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Kettle, Jeff

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Perovskite photovoltaics

Ready cells for large scale systems

For emerging photovoltaic technologies such as perovskites to become commercially and technically viable, it is important to understand how performances in laboratories translate to real world conditions. New analyses studies the yearly changes in the energy yield of perovskite solar cells under simulated real temperature and irradiance conditions.

Jeff Kettle

School of Computer Science and Electronic engineering, Bangor University, Dean St, Bangor, Gwynedd LL57 1UT, Wales, UK. Email: j.kettle@bangor.ac.uk

Perovskite solar cells are one of the most promising next generation photovoltaic (PV) technologies. Their power conversion efficiency has reached 28% when used in a tandem configuration with silicon [1], which is greater than the current silicon record efficiency (27.6% [2]). Measurement of the efficiency takes place under standard test conditions (STC), which are normally conducted using air mass 1.5 spectrum, an intensity of 100 mW/cm^2 (also known as 1-sun of illumination) and cell temperature of 25 °C. Such testing conditions can be vastly different to real world conditions where temperature, light intensity level and its spectrum constantly vary with time. Wolfgang Tress and colleagues from the Ecole Polytechnique Fédérale de Lausanne, in Switzerland, now present in Nature Energy one of the most comprehensive reports on the simulated outdoor performance of perovskite solar cells. [3] The researchers show that perovskite technology exhibits very promising performance in the prevalent weather conditions that they are likely to be deployed in that is comparable to silicon solar cell used as reference device. The researchers have recorded weather data from Switzerland, namely solar irradiance, ambient temperature, and wind speed, from 24 days distributed across a one year. These conditions are then reproduced in the laboratory and their effect on the efficiency and stability of multi-cation double-halide perovskite solar cells is investigated.

For the commercial viability of the technology, perovskite solar cells need to fulfil three requirements on long lifetime, high efficiency and low cost, otherwise they will be limited to niche markets. While indoor stability studies are more prevalent in the literature, outdoor tests have been considered to be of major importance to relatively more mature PV technologies such as organic and dye-sensitised solar cells. Outdoor testing provides an opportunity to understand materials and device degradation under field conditions. In some cases, outdoor tests corroborate failure modes observed in indoor testing and relate them to potential failures that occur in real world conditions [4]. However, other failure modes are reduced or increased in severity under such conditions and different failure modes are observed outdoors which are not observed indoors [5]. Furthermore, the case of organic and dye-sensitised solar cells has highlighted that standards issued by the International Electrotechnical Commission can overstress the devices leading to failure modes that do not necessarily occur in the field [6]. Therefore specific tests are needed to properly estimate the potential failure rates in emerging PV technologies, including perovskite.

Indeed, for perovskite solar cells, outdoor tests have raised awareness of issues such as reversible degradation, temperature dependence of solar cell performance and low light behaviour which were not taken into consideration in indoor testing [7-8]. In this respect, Tress and colleagues show that the highest performance is achieved in the morning and it decreases later on in the day as a consequence of reversible degradation, leading to a reduction in energy yield during these times (Figure 1a). This phenomenon is not observed when the device is measured continuously at STC but it is of critical importance to the deployment of PV technology. In fact, the energy demand from the grid is typically highest in the early evening [9] indicating that future studies need to address reversible to minimise this disruption. The researchers have also examined the temperature coefficient of their solar cells. While previous reports in perovskite solar cells have shown that this coefficient can be positive or negative depending on the chemical composition of the perovskite absorber layer [8], the researchers have found that the device efficiency does not increase or decrease monotonically with temperature for their multi-cation double-halide perovskite solar cells, illustrating a lack of clear trend for these record-efficiency and long-term stable devices (Figure 1b). Measuring low light behaviour is also important in order to predict energy yield from perovskite modules as this is a more common lighting condition than STC in many of the world's populous locations. For example, based upon weather station data from Bangor University in the UK from 2018, there were just 51.4 hours over the whole year where the solar irradiance was equal or greater than 1-sun and the mean irradiance during daylight hours was just 0.226-sun. Interestingly, Tress and colleagues report that the highest energy yields are actually obtained at low light conditions ($\sim 0.2 - sun, 20°C$), suggesting that perovskite solar cells are well-suited to northern climates or low-light indoor conditions.

For perovskite solar cells to be commercially successful, investors need to be to be able confidently forecast future energy yield. This cannot be accurately achieved with data only obtained at STC. Furthermore, as electricity infrastructure transforms towards smart grids, understanding variability in PV energy production will become a major component in the design and optimisation of energy exchange and storage at all temporal and spatial scales. Within this framework, the findings of Tress and colleagues on the different energy yield obtained under STC and real-life temperature and irradiance data are of crucial importance.

While the work of Tress and colleagues points towards the right direction, other factors come into play when discussing the commercial viability of perovskite solar cells. In particular, large scale devices should be considered in outdoor testing. At present, the vast majority of devices reported on are small sized laboratory scale devices with an active area of 0.2 cm^2 or less, including those reported by Tress and colleagues. One of the next steps that the community needs to address is how larger area and module sizing affect energy yield.

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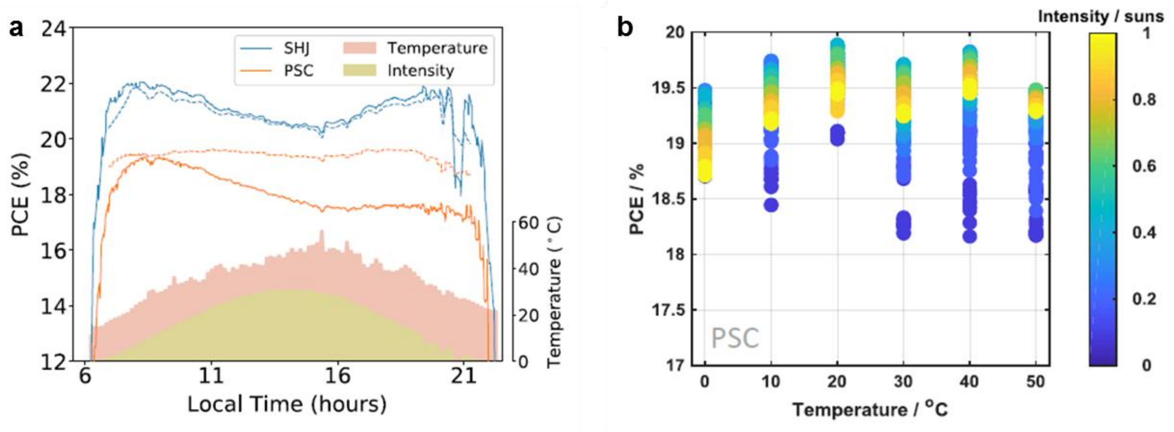

Figure 1. Perovskite solar cell performance under simulated weather conditions. (a) Diurnal performance of the perovskite solar cell under simulated temperature (pink shaded area) and illumination intensity (brown shaded area) real-world conditions (solid orange line) compared to predicted efficiency from STC characterisation (dashed orange line). Silicon solar cell performance is reported as reference (blue lines). (b) Power conversion efficiency

of the perovskite solar cell as a function of temperature and intensity of sun light showing lack of clear trend for the temperature coefficient.