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Synthesis of Titanium Oxide and Fabrication of High-Efficiency, Low-Cost Perovskite Solar Cells

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INTRODUCTION

Perovskite solar cells are solar cells that use a material with a crystalline structure called perovskite, are substances that contain organic ions, lead ions, and halide ions such as iodine and bromine in a crystalline structure. Perovskite is a general term for materials represented by the general formula ABX3, and is known as a unique group of materials with intriguing electrical and magnetic properties, including superconductivity. When A is a methylammonium ion (CH3NH3) +, B is a lead(II) ion (Pb2+), and X is a halide ion (I−), the resulting perovskite is methylammonium lead halide (CH3NH3)PbX (X = Cl, Br, I) . When formed into a thin film and exposed to light, it exhibits excellent photoresponsiveness, shown in the figure. [1][2]

Keywords: Perovskite solar cells, titanium oxide

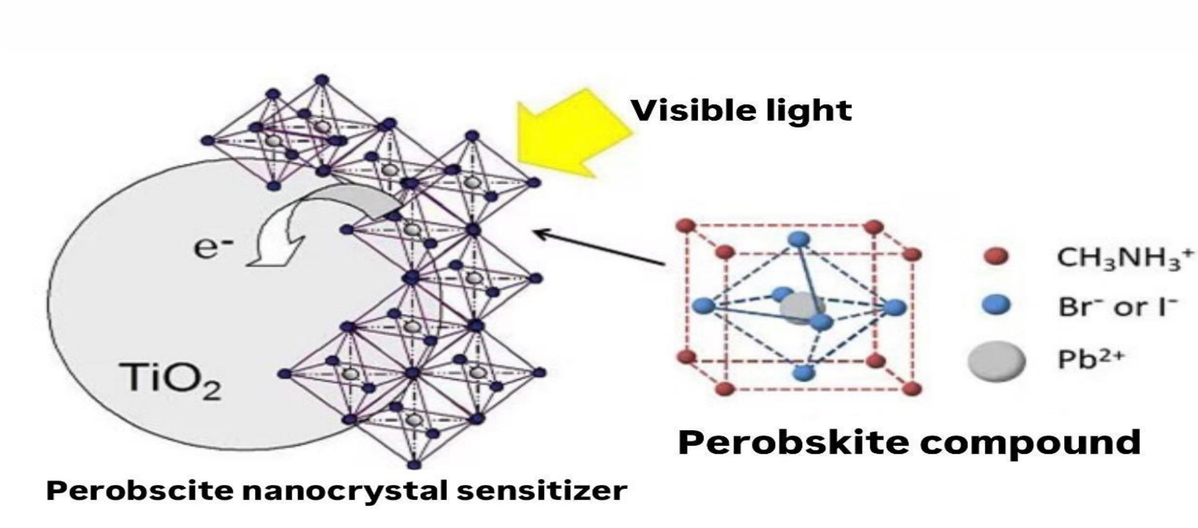

Fig 1. Perovskite solar cell, crystal structure of perovskite and molecular structure

DISCUSSION

When light strikes the perovskite layer, it absorbs the light, generating excited electrons and holes. The excited electrons are attracted to the electron transport layer (ETL) below, and the holes are attracted to the hole transport layer (HTL) above. The ETL is the negative electrode and the HTL is the positive electrode, creating a potential difference that enables light-based power generation. Generally, light is irradiated from the ETL side, so a transparent electrode called FTO is used on the negative electrode side, and gold or other materials are used on the positive electrode side.[3][4]

