

## PEROVSKITE SOLAR CELLS

### Abstract:

The pursuit of renewable energy sources has intensified in response to global environmental concerns and the need for sustainable energy solutions. Perovskite solar cells have emerged as a promising alternative to traditional silicon-based photovoltaics, offering high efficiency, cost-effectiveness, and scalability. This paper explores the structure, stability, and attempts to improve the performance of perovskite solar cells. The crystal structure of perovskites, characterized by the formula  $ABX_3$ , enables efficient sunlight conversion, with  $CH_3NH_3PbI_3$  being the most used material. However, perovskite films are susceptible to degradation from factors such as moisture, UV light, and thermal effects, posing challenges to their long-term stability. Research efforts have focused on enhancing stability by modifying perovskite stoichiometry, with promising results observed through the substitution of iodine ions with bromine ions. These modifications have led to improvements in crystal structure and optical properties, contributing to enhanced stability and performance of perovskite solar cells. Continued advancements in perovskite technology hold significant promise for meeting the growing demand for clean and sustainable energy in the future.

### Introduction:

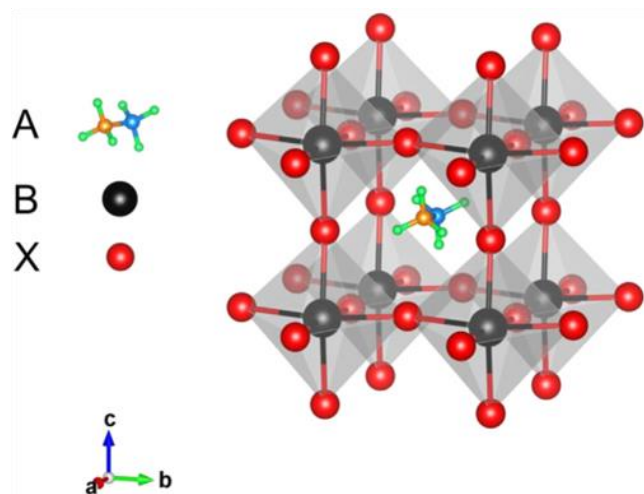
The growing demand for renewable energy has spurred research into advanced photovoltaic technologies, with perovskite solar cells emerging as a leading contender. These cells offer high efficiency, cost-effectiveness, and scalability, presenting a compelling alternative to traditional silicon-based photovoltaics. While silicon solar cells have been dominant, their energy-intensive fabrication processes and limited applications have prompted the search for alternative technologies.

Perovskite solar cells, with their exceptional light-absorption properties and facile fabrication methods, promise to revolutionize the renewable energy landscape. Their unique crystal structure allows for efficient sunlight conversion, while solution-based processing enables versatile applications, including flexible and transparent devices. As the world strives for a sustainable energy future, perovskite solar cells hold immense promise for meeting the growing demand for clean energy.

### Structure of perovskite:

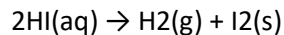
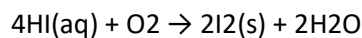
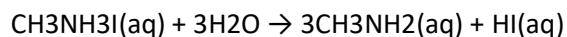
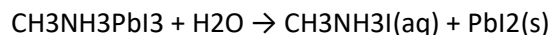
The term “perovskites” is used to describe a group of compounds characterized by the general formula  $ABX_3$ , which have the crystalline structure of calcium titanium oxide ( $CaTiO_3$ ). **Fig. 1** displays a schematic figure of the generic  $ABX_3$  perovskite crystal structure for a hybrid organic–inorganic metal halide perovskite. The A position contains an organic cation, B is a metal cation, and X is a halide anion. This structure was discovered in the 19th century; however, it has recently been applied to the field of photovoltaics, with unprecedented success [1]. The most explored Organic metal halide perovskite,

hereafter called perovskite, applied in photovoltaics, is  $\text{CH}_3\text{NH}_3\text{PbI}_3$ . This consists of a large organic cation, methylammonium  $\text{CH}_3\text{NH}_3$ , lead (Pb) as the smaller cation and iodine as the halogen anion [2].



### Stability of Perovskite:

The degradation of perovskite films can be attributed to several key factors, including exposure to oxygen and moisture, UV light, solution processing, and thermal effects [3]. Through a comparison of XRD patterns before and after exposure to water, researchers have proposed a series of reactions catalyzed by moisture for the decomposition of the perovskite layer:



Multiple studies have suggested that water acts as the catalyst for the reversible degradation of the perovskite material. The process of  $\text{CH}_3\text{NH}_3\text{PbI}_3$  decomposition has been schematically illustrated by Frost et al. [4]. This indicates that hydrogen iodide (HI) and methylammonium (MA) are soluble in water. The irreversible degradation of the perovskite layer poses a challenge for the lifetime of photovoltaic cells; however, the problem is compounded by the nature of the by-products [2]. One of the by-products of this reaction is  $\text{PbI}_2$ , which, itself, is soluble in water. The decomposition of  $\text{PbI}_2$  in installed modules could cause significant eco-toxicological problems in the field. Yang et al. [5]. investigated this degradation process by performing in situ absorbance and grazing incidence X-ray diffraction (GIXRD) measurements. The samples were kept in a carefully controlled measurement environment. The authors

fabricated an experimental apparatus, Yang et al. were able to control the relative humidity (RH) in which the films were measured, which allowed them to argue that this is a necessity to allow for valid comparison of degradation studies. The in-situ measurements provided a clear picture of the evolution of the CH<sub>3</sub>NH<sub>3</sub>PbI<sub>3</sub> film when exposed to various RHs.

