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► **To cite this version:**

Jed Kraiem, O. Nichiporuk, Pierre Papet, J.-F. Lelièvre, Alain Fave, et al.. Interdigitated Back Contacts Solar Cells on Transferred Si-Thin Film Epitaxially Grown on Porous Silicon. 15th International Photovoltaic Science & Engineering Conference (PVSEC-15), Oct 2005, Shangai, China. hal-03278184

**HAL Id: hal-03278184**

**<https://hal.science/hal-03278184>**

Submitted on 5 Jul 2021

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# Interdigitated Back Contacts Solar Cells on Transferred Si-Thin Film Epitaxially Grown on Porous Silicon

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**Abstract:** In this paper we propose a novel approach to thin-film silicon solar cells technology developed at INSA-LYON, named ELIT process (Epitaxial Layer for Interdigitated back contacts solar cell Transferred using porous silicon as a weakened layer). High crystal quality Si film is grown on porous silicon (PS) by Vapor Phase Epitaxy. This single crystal silicon epitaxial layer was processed into solar cells by realizing all contacts on the back side. Then, thin film solar cell is transferred onto a low-cost substrate before texturation and deposition of antireflective coating on the front side. Preliminary experiments of transferred IBC thin-film solar cell lead to 7.7% efficiency with a 70  $\mu\text{m}$  thick active layer.

**Key Words:** Layer Transfer Process, Silicon Thin Film, Rear Contacts Cell.

## 1 Introduction

One alternative to the conventional solar cells fabricated on bulk material is the realization of silicon thin film solar cells by epitaxial layer transfer process (LTP). Since few years, this approach appears to be one attractive way to realize cheap and efficient solar cells [1,2,3]. Efficiency up to 16.6% [4] was reported for solar cells realized on transferred epitaxial layer with conventional structure (both side's contacts, phosphorous diffused p-n junction). However, the high quality of epitaxial layer allows considering interdigitated back contacts (IBC) cell structure [5]. Actually, IBC structure which has recently received a lot of attention, mainly because of the successful development of such a technology by SunPower [6], offers multiple advantages comparative to conventional both sides contacts technology: higher short-circuit current (no shading loss), low serial resistance and simplified module assembling.

The aim of this paper is to present this novel approach to silicon thin film solar cells technology. For the first time interdigitated back contacts solar cells are realized on epitaxial thin film transferred from the substrate thanks to a sacrificial layer. All the process steps are described in order to demonstrate that this technology suits well to the epitaxial layer transfer process.

## 2 Layer Transfer Process

Layer Transfer Process using porous silicon as a weakened layer is a very promising method to realize thin film silicon solar cells. However, there are 3 critical steps: Epitaxial growth of high crystal quality Si film, Control and repeatability of the transfer, and Re-use of the initial substrate limiting Si consumption.

### 2.1 Porous Silicon

Porous silicon is formed by standard electrochemical etching of (100) silicon wafers doped with boron ( $\rho=0.008\Omega\text{cm}$ ) in HF solutions. A double phase etching process generates two superposed PS layers: a 1 $\mu\text{m}$ -thick top layer with a low porosity (23%) allowing high quality crystal growth, and a 0.5 $\mu\text{m}$ -thick buried layer with a high porosity (70%) for the further detachment of the epilayer.

### 2.2 Annealing and Silicon Epitaxy

Prior to epitaxy, porous silicon is annealed under hydrogen at 1100°C for 10 minutes. During this step, porous silicon restructuring leads to a densification of the surface. In the same time reorganization of the bottom layer leads to a fragilisation allowing subsequent detachment. Then epitaxial growth by VPE leads to a 70 $\mu\text{m}$  thick epilayer with a  $1.10^{16}\text{ cm}^{-3}$  doping level. Structural and electrical characterizations showed the high crystal quality of the epilayer [7].

### 2.3 Cell Process (Part 1)

For IBC cells, we use a simplified technological process. A typical fabrication sequence might be:  $n^+$  diffusion on the whole surface using solid source, etch a finger pattern in the  $n^+$  region and into the underlying silicon, Al deposition in the etched finger pattern and contacts annealing at 600°C for ohmic contact and BSF formation. The last step is deposition of the emitter contacts (Ti-Pd-Ag) aligned to Al contact grid.

### 2.4 Transfer

Then, epitaxial layer is transferred onto inexpensive substrate by an innovative method which allows a perfect control of the detachment and his repeatability (to be patented).

### 2.5 Cell Process (Part 2)

Finally, the residual porous silicon presents on the detached side is removed by chemical etching. Then texturation of the front side is realized using tetra-methyl ammonium hydroxide (TMAH) before deposition of a 75nm thick SiN antireflective coating. A weighted reflectance below 3% is achieved [8].

