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Research Article

Study and simulation of the silicon processing process

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Abstract — Our work is related to the numerical study and simulation of the silicon processing process by continuous flow in a cold crucible to manufacture photovoltaic cells by the Czochralski method . Numerical simulations of heat exchanges are carried out during the different stages of the process by COMSOL Multiphysics . The results obtained have made it possible to know the thermal field inside the silicon alloy in order to control the parameters during its development to realize photovoltaic cells with high efficiency.

Keywords: photovoltaic cell, silicon, simulation, electromagnetic induction , cold crucible

I.INTRODUCTION

Crystalline silicon remains the dominant technology in photovoltaics. Indeed, more than 93% of photovoltaic modules are made of crystalline silicon. On the other hand, a new generation of thin-film PV modules (amorphous silicon, other CIS technologies, Cd Te, etc.) is gradually appearing on the market. Due to the poor performance of traditional crystalline silicon photovoltaic modules, the use of these photovoltaic modules and their large-scale industrial development are still relatively limited. However, their manufacturing technique shows great potential to significantly reduce the cost of photovoltaic modules.

II.3D SIMULATION GEOMETER

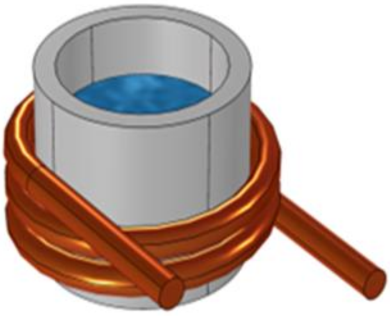

Fig. 1 Geometry in the air field [1].

This method has been invented by the chemist Polish Czochralski at the beginning of the 20th century . This technique consists of obtaining a monocrystalline structure by melting silicon high purity polycrystalline In A rotating quartz crucible placed in an argon drawing furnace to ensure an atmosphere neutral to avoid oxidation . The coil and crucible are present as separate components. They are represented as bounded structures, highlighting their shape and position in the surrounding air. The relative arrangement of the coil and crucible can be observed with respect to the air domain.

III.TIME SIMULATION

Time domain simulations, on the other hand, are used to analyze the transient behavior of the system over time. By simulating the time evolution of the magnetic fields and the temperature distribution in the system, we can analyze the time needed to reach the melting point and the heat degradation in the geometry. This information can be used to optimize the operation of the induction heating system, for example by adjusting the input power or frequency for example or the geometry of the system to improve heating efficiency and reduce heat losses.

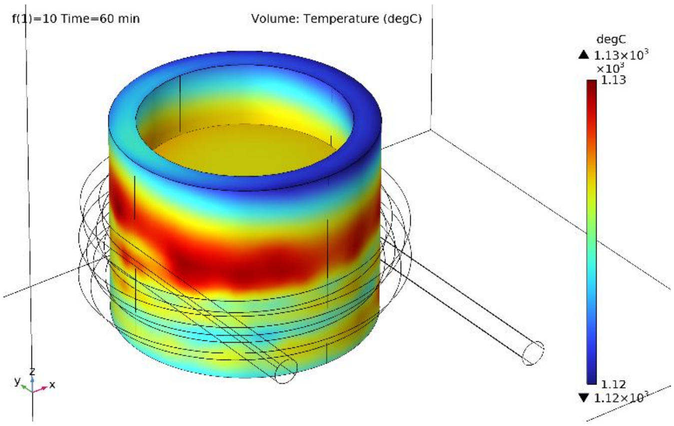

Fig.2 3D presentation of the temperature distribution in the regime stationary for f= 10 kHz