As expected, higher RH values cause a more rapid reduction in film absorption. This reaction occurs extremely quickly for the 98% RH case, for which the absorption reduced to half of its original value in only 4 hours. However, for the low RH (20%), extrapolation of the degradation curve suggests this would take 10,000 hours. This experiment was repeated for varied carrier gases, N<sub>2</sub> or air, which led to no meaningful change in the degradation of the absorbance. This indicates that the main cause of degradation in the perovskite film, under normal atmosphere, is moisture [2].

### Attempts to Improve Stability:

The most common perovskite material is CH<sub>3</sub>NH<sub>3</sub>PbI<sub>3</sub>. Variations on this conventional structure may lead to improved environmental stability. Noh et al. [6]. tuned the stoichiometry of CH<sub>3</sub>NH<sub>3</sub>Pb(I<sub>1-x</sub>Br<sub>x</sub>)<sub>3</sub> perovskites by substituting I ions with Br ions. XRD patterns showed that varying the Br composition induced a transition in the crystal structure. For the standard material, CH<sub>3</sub>NH<sub>3</sub>PbI<sub>3</sub> (x=0), the perovskite forms a tetragonal crystal structure. However, increasing the Br content causes a shift in the crystallographic arrangement. At x=0.13, the phase begins to transition from tetragonal to cubic. Varying the Br content also alters the band gap. The authors empirically determined the following quadratic relationship to describe how the band gap varies:  $E_g(x) = 1.57 + 0.39x + 0.33x^2$ . Fig. 2(a) displays the influence of varied stoichiometry on the optical properties of the perovskite layer. A systematic transition in the color of the film was observed. For low Br fractions (x<0.2), the efficiency remained almost unchanged. However, the stability of devices incorporating Br was found to be significantly improved. Fig. 2(b) displays the efficiency decay curve for perovskite solar cells fabricated using four different perovskite stoichiometries. Initially, the devices were exposed to a RH of 35%. No drastic reduction in performance was recorded. On the fourth day, the cells were exposed to a RH of 55%, as indicated by the red stripe in Fig. 2(b). This increased RH value caused a significant degradation for the x=0 and x=0.06 case. However, for higher Br contents (x=0.2 and 0.29), the efficiency remained quite stable. In fact, no large degradation was observed within the 20 days measurement period. This improved stability for higher Br content was attributed to, i) a reduced lattice constant, and ii) a transition from tetragonal to cubic phase.

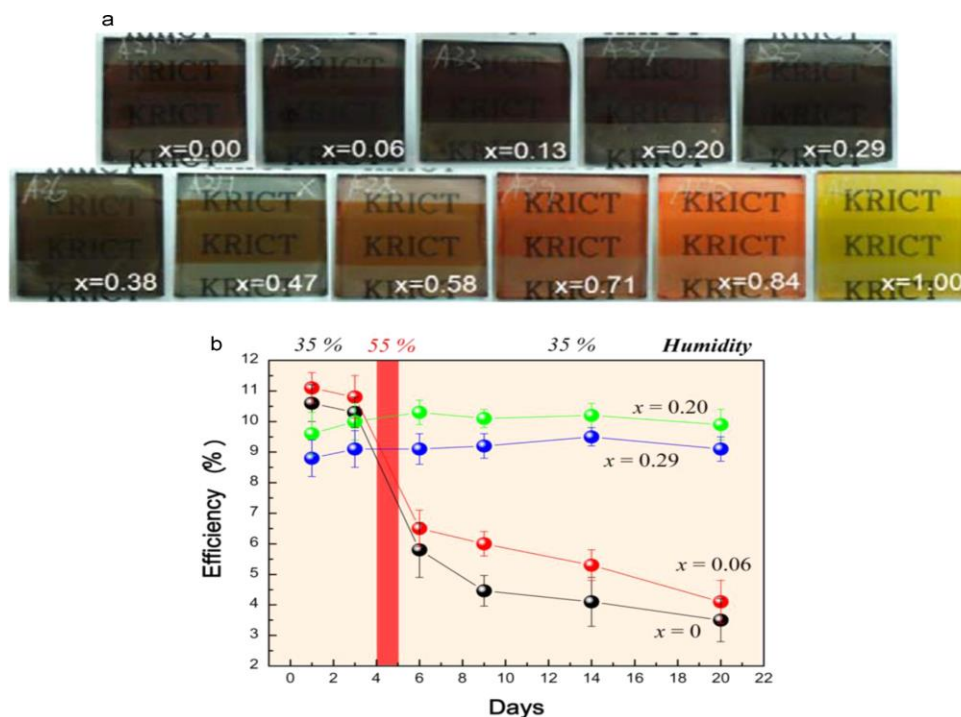


Fig 2. photographs of  $\text{TiO}_2/\text{CH}_3\text{NH}_3\text{Pb}(\text{I}_{1-x}\text{Br}_x)_3$  bilayer structures on FTO glass. These images clearly demonstrate how the optical response changes as the stoichiometry of the material is varied. Additionally, the efficiency decay curve for  $\text{CH}_3\text{NH}_3\text{Pb}(\text{I}_{1-x}\text{Br}_x)_3$  solar cells with different amounts of bromine is depicted. The red line indicates when the samples were exposed to increased relative humidity (55%) on the fourth day of testing [6]. For further details on the interpretation of colors in the figure legend, please refer to the web version of this article.

## References:

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