NREL

Furthering Advancement to Address Tough Problems Facing the Solar Energy Industry, Spurring the Next Wave of Solar Technology Innovations through Three Progressive Challenges and Cash Incentives

Cooperative Research and Development Final Report

CRADA Number: CRD-20-16742

NREL Technical Contact: Vincenzo LaSalvia

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

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Contract No. DE-AC36-08GO28308

Technical Report
NREL/TP-5900-87638
September 2023

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NOTICE

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Cooperative Research and Development Final Report

Report Date: September 25, 2023

In accordance with requirements set forth in the terms of the CRADA agreement, this document is the CRADA final report, including a list of subject inventions, to be forwarded to the DOE Office of Scientific and Technical Information as part of the commitment to the public to demonstrate results of federally funded research.

Parties to the Agreement:

Integrated Silicon Technologies, LLC (formerly Integrated Silicon Systems)

CRADA Number:

CRD-20-16742

CRADA Title:

Furthering Advancement to Address Tough Problems Facing the Solar Energy Industry, Spurring the Next Wave of Solar Technology Innovations through Three Progressive Challenges and Cash Incentives

Responsible Technical Contact at Alliance/National Renewable Energy Laboratory (NREL):

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Erik Ydstie | ydstie@gmail.com

Sponsoring DOE Program Office(s):

Office of Energy Efficiency and Renewable Energy (EERE), Solar Energy Technologies Office (SETO)

Joint Work Statement Funding Table showing DOE commitment:

Estimated Costs	NREL Shared Resources a/k/a Government In-Kind
Year 1	$ 25,000.00
TOTALS	$ 25,000.00

Executive Summary of CRADA Work:

The American-Made Solar Prize is a prize competition from the U.S. Department of Energy that is designed to revitalize U.S. solar manufacturing. The competition aims to support the growth of U.S. solar manufacturing and reenergize American energy innovation by tapping into American's competitive spirit and the nation's unparalleled innovation ecosystem leveraging national labs, incubators, facilities and more. National Renewable Energy Lab (NREL) will provide technical and business advisement to the noted Solar Prize finalists. The CRADA Participant is in the process of developing a new continuous process for making silicon wafers for solar cells in a novel approach to horizontal ribbon growth. Under this CRADA, NREL will characterize the chemical, electrical, and crystallographic properties of the as-produced wafers to and work with the CRADA Participant to improve and modify processing conditions.

CRADA benefit to DOE, Participant, and US Taxpayer:

- Assists laboratory in achieving programmatic scope, and/or
- Uses the laboratory's core competencies.

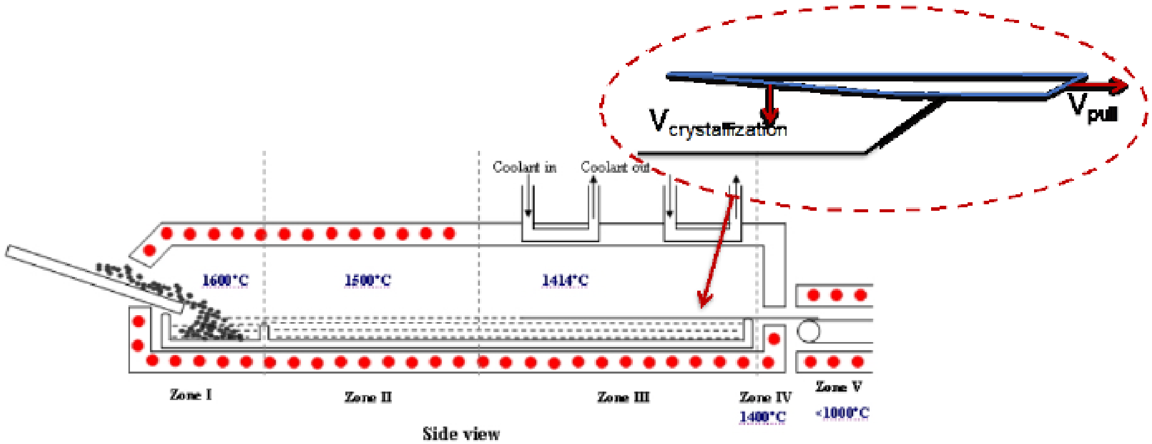
Summary of Research Results:

Purpose

IST is in the process of developing a new continuous process for making silicon wafers for solar cells in a novel approach to horizontal ribbon growth. Preliminary estimates are that the process has the potential of cutting the wafering cost in half relative to Czochralski and subsequent wire or laser cutting. IST requests the specialists at the DOE's NREL to characterize the chemical, electrical, and crystallographic properties of the as-produced wafers to and work with iST to improve and modify processing conditions.

Statement of Work

NREL and IST will work together to characterize the chemical, electrical and crystallographic properties of 12 silicon wafers produced in a novel approach to horizontal ribbon growth shown in the figure below. IST will produce wafer examples under different processing conditions such as heating, cooling and pull rates in the HRG process. These experiments will be carried out at Carnegie Mellon University. The different types of analysis will provide feedback on how adjust processing conditions to improve the electro-optical, thickness, and mechanical properties of the as-produced wafers. NREL researchers will characterize such material properties in their as-received state with several methodologies: photoconductance decay for determining minority carrier lifetimes, sheet-resistance measurements for determining doping concentrations and bulk-conductivity, Secondary Ion Mass Spectroscopy (SIMS) for impurity profiling, and x-ray diffractometry for determining crystallography of the material. In an effort to demonstrate the industrial viability of this novel approach to wafer production, NREL researchers will treat IST material with a number of industry-standard processes (Al_2O_3 or superacid surface passivation, thermal oxidation, phosphorus diffusion/gettering, inert annealing) and repeat the characterizations to determine material quality and robustness after typical cell processing budgets of time, temperature, and chemistry.



Task Descriptions

The Participant will:

- Task 1: The Participant will participate in a monthly check-in with the NREL Principal Investigator. If a check-in meeting is missed two months in a row, the agreement may be cancelled by the American-Made Challenges Solar Prize team.
    - Monthly check-ins between the NREL principal investigator and the Participant were not maintained due to COVID-19 shutdowns at the Participant's laboratory. While NREL prepared a set-up to characterize the products, no products were provided prior to (or after) COVID-19 shutdowns.
- Task 2: The Participant will provide products to be tested using different processing conditions and process configurations so that the process can be optimized for solar applications.
    - The Participant did not provide products to be tested, characterized, or processed – no work was completed.
- Task 3: Eyan Noronha and Erik Ydstie of IST will be available for phone/video meetings as necessary and will assist in the development of project.
    - Because of COVID-19 shutdowns at the Participant's laboratory resulting in no delivery of products shipped for testing, there was no correspondence between the Participant and NREL points of contact (Eyan Noronha, Erik Ydstie and Vincenzo LaSalvia).
- Task 4: IST will provide information as needed about the processing conditions and the configuration of the HRG process.
    - Because there was no work done for this CRADA, IST did not provide information about their HRG process.

NREL will:

Technical and business support provided by NREL to develop finalist concepts in advance of Demo Day events. The technical advisement will include:

- Task 1: NREL will characterize Participant's product in terms of electrical properties.
  - The NREL Principal Investigator set up a Sensitive Technique for Detecting Bulk Silicon Defects using Light Enhanced Hydrofluoric Acid Passivation. Using optimized chemistries and advanced calibration techniques suitable for the potential material products from IST, a photoelectrochemical technique was employed for characterizing the photocarrier lifetime using a photoconductance decay methodology. This technique was adapted from Nicholas E. Grant's previous work: https://dx.doi.org/10.3791/53614-v The in-house photoelectrochemical set-up is shown in Figures 1 and 2 below:

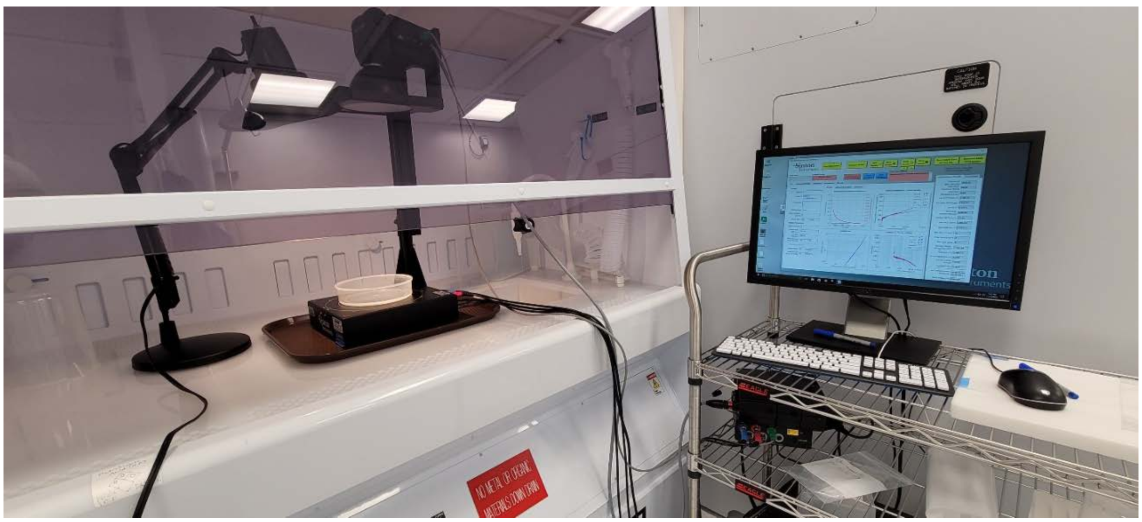


Figure 1. Sinton Instruments (WCT-120) photoconductance decay measurement technique with halogen light illumination and hydrofluoric/hydrochloric acid mixture for *in-situ* surface passivation suitable for silicon materials.

Figure 2. Close-up of Sinton Instruments (WCT-120) photoconductance decay measurement technique from inside the chemical hood with proper ventilation for safe use with hydrofluoric/hydrochloric acid mixtures. NREL prepared this set-up to characterize the products; however, no products were provided by the Participant to complete the planned testing.

- Task 2: NREL will characterize Participant's product in terms of chemical properties.
    - The Participant did not provide products to be tested in terms of chemical properties (e.g., SIMS, XPS, etc.); therefore, no work was completed.
- Task 3: NREL will characterize Participant's product in terms of crystallinity.
    - The Participant did not provide products to be tested in terms of crystallinity (e.g., x-ray diffractometry, etc.); therefore, no work was completed.
- Task 4: NREL will subject IST material to several industrial-standard chemical and thermal processes to further understand material viability throughout a typical solar cell process.
    - The Participant did not provide products to be subjected to standard chemical and thermal processes (e.g., RCA cleaning, alkaline etching, thermal oxidation, etc.); therefore, no work was completed.
- Task 5: NREL will develop summary report of characterization results.
    - The Participant did not provide products to be tested; therefore, no summary report was completed.
- Task 6: The Principal Investigator agrees to provide the following to DOE Office of Scientific and Technical Information (OSTI): (1) an initial abstract suitable for public release at the time the CRADA is executed; (2) a final report, within thirty (30) days upon completion or termination of this CRADA, to include a list of Subject Inventions; and (3) other scientific and technical information in any format or medium that is produced as a result of this CRADA.
    - This report meets the CRADA Final Report deliverable to complete the requirement in accordance with Article X.

Subject Inventions Listing:

None

ROI #:

None