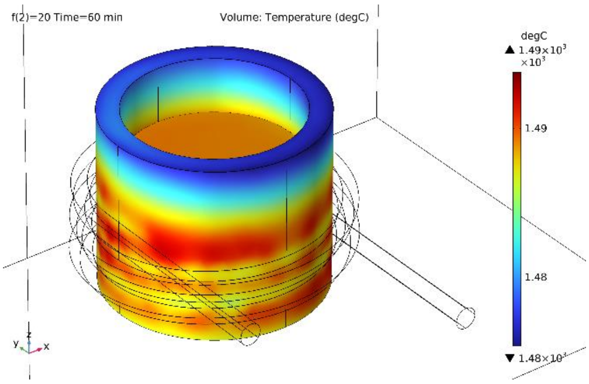

Fig.3 3D presentation of the temperature distribution in the regime stationary for f= 20 kHz

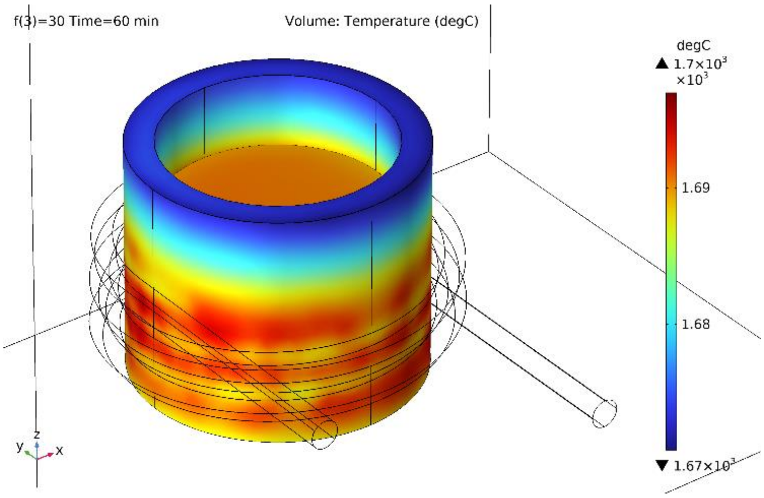

Fig.4 3D presentation of the temperature distribution in the regime stationary for f= 30 kHz

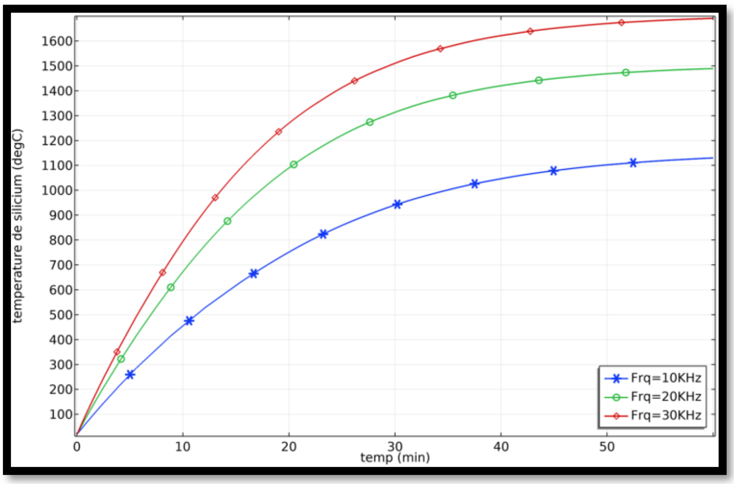

Fig. 5 The evolution of the system temperature .

Figure 5 shows the temperature evolution of the system, including the crucible and the silicon material, for different frequencies. The graph shows the temperature variations over time for frequencies of 10 kHz, 20 kHz and 30 kHz, while maintaining the same input current and voltage (60 A / 200 V).

