



OPEN Improved sustainability of solar panels by improving stability of amorphous silicon solar cells

Gautam Ganguly

As the world grapples with global warming, it becomes imperative to carefully examine the sustainable energy technology choices. Solar is the fastest growing clean energy source but today it contributes little to the electricity generated, so future installations will dwarf the existing installed base. There is a factor of 2–4 decrease in the energy payback time from the dominant crystalline silicon technology to thin film technologies. Essential criteria like use of abundant materials and simple but mature production technology point to amorphous silicon (a-Si) technology. Here we delve into the primary issue impeding adoption of a-Si technology—the Staebler Wronski Effect (SWE), that generates metastable, light induced defects which reduce the performance of a-Si based solar cells. We demonstrate that a simple change leads to a significant reduction in SWE power loss and define a clear path to elimination of SWE, allowing the technology to be widely adopted.

Solar cells are an important component of the sustainable energy mix required to contain global warming and the move to electricity based rather than a fossil fuel based economy. While cumulative solar installations aggregate 1.2 TW^{1,2} this contributes less than 5% of the electricity generated worldwide³. Clearly, the immensity of future installations will dwarf the current installed base. It therefore behooves us to take a careful look at our technology choices for the future. Since the current energy use is dominated by fossil fuels, the energy required to produce solar panels is very important in the contribution it makes to global warming. This energy requirement needs to be compared to the energy generated when the solar panel is deployed, and this is captured in the EPBT^{4,5}. EPBT is reduced by the specific yield (SY = energy generated in the field/ power output under standard condition/) of the solar panels which captures the standard power rating system used for solar panels that is measured at 25 °C and 1000 W/m² irradiance, and the energy generated by the solar panel in the field, which is impacted by the actual operating temperature that is typically much higher than 25 °C (about 40 °C on average) as well as the irradiance which is typically lower than 1000 W/m² (200–800 W/m²). Comparison of different commercially available technologies reveal that thin film technologies have lower EPBT^{4,5}. This accrues from the smaller temperature dependence of power⁶ and hence generate more energy at the higher than 25 °C operating temperatures and they also have a smaller irradiance dependence of power output⁷ resulting in more energy generation at the lower than 1000 W/m² irradiance in the field. While the industry has largely ignored these realities because the power output under standard (STC) conditions is easier to measure, technology based EPBT^{4,5} and SY⁸ can be determined and is significantly lower (2–4 times) for thin film technologies compared to the crystalline silicon technology that constitutes 95% of the industry currently.

Of the thin film technologies, a-Si has the advantage of the highest SY and uses abundant materials, requires the lowest manufacturing temperatures (about 200 °C) and the thinnest semiconductor layers (less than 5000 nm)^{9,10}. It suffers from one fatal issue—the so-called SWE¹¹ which limits its efficiency to 13% for three junction solar cells^{10,11}. However, 16% three junction solar cells have been demonstrated, before SWE^{10,11}, and over 20% four junction solar cells have been projected, in the absence of SWE¹². a-Si technology has already been proven in commercial volume production by numerous companies. The improvement of efficiency in the absence of SWE would put this technology in the very short EPBT range relative to other technologies⁷ and make it the first choice for sustainability.

Current best performance a-Si solar cells use a so-called hydrogen dilution method¹³ that reduces SWE, but single junction cells deposited at about 0.1 nm/s still exhibit about 20% SWE power losses while two and three junction cells have smaller losses¹⁴. It is well known that substrate temperature is a significant factor in the amount of SWE performance loss in a-Si based solar cells¹⁵. However, we have shown that it is not the substrate temperature but the chamber or gas temperature that determines the SWE performance loss¹⁶. This can be understood in terms of the polysilane based origins proposed for the SWE defects¹⁷ and suggests that reactions

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Stability Of Amorphous Silicon Materials And Solar Cells

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