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# Award No. DE-EE0000573

# Recovery Act: A Low Cost Spray Deposited Solar PV Anti-Reflection Coating
# Final Technical Report

**Recipient**: XeroCoat, Inc.

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| **Document Notes**:<br>Nothing in this document is considered confidential. | |

## Executive Summary

The objective of this Project was to develop the technology required to implement commercial scale manufacturing system to apply XeroCoat's high-performance liquid antireflection (AR) technology to photovoltaic (PV) module cover glass.

PV module glass is typically low iron glass which exhibits extremely low absorption of light at solar wavelengths. However, reflection losses from typical high quality solar glass are about 4.5% of the input solar energy. By applying an antireflection coating to the cover glass of their modules, a PV module maker will gain at least a 3% increase in the light passing through the glass and being converted to electricity. Thus achieving an increase of >3% in electricity output from the modules.

The pre-existing core technology, on which this project was based, is a process that deposits a layer of porous silica ($SiO_2$) on glass or plastic components. This porous layer acts as a broadband single layer AR coating for glass and plastics, with the added benefit of being a hydrophilic surface for low surface soiling.

This Project focussed on developing a method of coating to be used at commercial scale coupled with designing and testing the necessary subcomponents and subsystems required to demonstrate the commercial technology.

At the close of this project we had achieved:

1) Demonstrated AR performance verifying an economically viable AR coating solution
2) Investigated means of mass-production for liquid application of thin films
    a. Validated two coating methods
    b. Demonstrated at lab-bench scale these methods in operation
3) Developed market and customer relationships leading to external validation
4) Shown economic feasibility of AR coating as a path to increased solar PV generation
5) Working with potential end-users verified that the application of an AR coating reduces the cost of producing PV modules.

This Project was not able to be completed for commercial reasons effecting XeroCoat, inc.

## Accomplishments

The objective of the Project were divided into four tasks. Below, each of the tasks is summarised and accomplishments achieved during the Project.

**Task 1 - Laboratory demonstration**

Develop a coating application method compatible with both XeroCoat's AR technology and PV module glass manufacturing.

- Assessed commercially available liquid coating technologies.
- Based on technology survey Identified leading candidates roll coating and spray coating.
- Tested selected coating technologies and settled on atomised droplet spray coating and high speed gravure roll coating.
- Lab bench demonstration of each showing >2% added transmittance.

**Task 2.0 - Pilot coating system and customer testing**

Implement the coating method at a pilot scale which will allow for meaningful development of the equipment and deliver coated samples for testing to verify the performance and durability of the AR coating product.

- Installed pilot coating systems using both roll and spray techniques.
- Used pilot systems to work up engineering requirements for demonstration system.
- Produced small number of samples for internal and external testing.
- Work on the Pilot systems was not completed.

**Task 3.0 - Demonstrate final production processes**

Demonstrate by use of the modified pilot scale equipment a final production process which will allow a detailed equipment design to be undertaken.

- Developed Pilot coating system concept.
- Designed subsystems for glass cleaning, coating, curing and chemical delivery.
- Started engineering work and some construction of subsystems.
- Bench top testing of key design concepts was undertaken but not completed.
- Work on the Demonstration system was not completed.

**Task 4.0 Production equipment design**

Design and validation of production equipment to a stage where a customer will undertake to construct and implement a full scale production system for applying AR coatings on PV cover glass.

- Discussions with end users were undertaken to establish final Production system market requirements.
- Work on the Production system design was not completed.

## Project Activities

Summarise project activities for the entire period of funding, including original hypotheses, approaches used, problems encountered, departures from planned methodology and an assessment of their impact on the project results

**Task 1 - Laboratory demonstration**

Develop a coating application method compatible with both XeroCoat's AR technology and PV module glass manufacturing.

A coating application method must encompass:

Surface preparation (cleaning)

- Surface preparation by vertical glass washing with mechanical brushes and water only, using a commercial washer was trialled successfully.
- For some surfaces, depending on the sensitivity of the deposition process to variations in surface energy, chemical preparation was seen to be required, and successfully implemented.
- Surface preparation using plasma cleaning was also demonstrated to be acceptable.
- Investigated the need for ionised air flow prior to deposition , and an option to implement this was identified. Contact deposition is more susceptible to defects from dust and contamination – An ionised air curtain or blower prior to coating mitigates this issue.
- Showed that vertical and horizontal glass washing are both sufficient for each of the selected deposition processes.

