TiSi$_2$ and LIFT as potential alternatives to silver and screen printing for solar cells electric contacts

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Metallization & Interconnection WORKSHOP

ABSTRACT: Titanium disilicide (TiSi$_2$) deposited by Laser-Induced Forward Transfer (LIFT) shows promising characteristics to replace the current silver screen-printing process for the formation of the crystalline silicon solar cells' electrode [1,2,3]. In this work, an exhaustive analysis of the **main parameters influencing the deposition process** of titanium (Ti) fingers through LIFT such as laser wavelength, frequency, power or scanning speed, has been carried out. Continuous Ti deposited lines with a width of tens of µm have been obtained with a specific set of process parameters through LIFT process and after a rapid thermal processing **TiSi$_2$ material has been formed**. The resistivity of the TiSi$_2$ material decreased 2.9 times with respect to Ti alone, which is in good agreement with the literature and confirms the formation of TiSi$_2$ in its most conductive C54 phase [4,5]. Taking into account cost differences between silver and Ti, this material, with **a conductivity in the order of 10^6 S/m, shows a good potential** to be an alternative on a specific design of the electrode -number of fingers and busbars, thicknesses and widths, etc. [2].

Keywords: Metallization, titanium, titanium silicide, LIFT.

1. MOTIVATION

- Currently, **silver** is the material that introduces **the most price and supply risk** to the broad development of PV production so further work is needed in the PV community to replace it with more abundant metals [6].
- The **titanium silicide** material has been known for about four decades in the microelectronics industry, providing interesting conductivity properties, compatibility with crystalline Si technology and low contact resistances [7].
- Furthermore, the **LIFT direct printing process is a flexible, versatile and gentle process** which does not require direct pressure on the substrate, which will be a necessary requirement when evolving to thinner crystalline silicon wafers [3].

The combination of LIFT and TiSi$_2$ shows promising characteristics to replace the current silver screen-printing process to form the electrode of crystalline silicon solar cells and could be a **breakthrough in the search for new materials and processes in the rapidly evolving photovoltaic technology**.

2. LIFT PROCESS

In the LIFT process, a **thin film is initially deposited** onto a donor substrate transparent to a laser radiation. Then it is placed facing a receiver substrate and a **laser beam is focused on the interface, transferring the affected material** from the thin film. In this work, glass slides have been used as donor substrates, where Ti thin films have been deposited by sputtering, and monocrystalline silicon wafers –both polished and textured- as receiver substrates.

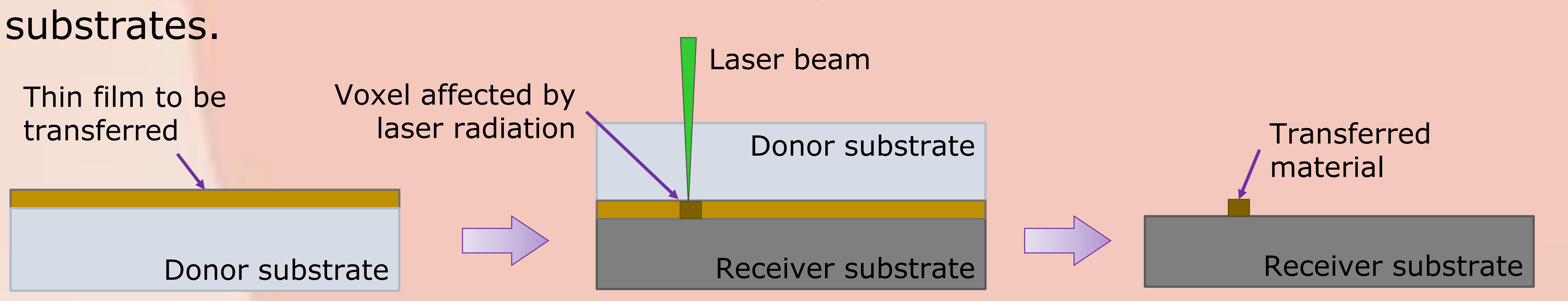

Fig. 1. Schematic of the LIFT process

3. TITANIUM DEPOSITION

Multiple experiments have been carried out **to find the optimal conditions**, using **infrared and green pulsed lasers**, with 1064 and 532 nm of wavelength respectively, and **tuning pulse power** through diodes' current (from 10 to 40 A), **frequency** (from 2 to 100 kHz) **and scanning speed** (from 300 to 1400 mm/s). Optimal parameters for this specific process have been found to be **532 nm, 20 A, 10 kHz and 300 mm/s**.