### 2.6 Substrate Re-use

Re-use of the initial substrate starts also by removing the residual porous silicon caused by the separation step. We optimize this step in order to minimize surface roughness and Si consumption. After testing several chemical etchings, RMS surface roughness below 3nm was obtained, 6 consecutives transfers using the same wafer were achieved and Si consumption was only 5.2 $\mu\text{m}$  per cycle [9].

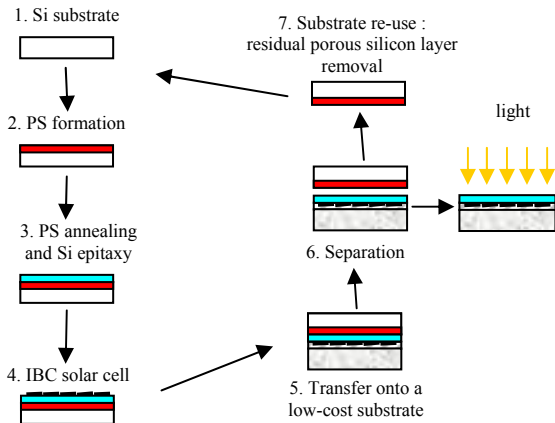


Fig.1 Schematic of the ELIT process

### 3 Results and Discussion

For the presented cell below, we used a simplified ELIT process. Cell fabrication was directly realized on detached 70 $\mu\text{m}$ -thick epilayer. Several IBC cells were realized on the same epitaxial film and were then separated by sawing. The results from the best cell are summarized here.

#### 3.1 Dark I(V)

We have extracted the parameters of the dark I(V) characteristics of the best cell using the one diode model (Fig.2). We observe that the shunt resistance is not as high as expected. One possibility to explain this weak value is the leakage current caused by the sawing damages at the cell perimeter. In the same time, serial resistance is relatively high for IBC cell. Optimization of the contact grid geometry and the contacts firing should improve this parameter.

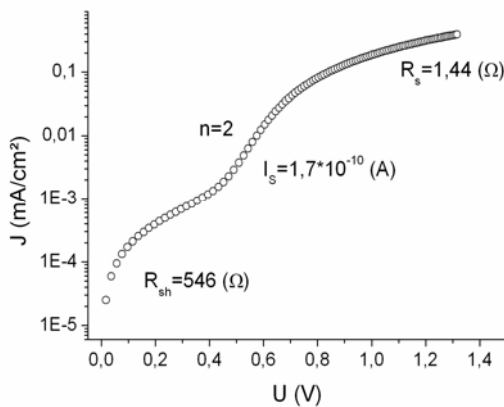


Fig.2 Dark current-voltage curve of IBC solar cell on epilayer

#### 3.2 Illuminated I(V) and Suns $V_{oc}$

Fig.3 represents illuminated I(V) characteristic and Suns- $V_{oc}$  pseudo-I(V).

Under an AM1.5 global spectrum, the best cell was found to be 7.7% efficient at one sun, with a  $FF=0.53$ , a  $J_{sc}=25\text{mA}\cdot\text{cm}^{-2}$  and a  $V_{oc}=557\text{mV}$ .

In order to estimate the potential of IBC cell on epilayer, Suns $V_{oc}$  system was used. The advantage of the Suns  $V_{oc}$  measurement is that it gives the solar cell current voltage curve without the effects of series resistance [10]. Cell efficiency

higher than 10% with a fill factor of 0.74 can be obtained.

With optimizing the cell architecture and contacts ohmicity higher efficiencies on transferred IBC cells can be reached.

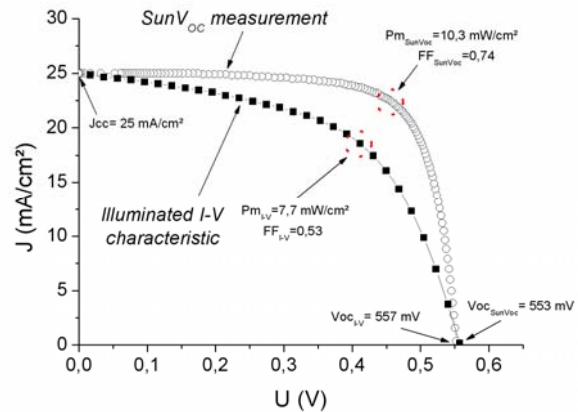


Fig.3 Illuminated and Suns  $V_{oc}$  current-voltage curves of IBC solar cells on epilayer

### 4 Conclusions

Finally for the very first time, we show that it is possible to fabricated interdigitated back contacts solar cells on transferred epitaxial layer and we demonstrate this technology suits well to the layer transfer process. In our preliminary experiments a 7.7 % efficiency solar cell was obtained in a 70  $\mu\text{m}$  thin active layer. The cell so far shows high serial resistance due to non optimized cell architecture. Given the scope of possible improvements (higher quality emitter and optimized contacts geometry) we are confident that high efficiencies can be obtained with such technique.

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