The x-axis represents time, indicating the duration of the simulation or experiment. The y-axis represents temperature in degrees Celsius (°C), indicating the temperature variations of the system

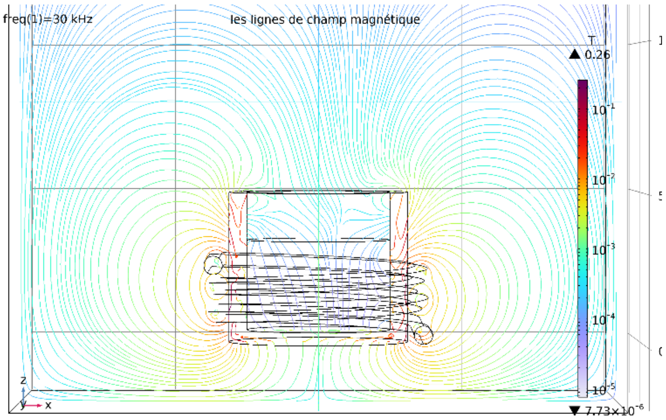

Fig.6 The distribution of the magnetic flux within the system for f= 10 kHz

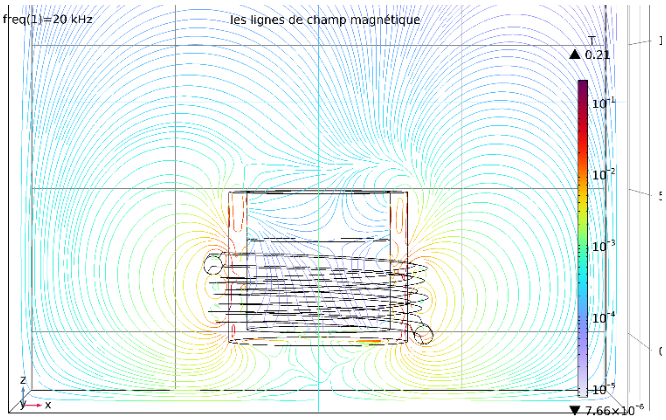

Fig.7 The distribution of the magnetic flux within the system for f= 10 kHz

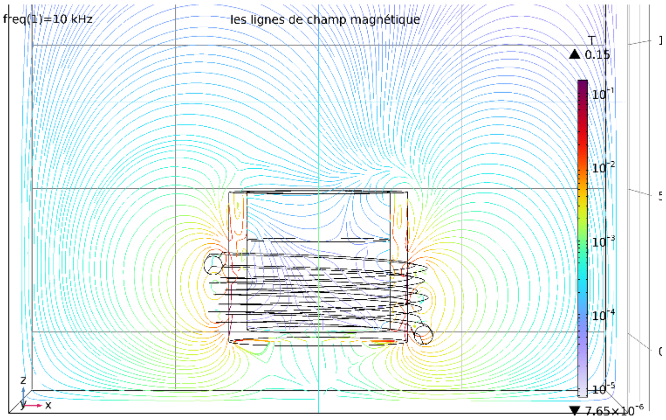

Fig.8 The distribution of the magnetic flux within the system for f= 10 kHz

The input current represents the electrical energy flowing through the coil, which generates the magnetic field.

The diagram highlights the distribution of magnetic field lines within the cross section. It visually represents the trajectories and intensity of the magnetic field lines crossing the different regions of the system.

IV DRAWING STAGES

We start with the material melted at a temperature just above the melting point with a temperature gradient controlled . The germ East place in a " shuttle " suspended above the liquid by a rod . The liquid solidifies on the germ while keeping the same crystalline organization (epitaxy) as it progresses that we pull the germ up while doing it turn .