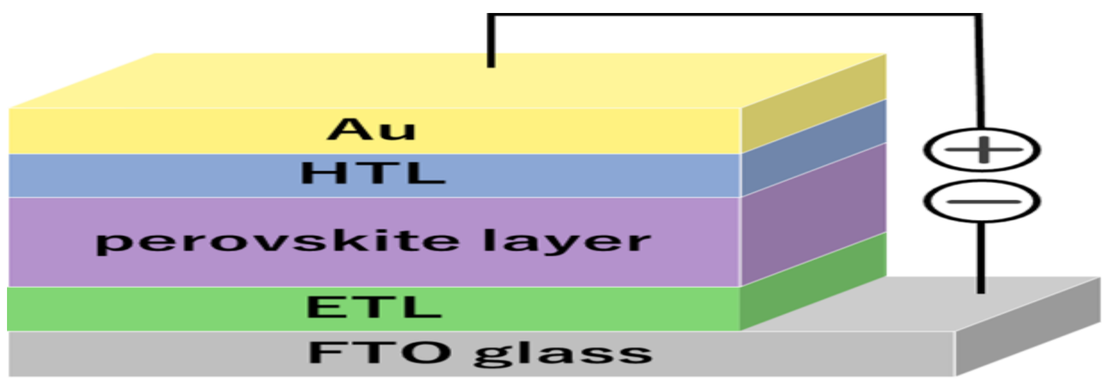

Figure 2: Structural diagram of a perovskite solar cell

The strength of perovskite solar cells is their ease of fabrication. They are fabricated using the spin coating method, in which a solution is applied to a substrate and the substrate is rotated to create a clean film. A titanium dioxide solution, which will become the electron transport layer, is spin coated onto a glass substrate with FTO, and then a perovskite layer is spin coated on top of that, and then a hole transport layer is spin coated on top of that. Gold electrodes cannot be fabricated by spin coating; gold must be evaporated in a vacuum and attached to the substrate. Another advantage of perovskite solar cells is that they are easy to fabricate, meaning the cost of the equipment required for manufacturing is low, making them inexpensive to produce.[5][6]

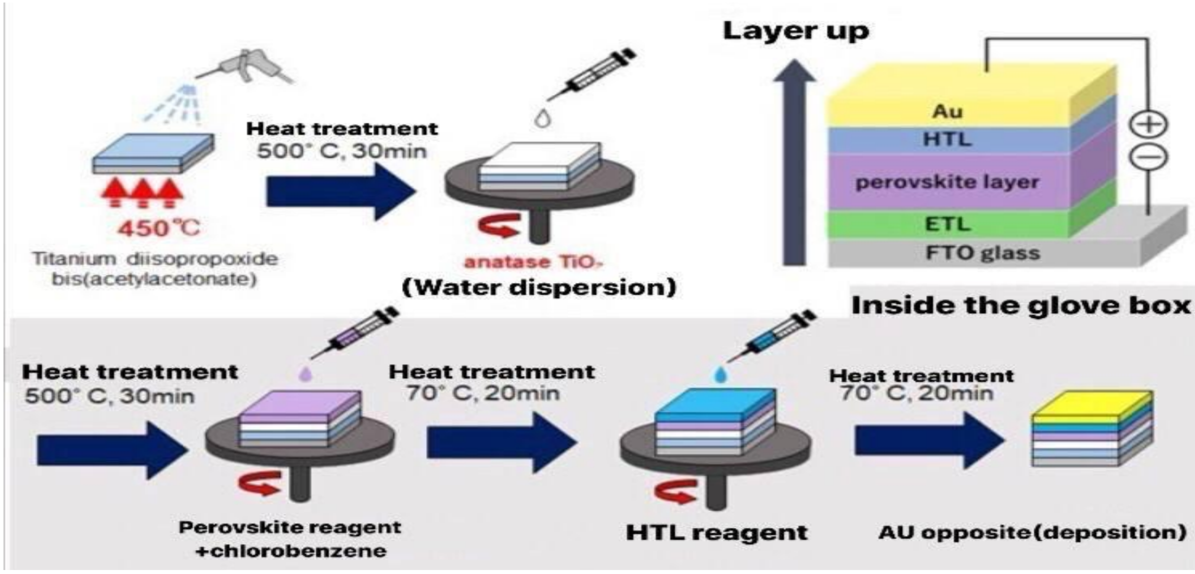

Figure 3: The fabrication process of a perovskite solar cell.

Titanium dioxide is often used in the electron transport layer. Titanium dioxide has a variety of crystal structures (Figure 4) divided into three phases: Brooktile, which has a high surface area; Rutile, which has a more thermodynamically stable tetragonal phase; and Anatase, which has a stable tetragonal phase. Anatase is considered one of the best phases of titanium dioxide due to its high stability, surface area, and crystallinity. Titanium dioxide has a one-dimensional, single-crystal structure that is often chosen as a photoanode due to the potential for dye binding to improve its photovoltaic performance. By applying these techniques to perovskite solar cells, we aim to improve power generation efficiency.[7][8][9][10].