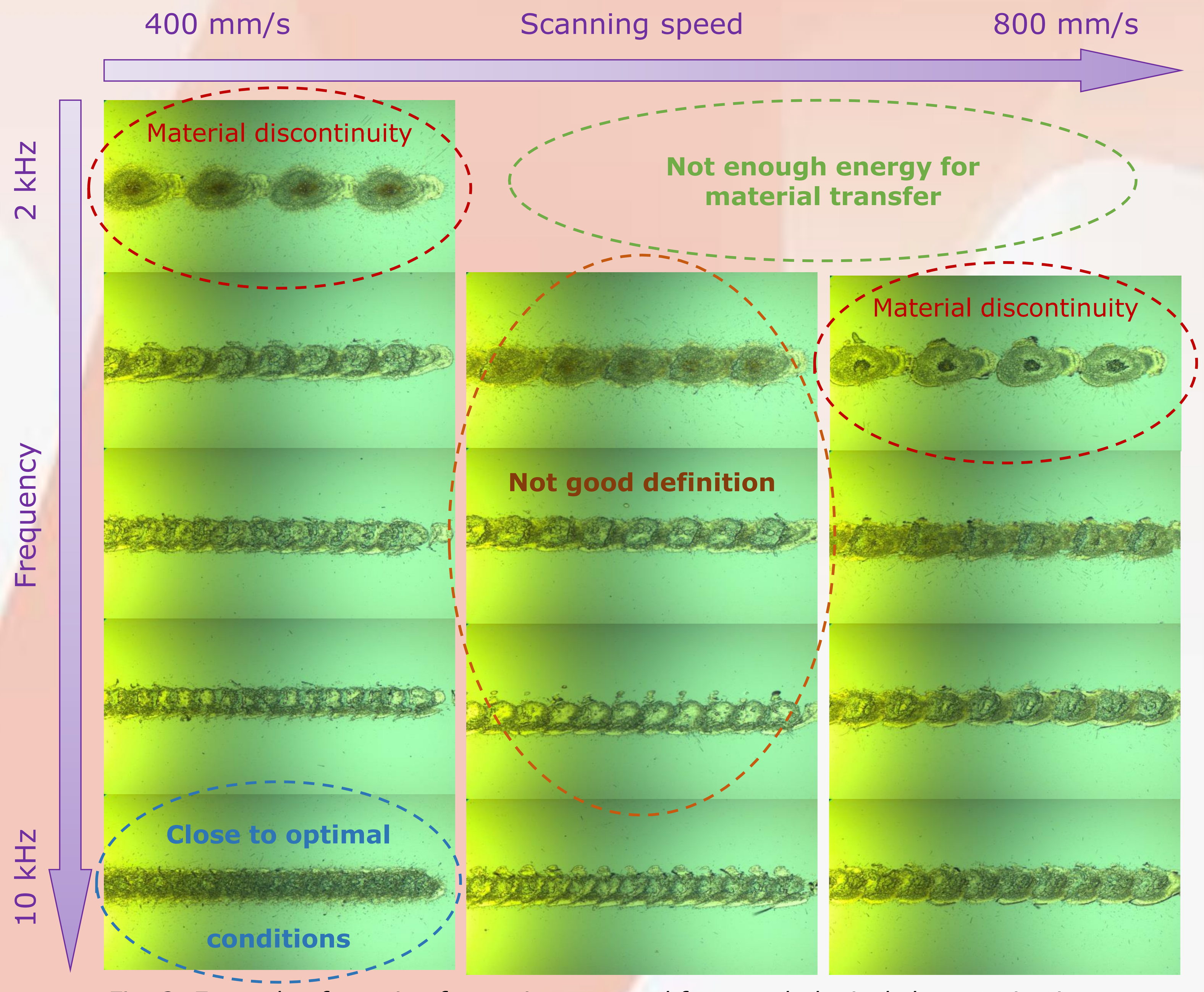

Fig. 2. Example of matrix of experiments used for morphological characterization

4. TiSi$_2$ FORMATION

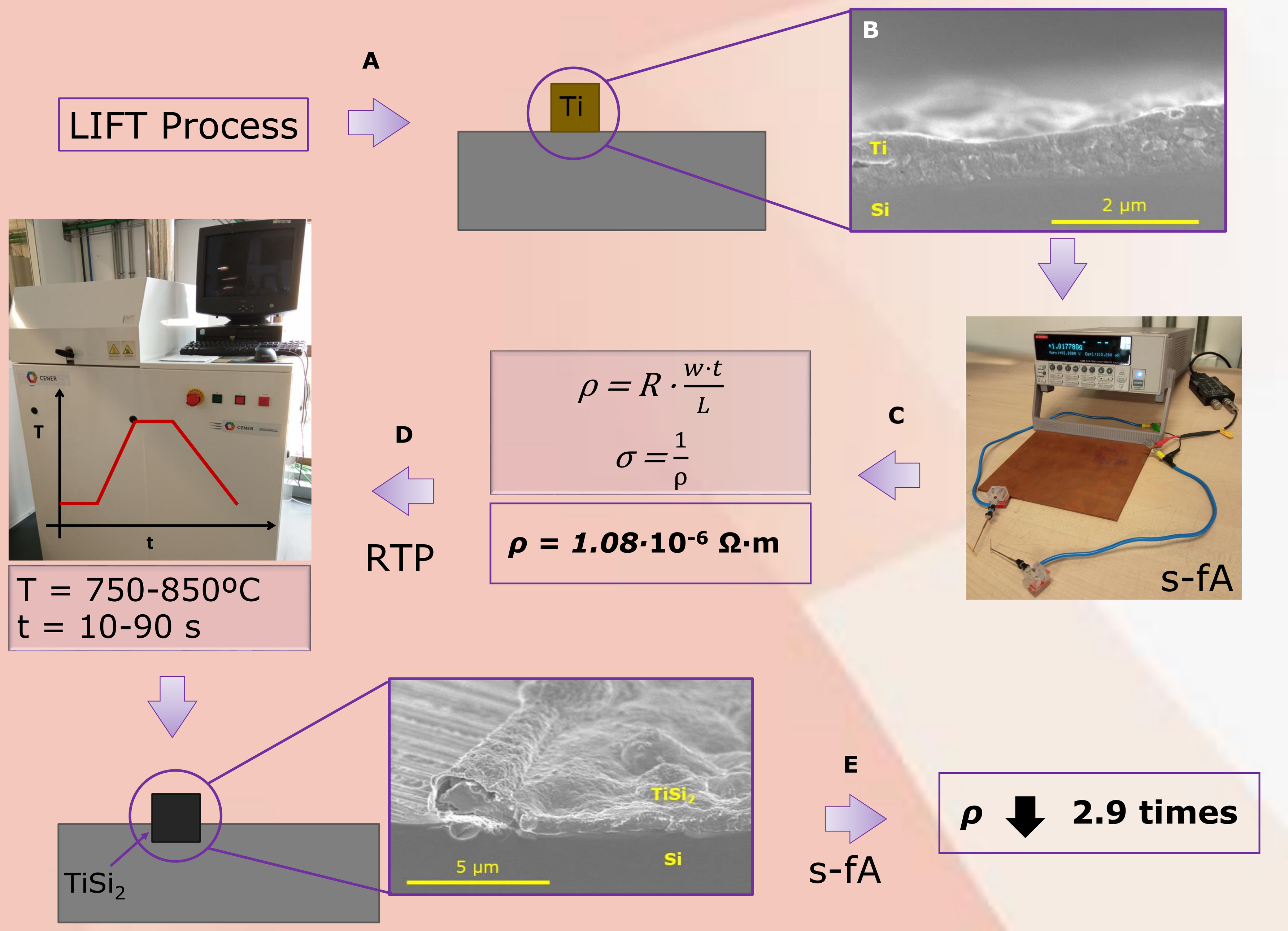

Fig. 3. Workflow followed in this research

Once the **Ti line or finger** has been deposited on the Si wafer by LIFT (A), its **width (*w*) and thickness (*t*) have been measured** (B) by means of scanning electron microscopy (SEM) and its electrical resistance (*R*) has been characterized using a sub-femtoamp (s-fA) meter (C).

Fingers used for this characterization have 4 cm of length (*L*), 100 µm of *w* and 600 nm of *t*. According to equations of C, **resistivity (*ρ*)** have been calculated. Then, Ti fingers have been rapidly thermally **annealed** (D, RTP). During this process, **Ti reacts with Si from the substrate to form TiSi$_2$**.

To check this formation, fingers have been electrically characterized again (E). Annealing at 800ºC during 30 s, a **reduction of 2.9 times in *ρ*** has been obtained, which is in good agreement with the literature and confirms the formation of TiSi$_2$ in its **most conductive C54 phase** [4,5].

Fig. 4 shows a picture of a **Ti electrode**, including **fingers and busbars, deposited by LIFT** on the silicon nitride antireflective (AR) layer as a proof of concept.

Fig. 4. Picture of a Ti electrode

5. CONCLUSIONS & FUTURE WORK

- **LIFT deposited continuous Ti fingers** have been demonstrated adjusting process parameters.
- After a thermal annealing process on these Ti fingers, **C54 TiSi$_2$ fingers have been obtained** joined with a decrease in conductivity compared to Ti deposited fingers.
- Future work will be devoted to explore the way to get Ti in contact with the Si of the substrate through the AR layer, to deposit **TiSi$_2$ C54 lines directly by LIFT** without the need of an additional high temperature process step, and to check **final performance** on state of the art crystalline silicon solar cells.

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