

Perovskite – New Material for Thin-Film Solar Cells

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Abstract – In the past five years methyl-ammonium lead trihalide perovskite solar cells have shown remarkable progress in power conversion efficiencies due to its unique properties. Single crystals of $\text{CH}_3\text{NH}_3\text{PbI}_3$ were grown on the base of condensation of concentrated aqueous solution of the precursor. It was established on the basis of examine of UV-vis absorption spectrum, that the band gap of the $\text{CH}_3\text{NH}_3\text{PbI}_3$ is 1.52 eV. Photoluminescence (PL) spectrum was obtained for $\text{CH}_3\text{NH}_3\text{PbI}_3$ single crystal at room temperature. Measurements were performed on reflection geometry under the excitation at 405 nm.

Index Terms – Solar cell, perovskite, crystal growth.

I. INTRODUCTION

GLOBAL ENERGY demand has been increasing with industrial development and population growth. To date over 80% energy consumption is generated from fuels, which causes the environmental pollution and global climate change. In the future, the renewable energy including Photo Voltaic (PV) will become a major energy resource at about 2050. The first solar cells (SCs) were fabricated from silicon p-n junction and now silicon SCs are leading at commercial PV market. Due to indirect gap of silicon the active layer must be thick (~200 μm) to efficiently absorb sunlight. The charge generation and transport in Si are sensitive to defects, so high purity solar-grade silicon is required. This makes SCs on silicon substrates expensive.

Thin-film solar cells based on CdTe, CuInGaSe and amorphous silicon usually use high temperature and vacuum vapor deposition processes. Also it contain rare (In, Ga) and toxic (Cd, Te, Se) elements. To be a competitive with fossil fuels, it is necessary for PV cells to reduce the total cost and developing the new materials, device structures, and processes. Researchers focus their attention on new technologies such as organic photovoltaic (OPV), dye-sensitized solar cells (DSSCs), and quantum dot solar cells, but all their efficiencies are low and device stabilities is not sufficient [1,2].

At the past five years, methyl-ammonium lead trihalide (perovskite - $\text{CH}_3\text{NH}_3\text{PbI}_3$) has generated significant interest in the photovoltaic application due to its unique properties, low cost and facile deposition techniques. Solution-processed perovskite solar cells have achieved high PCE (power conversion efficiency) values from 3.2% at 2009 [3] to 15% at 2013 [4]. At the end of 2014 optimized PCE amounted to 20.2% [5]. Such high PCE values is attributed to optimal optical band gap (1.5eV), high absorption coefficient, weakly bound excitons, that easily dissociate into free carriers, and extraordinarily electron-hole diffusion length [6]. Now $\text{CH}_3\text{NH}_3\text{PbI}_3$ has been suggested as a novel low-cost solution-processed material for high efficiency hybrid solar cells.

II. PROBLEM DEFINITION

The key parameters of semiconductor for solar cells application include optical band gap, absorption coefficient and carrier diffusion length. So the investigation of the fundamental properties of methyl - ammonium lead halide is actual goal. Most of the published articles have dealt with the solar cells with thickness around 300 nm. It was firmly established that size and crystallinity of perovskite grains are crucial in determining the efficiency of solar cells [7]. Large density of charge traps have been observed in the grain boundaries of polycrystalline perovskite films [8]. The elimination of the grain boundaries reduced charge traps and increased carrier diffusion length, thanks to the formation of columnar structure [9].

Control over structure, grain size, and degree of crystallinity remain key scientific challenges for the obtaining high PCE values. Single crystals of $\text{CH}_3\text{NH}_3\text{PbI}_3$ show remarkably low trap densities and high carrier diffusion length [10].

There are four methods synthesis $\text{CH}_3\text{NH}_3\text{PbI}_3$ single crystals [11, 12]. The first method is a top-seeded solution-growth (TSSG). The small temperature gradient between the bottom and the top of the solution induced sufficient convection to transport the material to the large crystals, which provides a stable supersaturate solution and temperature gradient during the whole crystal growth process and enables a homogeneous crystal growth. The second method is a growth from a supersaturated precursor solution by cooling down the hot solution from 65 to 40 °C. The third method is an antisolvent vapor-assisted crystallization method. Single $\text{CH}_3\text{NH}_3\text{PbI}_3$ crystals grow out of the solution when the precursor solutions are mixed with the orthogonal solvent [11]. The fourth method is inverse temperature crystallization [12]. Crystals grown with the third method have the worst parameters. The fourth method needs a specific solvent – γ -butyrolactone which is not available for us. The choice of a suitable solvent medium has always been a defining factor for the quality of ensuing crystals.

We used the combination of the first and the second methods to grow single crystals of $\text{CH}_3\text{NH}_3\text{PbI}_3$. In this work, the growth of methyl-ammonium lead trihalide perovskite single crystals, structure and optical properties have been investigated.

III. EXPERIMENTAL RESULTS

Two precursors were prepared for synthesis of $\text{CH}_3\text{NH}_3\text{PbI}_3$: $\text{CH}_3\text{NH}_3\text{J}$ and $\text{Pb}(\text{CH}_3\text{COOH})_2 \cdot 3\text{H}_2\text{O}$. The synthesized $\text{CH}_3\text{NH}_3\text{J}$ (6 g, 0.3 M) and $\text{Pb}(\text{CH}_3\text{COOH})_2 \cdot 3\text{H}_2\text{O}$ (14 g, 0.3 M) were dissolved in 50 ml hydro iodic acid stabilized with 1.5% hypophosphorous acid. The obtained solution was kept to $T=90^\circ$ to evaporate HJ. The received powder was washed with acetone and then kept in darkness and dry atmosphere. Than $\text{CH}_3\text{NH}_3\text{PbI}_3$ powder was transferred to the bottom of 50 ml beaker with stabilized hydro iodic acid used as a solvent to produce a supersaturated solution. A little crystal of $\text{CH}_3\text{NH}_3\text{PbI}_3$ was put to the solution as a fuse. The bottom of the beaker was kept to $T=75^\circ\text{C}$ to maintain a relatively high temperature for the growth of single crys-