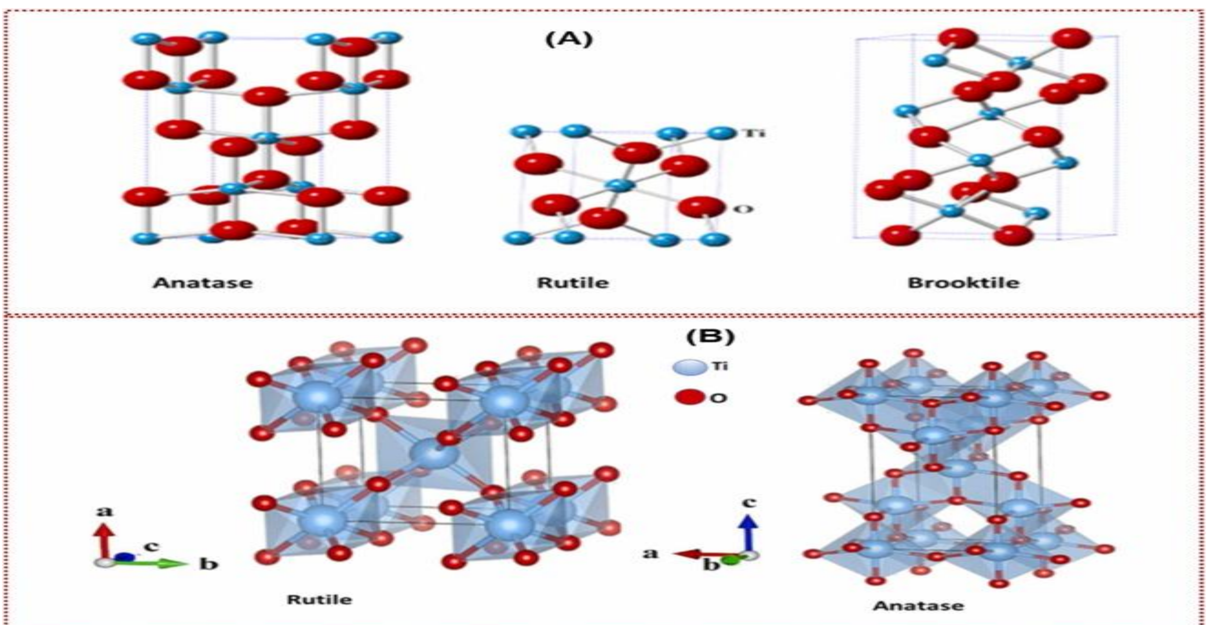

Fig. 4. (a) and (b) Crystal structure of anatase, rutile and brooktile [8] [9]

RESULTS

When an electron transport layer was created using anatase and brookite titanium dioxide, the energy conversion efficiency was 13.86% for anatase alone, 14.92% for brookite alone, 16.82% when brookite was formed on anatase, and 13.45% when anatase was formed on brookite. It became clear that the materials and their combinations in the electron transport layer contribute to power generation performance.

Through this study, the efficiency of solar cells can be improved by up to 16.82% when placing a layer of brookite over anatase. These results represent a major gateway to the development of perovskite solar cells, by controlled stacking and arrangement in different metallic forms of titanium oxides.[11]

