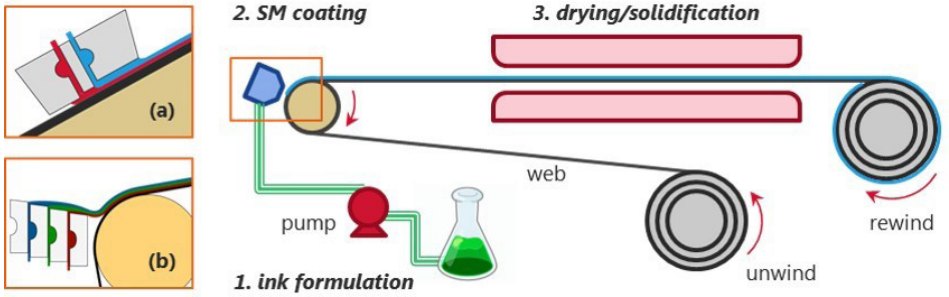
U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Development of Roll-to-Roll Simultaneous Multilayer Deposition Methods for Solid-State Electrochemical Devices Using Highly Particulate Loaded Aqueous Inks



Process overview of the Simultaneous Multilayer Roll-to-Roll (SM-R2R) coating from highly particulate loaded aqueous inks (HIPLAIs). Two types of SM coating dies are depicted in insets: (a) 2-layer slot die coating and (b) 3-layer slide coating.
Photo credit Saint-Gobain Ceramics and Plastics, Inc.

Solid state electrochemical devices (SSEDs), such as photovoltaics, fuel cells, and capacitors, have extensive use in energy-related applications. These devices are comprised of multilayer films that are currently manufactured from highly particulate loaded aqueous inks (HIPLAIs) layer-by-layer either serially or in parallel. There is extensive opportunity to consolidate these layer-by-layer methods into fewer concurrent steps to reduce manufacturing complexity, improve product yield, and increase performance. Improving SSEDs by utilizing simultaneous multilayer roll-to-roll (SM-R2R) coating methods can help realize these benefits.

This project is developing a SM-R2R coating from HIPLAIs to lower production cost, increase performance, and reduce life cycle energy consumption of SSEDs. These multilayer coatings will be developed and tested in a novel solid oxide fuel cell (SOFC) as a platform to realize these benefits. The project will begin by determining the ink characterization for the coating, and then producing and testing a two-layer coating for SOFC integration. The SM-R2R process will then be used to produce and test a six-layer coating. A techno-economic analysis will then be completed for the SM-R2R process for both the two-layer and six-layer coatings.

Benefits for Our Industry and Our Nation

The SM-R2R coating under development is expected to have significant manufacturing impacts, particularly in ceramic coating, drying, and forming processes. This project seeks to improve the current single layer casting methods by combining these methods into a simultaneous multi-layer coating process. Using state-of-the-art SM-R2R coatings are expected to have numerous benefits for SSEDs, including:

- Consolidating the manufacturing steps of six separate layers into a single step will lead to lower manufacturing costs and energy savings
- Improving lifecycle energy consumption through reduced energy consumption during manufacturing, reduced capital costs, and higher device performance and durability

Applications in Our Nation's Industry

This SM-R2R coating of HIPLAIs technology is expected to have many benefits to manufacturing of devices comprising multilayer particulate films. Immediate applications include lithium-ion batteries and SSEDs like photovoltaics, fuel cells, and capacitors. Other applications include solar control windows, flexible electronics, and membranes for separations and catalysis.

Project Description

The project objective is to develop, build, and test the SM-R2R coating process to produce up to six functional layers simultaneously from HIPLAIs. The project aims to lower production cost, increase performance, and reduce life cycle energy consumption for SSEDs using this coating process. The project outcomes address three core elements: (a) development of ink formulation design rules specific to SM coating and multi-layer film property considerations; (b) SM coating process die designs and operating conditions tailored to HIPLAIs; and (c) drying and solidification optimization with respect to final device quality and performance.

Barriers

- Overcoming known technical risk factors, including die contamination, layer intermixing during drying, and cracking of thick multi-layer films during drying and sintering

Pathways

The project is structured to address the key barriers and minimize risk. The ultimate goal is to develop a SM-R2R coating for SSEDs using HIPLAIs.

The first project pathway will develop and optimize a two-layer SM-R2R coating. This validation will involve characterizing the inks, producing and testing a two-layer coating, and then integrating the coating into electrochemical devices. The two-layer coating will be tested for ease of manufacturing, and ink formulation compatibility.

The second pathway will develop and test the simultaneous six-layer slide coating. Like the two-layer coatings, these coatings will be produced, tested, and integrated onto electrochemical devices. These tests and analyses will validate the reliability of the SM-R2R manufacturing method.

The third pathway will develop a techno-economic analysis based on the process parameters for both the two-layer and the six layer coating. This analysis will determine the impact of the SM-R2R manufacturing methods on energy and material consumption, as well as capital expenses. This will be done to compare the experimental results against conventional methods for fabricating various electrochemical devices.

Milestones

This two-year project began in August 2018.

- Verify proof-of-concept for 2-layer simultaneous coating by cross-sectional microstructural and chemical characterization of laboratory devices and design rules established for 2-layer slot process based on coatability assessments (2019)

- Establish design rules for 6-layer configuration with demonstrated functionality devices matching or exceeding the baseline device performance and the techno-economic impact evaluated for SM-R2R process (2020)

Technology Transition

Saint-Gobain Ceramics and Plastics is partnering with Oak Ridge National Laboratory to assess the potential impact of this novel ceramic casting process. Following successful development, the project team plans to advance the technology through markets Saint-Gobain currently has programs, partnerships, or participation. Based on the results identified by the techno-economic analysis and an advisory board, the project team will also consider technology advancement and transfer strategies in other markets.

Project Partners

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