Optimization of the Morphological Structure of Spin-Coated $MAPbBr_3$ on p-GaAs Substrates for Perovskite/GaAs-based Photon Up-conversion Solar Cells

Kobe Univ. [1], INSA Lyon[2], ○Hambalee Mahamu[1], Matthias Bourzier[2], Shigeo Asahi[1], and Takashi Kita[1]

E-mail: 203t268t@cloud.kobe-u.jp

Schockley-Queisser limit is the well-known theoretical limitation of a single junction solar cell (SC) in terms of conversion efficiency. There are types of energy conversion loss in solar cells including thermalization and transmission loss which are able to be manipulated by bandgap engineering. In 2017, two-step photon up-conversion solar cells (TPU-SC) were proposed theoretically and experimentally. The SCs consist of a wide-bandgap semiconductor (WGS) and a narrow-bandgap semiconductor (NGS) i.e., Al0.3Ga0.7As and GaAs respectively, creating an interface where InAs quantum dots (QD) were inserted. The quantum states allow in-plane excitation, and therefore, below-bandgap photon absorption [1].

Lead halide perovskite semiconductors show high potential for conversion efficiency. Consequently, it is interesting to study the interface between III-V and perovskite semiconductors, and the contribution to photon up-conversion processes. We, therefore, proposed $MAPbBr_3$ / GaAs-based TPU-SCs. The structure consists of $MAPbBr_3$ and i-GaAs as a WGS and NGS respectively. The expected efficiency is 46.7% at 1 sun and 54.2% at 100 sun.

In order to optimize spin coating conditions contributing to the morphology of $MAPbBr_3$ layer, we attempted to achieve a fully covered $MAPbBr_3$ film on p-GaAs substrate under various conditions. The growth processes are based on the traditional approach [2]. The reactants for $MAPbBr_3$ solution were MABr and $PbBr_2$ in DMF with different MABr : $PbBr_2$ ratio and percentages by weight. We added two different cosolvents to add more experimental conditions, namely DMSO and HBr. The solution was spun on cleaned p-GaAs substrates using two-step spin coater. The first and second step conditions are the following: 1500 rpm / 20 s and 3000 rpm / 30 s respectively. Subsequently, 30 µL of toluene was dropped on the spinning substrated just 20 s before the spin coater stopped. There are also samples fabricated without anti-solvent. The samples were heated at different temperatures for 10 min. We observed that increasing in MABr ratio allows stronger emission intensity. Moreover, HBr cosolvent provides stronger emission intensity compared to DMSO. The comparison of photoluminescence (PL) spectra of the samples in which DMSO and HBr were included (without anti-solvent) with 1:1 molar ratio 40%wt, annealed at 80°C, is indicated in Fig.1. The asymmetric feature is caused by a deconvolution peak at ~560 nm associated to trap states contributed by Br vacancy defects at the surface [3]. A relatively small FWHM, in the case of HBr, is attributed to the homogeneity of the crystal size.

The coverage on p-GaAs substrates, on the other hand, was achieved under the following condition: 1:1 molar ratio 20%wt with DMSO as cosolvent and toluene as anti-solvent dropped during spin coating, annealed at 60°C. The 3-dimensional graphical result is indicated in Fig.2. The morphological structure of $MAPbBr_3$ is uniform despite some isle. The coverage of the film is sufficient to prevent undesired pinholes.

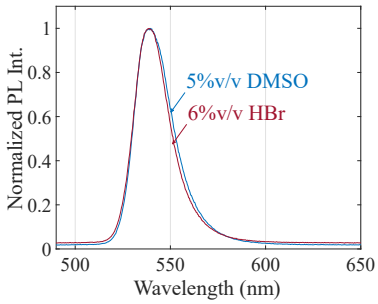

Fig.1. PL spectra of $MAPbBr_3$ film on p-GaAs without using toluene

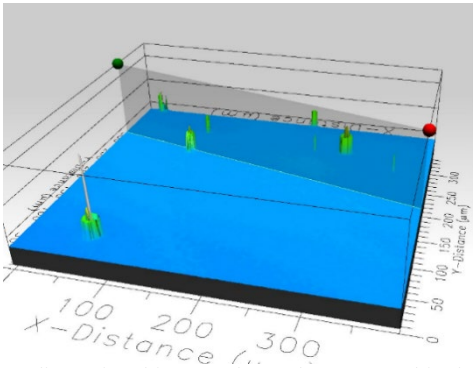

Fig.2. 3-dimensional image of $MAPbBr_3$ perovskite layer on p-GaAs substrates

[1] s. asahi, h. teranishi, k. kusaki, t. kaizu, and t. kita, nat. commun. 8, 14962 (2017).
[2] J. H. Heo, D. H. Song, and S. H. Im, Adv. Mat. 26, 8179 (2014).
[3] K. H. Wang, L. C. Li, M. Shellaiah, and K. W. Sun Sci. Rep. 7 (2017).