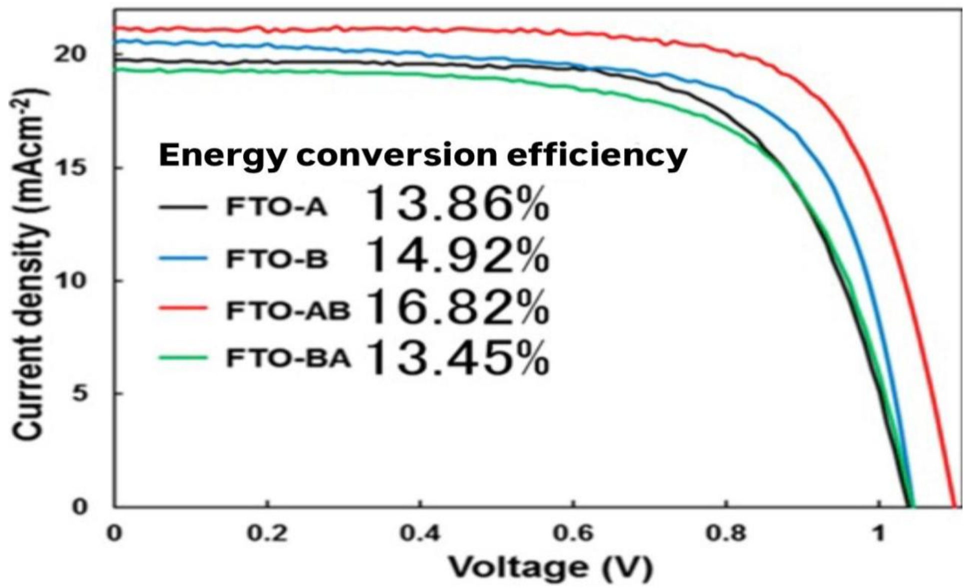

Fig 5. Current-voltage characteristics of perovskite solar cells

This is an electron microscope image of a cross section of a perovskite solar cell fabricated on an FTO glass substrate. A titanium dioxide electron transport layer, a perovskite layer, a hole transport layer, and gold are deposited on top of the FTO. The thickness from the titanium dioxide to the gold electrode is less than 1 μm, and fabricating it on a resin substrate such as ITO-PEN makes it possible to bend it.[12][13]

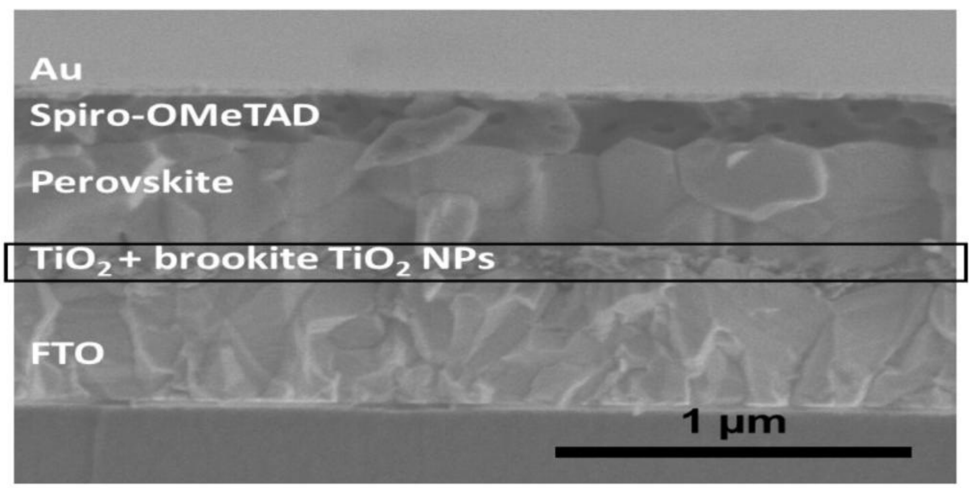

Fig 6. This is an electron microscope image of a cross section of a perovskite solar cell fabricated on an FTO glass substrate.[13]

By using a resin substrate (ITO-PEN) instead of a glass substrate, it is possible to create flexible solar cells as shown in the photo. However, when fabricating on resin, some ingenuity is required to keep the temperature below the heat resistance temperature of the resin, and power generation efficiency is slightly lower than with glass

An international research group has demonstrated a method for manufacturing polycarbonate-based perovskite solar cells compatible with industrial production processes for flexible photovoltaic devices. A polycarbonate-based perovskite solar cell with a power conversion efficiency of 13% was developed by developing a solvent-resistant layer

Tests indicated that 87% of the efficiency was maintained after 1,000 bending cycles with a 20 mm radius. Dark storage (ISOS-D-1) and thermal stability (ISOS-T-1) tests reached 1,886 hours and 144 hours, respectively

