Process for the Preparation of Halide Perovskite Andperovskite-Related Materials (Yeda)
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Summary

Perovskites are a class of crystalline materials that have in general a chemical formula of ABX3. Lead-halide hybrid organic-inorganic perovskites have recently emerged as highly efficient optoelectronic materials. Such materials are being intensively investigated and developed for photovoltaics (PV), photo detection, light-emitting diodes and laser devices. The most attractive parameters of these materials are their low energetic and monetary cost, coupled with their composition of only earth-abundant elements. Lead-halide hybrid organic-inorganic perovskites are highly promising candidates for incorporation into solar cells, with certified efficiencies of PV devices comparable to those of silicon. Silicon-based solar cell absorbs only part of the solar spectra, defined by the material band gap, the rest is reflected or wasted due to heat loss. To overcome this limitation, several PV materials can be used, each tuned to a specific part of the solar spectrum. While such cells exist and can be highly efficient, they require expensive manufacturing techniques that limit their applications. Perovskites are cheap to fabricate, and their band gap can be adjusted by combination of different cations and anions at the crystal lattice, to soak up sunlight in the ultraviolet and visible parts of the spectrum, so they can be effectively combined with silicon PV that absorb in the infrared. Such perovskite-silicon tandem cells have been shown to generate a higher voltage than either single component. High voltages are especially important if one wants to use such cells for charging of batteries and solar fuel production. In addition the higher the voltage, the lower any current-related resistive losses in wires that connect the cells to the outside world. Here we present a method for the preparation of halide perovskites for optoelectronic devices and solar cells. Our method is advantageous in terms of simplicity, reduced toxicity and a highly controlled morphology of the resulting materials.

Applications

Applications Solar cells Other optoelectronic devices (e.g., photodetectors, light-emitting diodes, lasers).Development StatusA range of halide perovskites were fabricated in the laboratory, either by electrochemical assistance or by spontaneous reaction in the solution, using a variety of precursors. Different fabrication conditions were tested and the resulting materials were characterized in terms of morphology and efficiency of solar cells comprising these perovskites. (Partially published in https://doi.org/10.1021/acs.chemmater.7b02314).Market OpportunityIn general, PV technologies can be viewed as divided into two main categories: wafer-based PV (also called 1st generation PVs) and thin-film cell PVs. PV is a fast growing market: Commercial and industrial solar PV capacity is forecast to expand from 150 GW in 2018 to 377 GW in 2024 (IEA, "Renewables 2019," IEA, Paris, 2019). Si-wafer based PV technology accounted for more than 90% of the total production in 2018 (Annual report, Fraunhofer-ISE, 2018). Since the first perovskite photovoltaic device was reported with only 4% efficiency, perovskite solar cells have shown potential both in the rapid efficiency improvement with lab record of 26.7% and in cheap material and manufacturing costs. According to a recent report, more than a dozen firms are involved in commercializing perovskite solar cells (The reality behind solar power's next star material, Nature, 2019).

Advantages

Simple and straight-forward fabrication method Easily scalable method Excellent morphology control of the perovskites.

Technology's Essence

Halide perovskites are promising materials for a new generation of potentially printable and efficient devices due to their excellent electronic and optical properties. Nevertheless, their manufacturing methods suffer from several significant drawbacks: Spin-coating is the most common method for perovskite deposition since it requires a relatively simple equipment and low temperature. Major drawbacks of spin-coating is the toxicity of the solvents in use and inability to scale up to high volume manufacture. Vacuum evaporation may include multiple sources with a high level of control over the evaporation rate of each precursor. This method is less popular, mainly due to its increased level of complexity and higher energy input, compared to spin-coating. Spray coating usually includes a single source with high level of control over the spraying rate and substrate temperature. Often the sprayed liquid is very toxic, as in the case of perovskites, and the system requires isolation from the environment. To date, a simple, cost-effective and non-toxic method for the fabrication of perovskite-based devices has yet to be developed.The SolutionA simple, scalable method for the fabrication of halide perovskite optoelectronic devices.Technology EssencePerovskites are crystalline materials with the formula ABX_3, in which A and B are cations and X represents an anion. Most common type of perovskites for light harvesting layer are hybrid organic-inorganic perovskites (HOIPs), A is an organic cation, B is a metal cation, and X is a halide anion. The most studied material is methylammonium lead iodide ($MAPbI_3$) since it has a direct bandgap (~1.6 eV) close to that needed for an optimal single junction solar cell. HOIP synthesis usually involves the use of toxic metal salts (for example, lead iodide or lead acetate) and organic solvents (such as dimethylformamide). Furthermore, the combination of both: metal salt with several organic solvents, such as dimethyl sulfoxide, increases the toxicity of the solution in use. The new fabrication method utilizes a metal or a metal alloy and an organic halide salt. In the first step, a layer comprising one of the components is deposited on a substrate. Then, the deposited layer is treated with a solution or a vapor of the second component to form a halide HOIP on a solid surface.The main advantage of the presented method is the reduced toxicity of the solution used in the process. Additionally, in solid metal form Pb (and Sn) are much less toxic than the salts of the same metals. Further advantages are the preparation simplicity and good morphological control of the resulting perovskites. This method involves a direct conversion of an elemental metal or a metal alloy to a halide perovskite or a perovskite related material. HOIP can be deposited on a large variety of solid substrates, including transparent oxides: a material type compatible for fabrication of tandem perovskite-silicon solar cells.

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