Sr_{0.2}CrO_3$ / $SrTiO_3(100)$ is investigated under ultra-violet (UV) radiation at temperatures from 400°C up to 550°C.

I-V – Measurement with electrical load

The graphs show the I-V-curves under open-circuit conditions and under electrical load.
An electrical load with an internal resistance of ~300Ω leads to a reduction of U_{OC} from 0.73V to 0.41V (Fig. 7a).
This results in a current flow of 1.38mA (Fig. 7b).

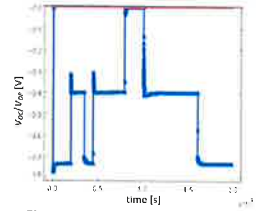


Fig. 7a: U_{OC} and voltage at the working point at 525°C

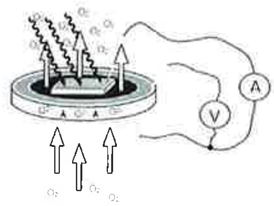


Fig. 6: Sketch of HT-PV cell under electrical load

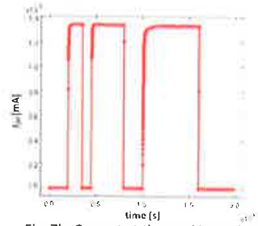
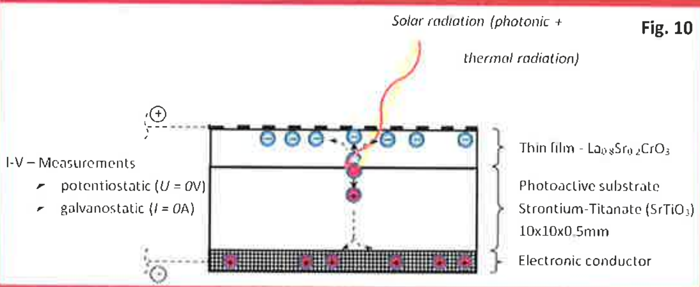


Fig. 7b: Current at the working point at 525°C

I-V – Measurements

In a first step, the HT-PV cells were characterized by measuring of current-voltage (I-V) curves.
The I-V measurement was performed depending on:

- temperature,
- light intensity and
- wave-length



For this test-series, HT-PV cells with the dimension of 5x5x0.5mm were used. The results of short-circuit (I_{SC}) current and open-circuit voltage (U_{OC}) are shown in Fig. 4. In an other step the HT-PV cell was scaled to 10x10x0.5mm. The I_{SC}/U_{OC} curves under illumination of 10WLED/365nm were measured for a longer period (see Fig. 5).

Short-circuit current (I_{SC})curves and open-circuit voltage (U_{OC})

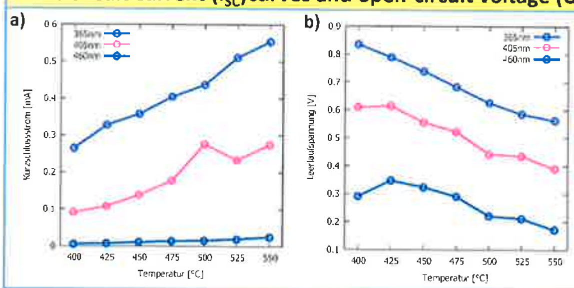


Fig. 4: I_{SC} (a) and U_{OC} (b) characteristics depending on temperature, light intensity and wave-length. For all light sources, I_{SC} is constantly increasing whereas U_{OC} is decreasing with temperature. The highest value has been reached by illumination with LED 10W/365nm.

Further Current-Voltage measurements

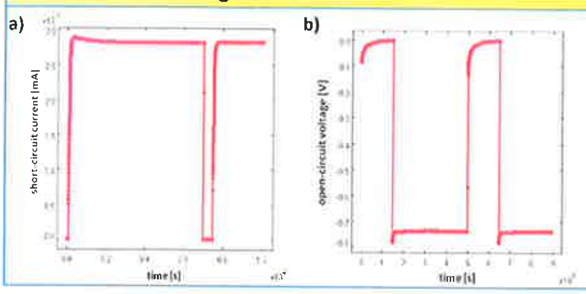


Fig. 5: I_{SC} (a) and U_{OC} (b) characteristics at 525°C under illumination with LED 10W/365nm for a measurement time of more than 2.5 hours.

Electronic Structure

Charge-excitation gap

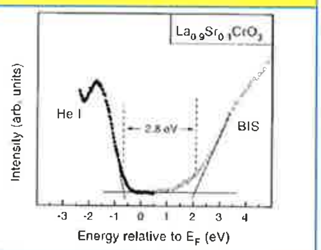


Fig. 9: The He I valence-band and BI spectra of $La_{0.9}Sr_{0.1}CrO_3$ near Fermi energy to get an estimate of the band-gap approximately 2.8 eV [2].

Absorption of Light

Due to the high band-gap (E_g) of the HT-PV cell (Fig. 10), only short-wave radiation (Fig. 8) leads to the exitation of charge-carriers.

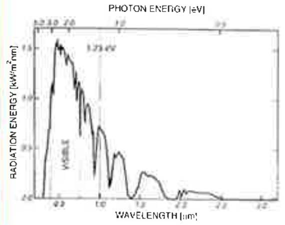


Fig. 8: Solar energy spectrum (AM of 1.5) in terms of radiation energy vs. photon wavelength [1].

It is well known that $SrTiO_3$ shows an E_g of 3.2eV, and $La_{0.9}Sr_{0.1}CrO_3$ shows an E_g of 2.8eV as seen in Fig 9.
In order to raise the photo-voltaic effect, the light absorption in both materials needs to be increased e.g. by doping.

Summary

✓ Reproducible current-voltage measurements possible.
✓ Current shows linear positive correlation with cell size, Voltage remains stable/unaffected by cell size.
✓ Current and Voltage remain stable over time.
✓ Spectrum effecting photo-voltage needs to be enlarged through reducing the semi-conductor's band-gap.

References:
[1] S. R. Wenham, M. A. Green and M. E. Watt, Applied photovoltaics, Centre for Photovoltaic Devices and Systems, Sydney, 239-246 (1994)
[2] K. Maiti and D. D. Sarma, Electronic structure of $La_{1-x}Sr_xCrO_3$, Phys. Rev. B, 54, 7816-7822 (1996)