Perovskites meet 2D materials: A novel materials platform for efficient energy harvesting and neuromorphics

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An aggressive technological deployment will soon affect the planet's energy landscape, demanding a swift transformation from the predominant use of fossil fuels to that of renewable energy installations. With its concurrent arrival, the Internet-of-Things (IoT) deployment promises to create a largely distributed global network of wireless sensors and wearables connected to the ''cloud'': Humankind is exploiting new technological platforms able to impact sustainable development and prosperity toward Industry 4.0 revolution. These platforms will create a robust demand of energy for their power supply, making a battery-free operation mandatory together with the need of a low manufacturing cost and reduced environmental impact. 2D-material enabled ''harvesters'' span across a wide range of scales. The demonstrated prototypes include self-powered miniaturized IoT devices, to large scale renewable energy infrastructures.[1]

The heterogeneity of peculiar ions and carriers observed in hybrid organic/inorganic materials is the source of their emergent cross-coupled light and electric field tuneable functions with potential utility in novel opto-electronic applications. Mixed halide perovskites (HPs) have been used as active layers in high performing perovskite solar cells (PSCs) that led to efficient solar energy harvesting. The power conversion efficiency (PCE) of PSCs has rapidly increased and is now approaching the state- of-the-art PCE of 26.1% obtained by crystalline-silicon PVs.[2] However, this impressive PCE obtained on small-area cells and in laboratory conditions should be also valid to large-area PV panels in real outdoor conditions. Through interface engineering, the incorporation of the 2D materials improves the charge dynamics of the interfaces and most importantly protects the perovskite layer against degradation.[3] Graphene Flagship partners demonstrated the validity of this technology through the entire value chain, from materials development, perovskite modules and panels fabrication and their integration in an autonomous solar farm (of $5m^2$ perovskite PV panels), to outdoor field tests, and assessment of the real energy production output.[4] The energy production of the solar farm was monitored for 12 months, demonstrating a remarkable 20% reduction (T_{80}) of the PV performance over 8 months of operation. The data analysis demonstrated that the perovskite panels enabled by 2D materials are promising for outdoor operation at elevated temperatures, such as in high-irradiance global locations.

Targeting beyond PV applications, HPs' rich dynamics enabled by inherently coupled ionic and electronic degrees of freedom have also led to the demonstration of optoelectronic memristors that emulate synaptic- and neural-like dynamics.[5] A single printable material stack fabricated with low manufacturing cost at low temperature, combining both efficient solar energy harvesting and memristive functionalities would constitute a transformational breakthrough. We have demonstrated that an inverted PSC with an average PCE of >17% with appropriate electric biasing procedure exhibits stable resistance switching characteristics at low voltages without losing its PCE performance even after thousands of switching cycles. Moreover, a high resistance state (HRS) to low resistance state (LRS) ratio of up to 10^5 and light-tunable switching cycles in the millisecond regime with an endurance of 3×10^3 cycles with no detectable HRS/LRS ratio drop.

References

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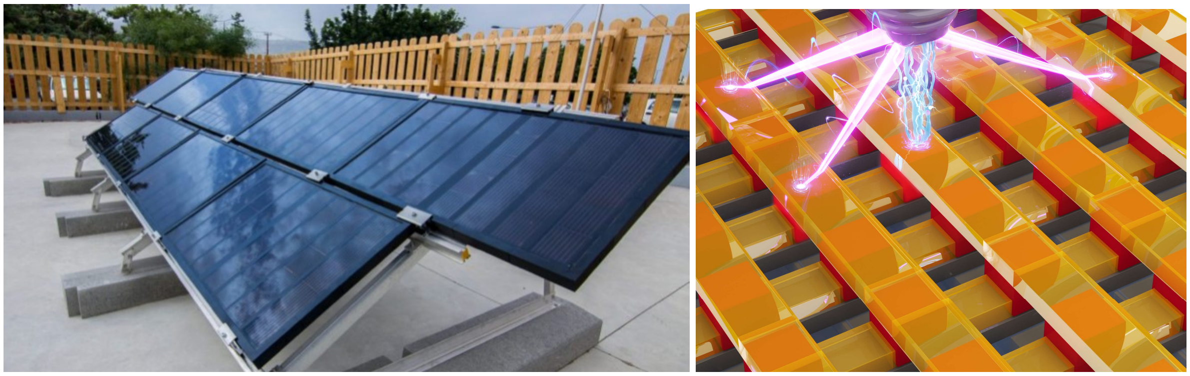

Figure 1: A) A photograph of the solar farm in HMU. B) Demonstration of a PSC operating simultaneously as an efficient, stable memristor and solar energy harvester.