The perovskite solar cell was fabricated as follows: a substrate made of polycarbonate (PC) and indium tin oxide (ITO), an electron transport layer of tin oxide (SnO2), a perovskite layer, a hole transport layer, and gold (Au), which forms the cell's anode. The ITO layer was further optimized by controlling the transmittance, sheet resistance, and surface roughness, and all layers, except the two electrodes, were solution-processed at low temperatures below 100°C. The figure below shows a schematic of a solar cell structure based on a polyatomic carbon substrate coated with indium tin oxide. The other figure shows four perovskite solar cells fabricated on a polyatomic carbon film[14]

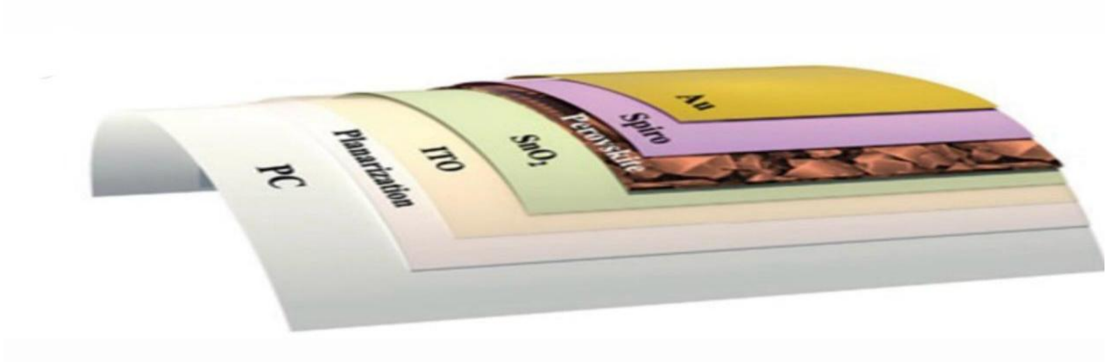

Fig 7: a schematic of a solar cell structure based on a polyatomic carbon substrate coated with indium tin oxide

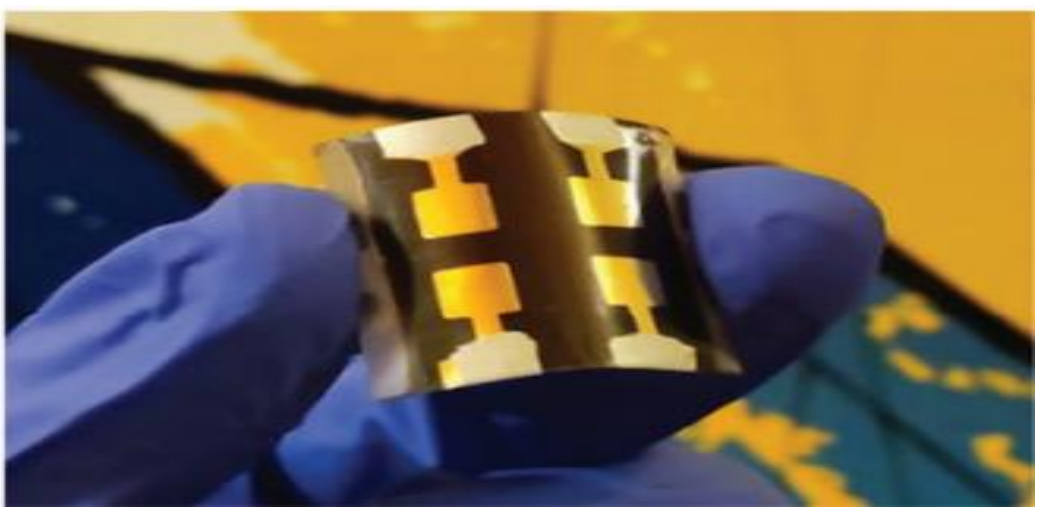

Fig 8: shows four perovskite solar cells fabricated on a polyatomic carbon film

CONCLUSION

Perovskite solar cells are attracting interest as the next generation of solar cells. These cells offer advantages over conventional silicon solar cells, such as lower manufacturing costs, light weight, and flexibility, making them suitable for installation in a variety of locations. The technology is currently being developed to address issues such as improved durability and increased surface area, with the goal of full practical implementation beginning in 2025. Specialized companies have also begun demonstration trials, and the technological innovation is expected to contribute to achieving a sustainable, economical energy society while reducing environmental impact[15]

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