Deposition of the AR layer (coating)

- Many deposition technologies were trialled, and two were identified as meeting the required throughput, scalability, performance and cost targets for this Project.
- The two methods are very different and, in order to mitigate technical risks, both methods were pursued.
- Both coating techniques were being developed for eventual trials at pilot scale.
- AR coating performance of >2% was demonstrated using both deposition methods.
- For each of the deposition methods the process window was investigated, and in each case was found to be suitable for a Production System.
- Testing was been undertaken on both systems to a sufficient extent to be able to prototype the two systems at XeroCoat's own facility.
- Where possible equipment was borrowed to minimise the development costs.
- Prototype equipment for testing both deposition methods was procured, assembled and tested on XeroCoat's site.
- Both systems performed to a level which verified that they could successfully fulfil the Production System requirements.

Chemical reactions that make the AR layer permanent (cure)

- Conceptual design work for the curing component for the Pilot Line was undertaken by XeroCoat and vendors.
- There is an issue of integration and compatibility between the selected coating deposition method and the curing systems.

**Task 2 - Pilot coating system and customer testing**

Implement the coating method at a pilot scale which will allow for meaningful development of the equipment and deliver coated samples for testing to verify the performance and durability of the AR coating product.

Design, deliver and commission pilot system

- Engineering staff worked with vendors and equipment integrators to evaluate the concepts and work out the options available.
- Vendors for key components were identified and most parts ordered.
- Long lead items were being staged to allow the Project timeline to be kept.
- The chemical delivery subsystem was under construction.
- Solution management component has been constructed and verified to work on the lab bench. Bench system was disassembled and integration into prototype coating systems was ongoing.
- Stability of solution management system assessed. Significant work expended investigating anomalous refractive index shifts as function of time. Suspect contamination from component in system. Did not discovered exact cause.
- Developed open-loop method to allow other work to continue.
- Curing system for Pilot scale testing was delivered and assembled on XeroCoat's site. This was not able to be completed or tested.

Customer samples

- Worked with potential customers to assess the market requirements.
- Potential customers and third party test laboratories were being contacted to start setting up relationships for the testing of the coatings delivered by the later stages of this Project.
- Visits to end users of the technology and hosting staff from such end users allowed XeroCoat to verify the technology path would be of benefit to the solar industry in the USA and globally.
- Some preliminary sample pieces were sent to NREL for assessment. Measurements made at NREL confirmed XeroCoat's internal findings on performance, but some data was ambiguous. NREL will retest at XeroCoat's request. Exposure and durability testing was being pursued, but did not start.
- Measurements by American, European and Asian companies confirmed AR performance.

Internal testing

- A set of internal performance and durability tests were being designed to validate the coating products from this Project.
- Equipment and procedures for testing were set up at XeroCoat's site.

**Task 3 - Demonstrate final production processes**

Demonstrate by use of the modified pilot scale equipment a final production process which will allow a detailed equipment design to be undertaken.

- Started assessing engineering needs and constraints.
- Cure system design and test work started.
- Worked with vendor on chemical delivery design.
- Cure system assembly started. Five chambers installed. Verification was not completed.
- Chemical delivery system bench version built, verified operation and disassembled pending pilot system.

**Task 4 - Production equipment design**
Design and validation of production equipment to a stage where a customer will undertake to construct and implement a full scale production system for applying AR coatings on PV cover glass.

- Identified and contacted some potential end users for input.

## Technology Transfer Activities

The project did not result in any fully developed products.
No publications were made under the award.

Other activities, technologies/techniques:

- Established feasibility of spray application.
- Verified need in market.
- Demonstrated AR performance and durability.
- Established connections into the solar glass industry.
- Built relationships within PV module makers' technical and testing sections.

## Computer Modelling

No computer modelling was performed.