[Extended Abstract]

"Roll-to-roll Advanced Materials Manufacturing Lab Consortium"

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The transition of new materials and structures into viable products is a process with many pitfalls. A much-discussed aspect of this problematic transition is the so-called "valley of death" (depicted in Figure 1) in funding support between basic materials discovery research – often funded by the government – and product-focused development supported in the private sector.

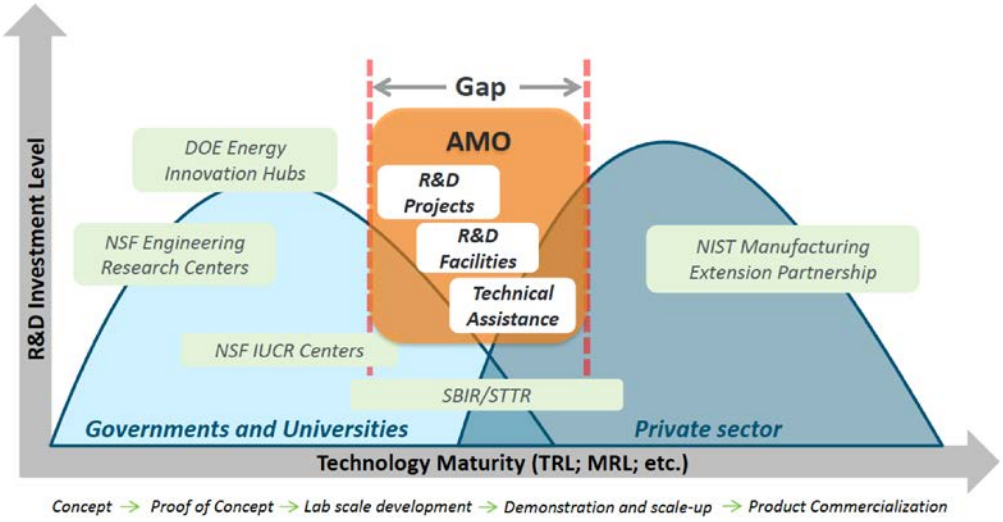

Figure 1. The "valley of death" in materials development

A key factor in this valley or gap is the lack of support of process-related technology development to demonstrate and enable scalable manufacturing of materials that are often initially fabricated and researched using lab-scale processes. The U.S. Department of Energy (DOE) Advanced Manufacturing Office (AMO) aims to address mid-technology development in this gap by supporting R&D projects and shared facilities, by creating public-private partnerships for manufacturing technology development, and by providing technical assistance to manufacturers across a wide range of manufacturing technologies related to energy efficiency and clean energy technologies. Figure 2 shows a range of technology areas that enable or support manufacturing of products that are critical to national energy systems and/or relate to emerging national and global topics that involve energy.

Figure 2. Advanced manufacturing technology areas of interest to DOE

Roll-to-roll (R2R) processing is identified (bottom-center of the middle graphic) as one of these critical advanced manufacturing technologies. While R2R processing is not new, modern variants are needed for enabling widespread commercialization of 2D engineered materials for electrochemical energy storage and conversion, electrolytic hydrogen production, smart flexible sensors for building energy efficiency improvement, flexible displays such as organic light emitting diodes (OLEDs), membranes for water applications, and flexible photovoltaics. These applications have the potential to significantly impact U.S. manufacturing sector recovery, environmental security, energy security, and sustainable transportation adoption. The shape, size, and morphology of the materials, the chemistry of the formulation, the nature of slurries, their coating rate, the rate of drying, etc., all play a role in determining the final coating architecture, quality, and performance. In addition, non-destructive evaluation (NDE) of the produced coatings for improving in-line quality control (QC) and identification of defects, prior to down-stream value added steps being performed, is of paramount importance. DOE understands the criticality of development in these areas because the cost targets for advanced energy storage and conversion applications will not be met without significant and timely advancements in R2R manufacturing. As an example, current baseline technology cell costs in the Li-ion battery industry are about 2.5× the $100-125/kWh ultimate DOE target. In order to reach the target performance of 500 Wh/kg, novel R2R processing technologies will be required.

In response to these cross-cutting needs and to assist in reaching the low $/m^2 costs of these critical energy related applications, AMO created a multi-laboratory and industry partnership, including Oak Ridge National Laboratory (ORNL), Argonne National Laboratory (ANL), Lawrence Berkeley National Laboratory (LBNL), and the National Renewable Energy Laboratory (NREL), in collaboration with Eastman Kodak Business Park and Citrine Informatics. The goal of this consortium is to enable advanced R2R manufacturing research and development to demonstrate a new materials-genomic approach to optimization of process parameters for finding transformational improvements in manufacturing technologies. This consortium creates a national team of experts and capabilities covering aspects from materials genome modeling and simulation through powder materials synthesis, slurry formulation and scale-up, pilot

deposition and curing process development, non-destructive evaluation development, and big data analytics and validation, to full scale production of rolled goods. As shown in Figure 3, the laboratories involved in the consortium bring to bear a breadth of capabilities that especially small companies developing new materials and products may not have or have access to.

Figure 3. Lab capabilities under the R2R-AMM Consortium

During a one year seed effort, the labs successfully demonstrated their combined capabilities on the topic of Li-ion battery manufacturing. This project included tasks to utilize advanced electron microscopy to measure particle sizes of NMC electrode material, prepare and characterize slurries and electrode coatings, determine the areal weights of the coatings, prepare coatings for matching anodes, explore X-ray fluorescence for areal loading measurement, further develop a real-time porosity diagnostic for in-line metrology studies, conduct x-ray tomography and other advanced characterization of the coated materials, and conduct device testing for rate capability, AC impedance, and initial capacity fade. Additionally, the team developed models for droplet studies, drying of slurries, and porosity diagnostics of two or more layers of cathode materials.

While the laboratories have extensive capabilities to bring to bear, it is critical that the consortium work with and address challenges that are relevant to industry. In this light, DOE is supporting a collaborative opportunity for industry to work with the consortium to develop new processes, evaluate new materials, and explore manufacturing technologies related to R2R processing of clean energy and energy efficiency materials. The mechanism of this opportunity is a solicitation for proposals on these topics that would lead to cost-shared work at the laboratories to assist industry in advancing R2R technologies. A range of industry collaborators is of interest, including both equipment developers as well as companies commercializing new products related to clean energy and energy efficiency that are or could be manufactured using R2R processes. A broad range of collaborative topic areas can be envisioned, including synthesis of coating materials; development of coating/deposition, drying/curing, and additional treatment processes; application of new materials to R2R processes; development of material-

specific inspection techniques; application of advanced, high-energy characterization tools for inks and slurries as well as for membranes and active layers; modeling and simulation; testing of R2R equipment/processes in new applications; and application-specific device fabrication and testing. Details and instructions for this solicitation, as well as more information on lab capabilities, can be found at FedBizOpps.gov, under solicitation number: ORNL-R2RAMM-2017-02-02.