Technical Assistance Request

Materials Characterization and Predictive Modeling for Increased Bankability of Cell-Crack-Tolerant Metallization in PV Modules

Osazda Energy requests technical assistance of National Renewable Energy Laboratory (NREL) for advanced materials characterization of metal matrix composite (MMC) metallization, named as MetZilla, and its predictive degradation modeling. The purpose is to demonstrate that Osazda's new metallization provides superior electromechanical performance over conventional silver paste to reduce the cell-crack-induced module degradation, thus improving module lifetime and power generation. Gathering such critical evidence is requisite of any utility-scale PV projects, and we have identified it as a critical path in commercializing the MMC product [1].

Problem Statement and Materials Solution: Silicon solar cells crack during manufacturing, shipping, installation, and operation. These cell cracks can eventually propagate through metal gridlines and busbars on solar cells, leading to module power loss over time, and can be a root cause of hotspots. Technical approaches to mitigate the impact of cell cracks include improved designs for cell shape, cell wiring, metallization patterns, and module construction. Multi-wire technology has also emerged as a possible solution to the cell-crack-induced module degradation. In comparison, Osazda's MMC metallization is a low-cost [2], drop-in solution that provides improved fracture toughness, electrical crack-bridging, and self-healing[3-6], while eliminating the need for retooling the module manufacturing line. Osazda's composite metallization makes use of surface-functionalized multiwalled carbon nanotubes (MW-CNTs) embedded in commercially available silver paste. Figure 1(a) conceptually captures how multiwalled carbon nanotubes (MW-CNTs) embedded in a metal matrix can electrically bridge the gap in cracked or severed metal lines. The scanning electron micrograph (SEM) images in Figure 1(b) visually demonstrates this composite engineering strategy, where the CNTs mechanically and electrically bridge the gaps in severed MMC gridlines, providing redundant electrical conduction pathways.

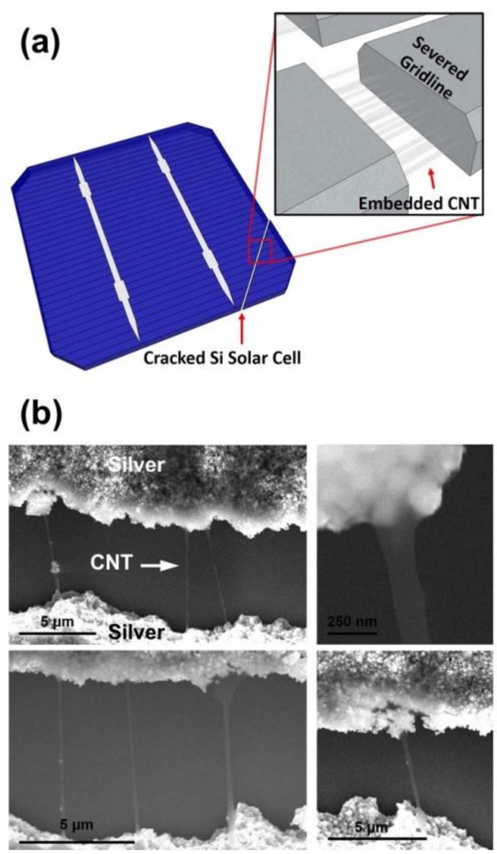

Figure 1: (a) Conceptual diagram of electrically bridging cracks in gridlines and (b) experimental observation of carbon nanotubes bridging cracks.

Proposed Activity: For this technical assistance request, we will specifically focus on how the characteristics of silver particles (i.e., shape, size, aspect ratio, and mixed shapes/sizes), in concert with MW-CNTs incorporation, can improve the electrical and mechanical properties of screen-printed and fired gridlines. We expect that a proper combination of particle sizes and shapes would maximize the electrical percolation paths in the gridlines, *while minimizing the silver usage*. The silver usage for silicon PV is 11% of the global silver supply in 2020, and the percentage is expected to grow rapidly in the next decade. The volatility of silver commodity market also makes it highly desirable to reduce silver usage. Carbon nanotubes, when properly functionalized, coordinate around silver particles and influence the particle sintering during firing. The advanced materials characterization by NREL would reveal the intricate interplay between physics governed by silver particle shape and size and chemistry governed by CNT's surface functionalization, and how this interplay determines electrical and mechanical properties of the gridlines. The proposed work will also answer how the metal failure mode may evolve as less silver is used and how the particle shape engineering can potentially achieve the same level of conductance as the conventional gridlines, especially with carbon nanotube incorporation. This technical assistance is necessary for us to deliver high-durability solar panels that last longer than those on the market today at minimal cost.

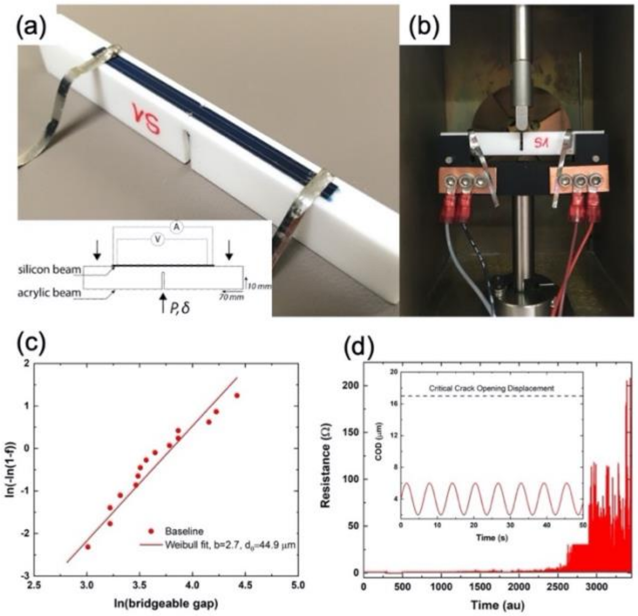

Figure 2: Three-point-bending test setup at NREL to identify the failure mode of MMC gridlines and establish their predictive degradation model.

Technical Assistance from NREL: Osazda will work with Dr. Nick Bosco's group at NREL, who specializes in advanced mechanics and degradation modeling [7]. We will make use of his three-point-bending test [see Fig. 2] to strain the metal gridlines in a cyclic pattern until their mechanical and electrical failure. Figure 2(a) shows a thin rectangular piece of a cell with two parallel gridlines, which is laser-scribed and mounted on an acrylic beam. The ends of the gridlines are interconnected to a DC power supply. The composite beam is placed in three-point flexure [Fig. 2(b)], while the resistance across the gridlines is monitored. Only one crack is produced at the center of the cell that the gridlines initially bridge. With cyclic opening of the crack, we can determine the failure mode of composite gridlines [Weibull analysis, Fig. 2(c)] and the probability of failure [Fig. 2(d)] to predict the performance degradation and lifetime of gridlines against thermomechanical stress.

Outcome: The proposed work will clearly establish the MMC microstructure-function relationship within the context of materials durability. The proven cell-crack-tolerance of Osazda's low-cost, screen-printable, composite metallization technology would increase its bankability for utility-scale PV projects and accelerate its market adaptation.

References

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