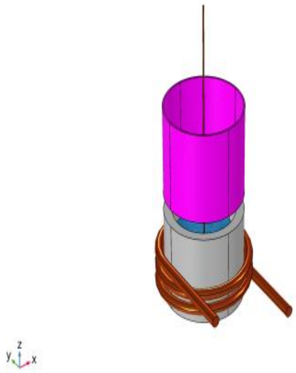

Fig.9 Germ placed in the crucible above the liquid for drawing

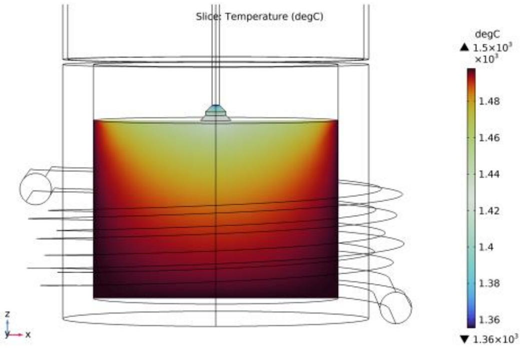

Fig.10 Temperature assessment for the 1st stage of the draw

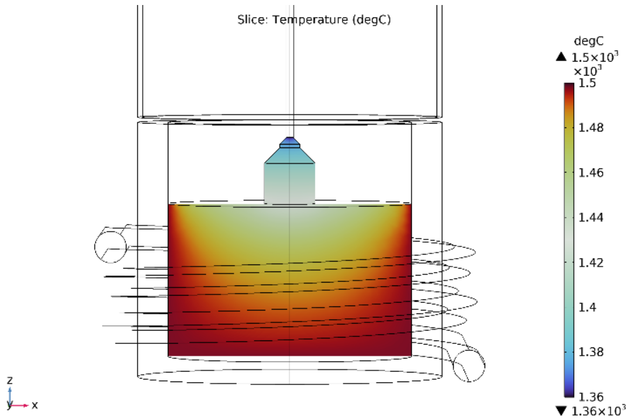

Fig.11 Temperature assessment for the 2nd stage of the draw

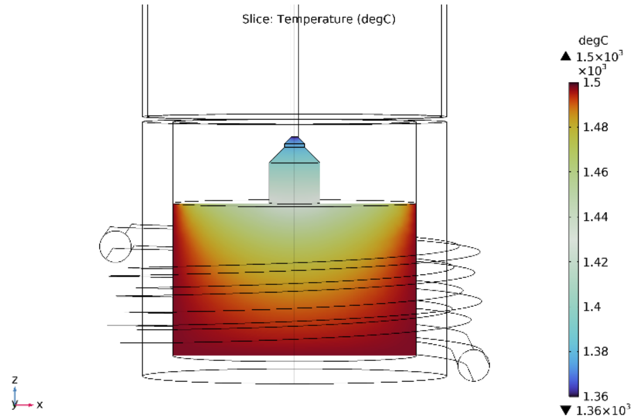

Fig.12 Temperature assessment for the 3rd stage of the draw

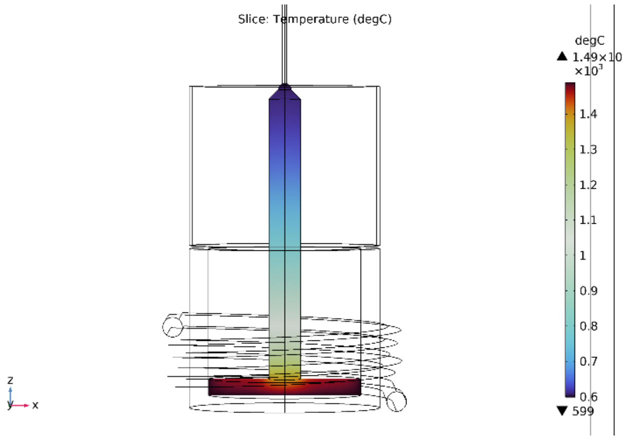

Fig.13 Temperature assessment for the last stage of the draw

VI .CONCLUSION

This paper proposes a simulation study of the interaction between the coil, the graphite crucible and the silicon using COMSOL Multiphysics can provide valuable insights into the heating and melting behavior of silicon during induction heating and help to optimize the design and operation of induction heating systems.

By using both frequency-domain and time-domain simulations in our study, we can gain a comprehensive understanding of the heating and melting behavior of the system, including the time required to reach the melting point and the heat degradation in the geometry.

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