

Properties of Lead-Free Perovskite-Like $\text{MA}_3\text{Sb}_2\text{Br}_9$ Crystal Growth and Its Sensing Applications

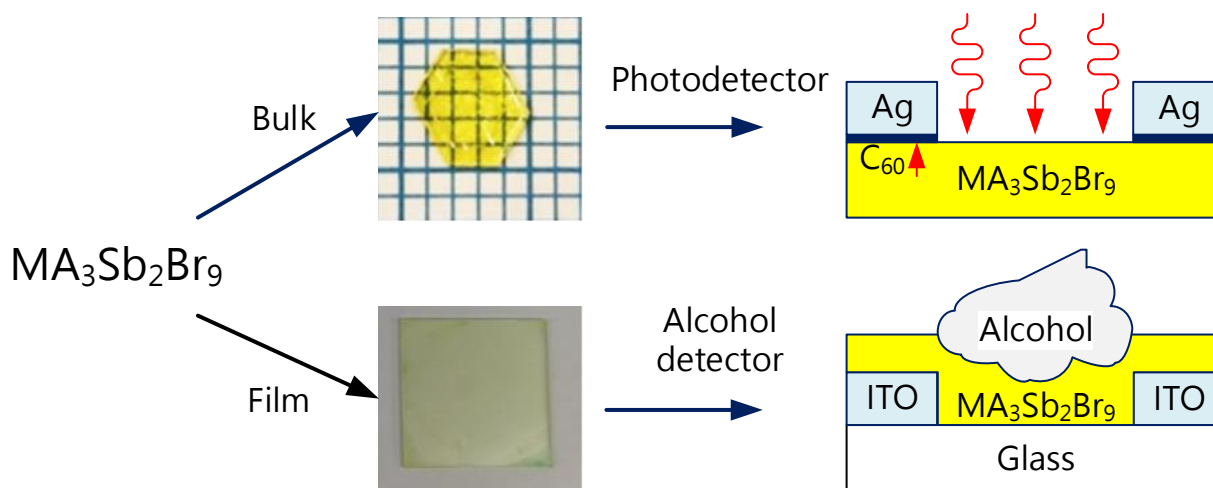
Chien-Min Hun, Lung-Chien Chen*

Department of Electro-Optical Engineering, National Taipei University of Technology, Taipei 10608, Taiwan

*Corresponding author: E-mail: ocean@mail.ntut.edu.tw

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Graphical Abstract



Two kinds of perovskite-like $\text{MA}_3\text{Sb}_2\text{Br}_9$ detectors were studied in this work. One is $\text{MA}_3\text{Sb}_2\text{Br}_9$ MSM-type visible photodetector prepared by inverse temperature crystallization method. The other one is $\text{MA}_3\text{Sb}_2\text{Br}_9$ transistor-type alcohol detector prepared by spin coating method.

Abstract

In this work, we studied a lead-free perovskite-like material $(\text{CH}_3\text{NH}_3)_3\text{Sb}_2\text{Br}_9$ ($\text{MA}_3\text{Sb}_2\text{Br}_9$) in bulk and film and applications for photodetector and alcohol detector, respectively. The $\text{MA}_3\text{Sb}_2\text{Br}_9$ bulk visible photodetector is prepared by inverse temperature crystallization method and the $\text{MA}_3\text{Sb}_2\text{Br}_9$ film alcohol detector is prepared by spin coating method. First of all, we have fabricated a photodetector based on $\text{MA}_3\text{Sb}_2\text{Br}_9$ perovskite-like single crystal, which as a perovskite-like photosensitive layers play an important role in the photoelectric properties of photodetectors. Here, $\text{MA}_3\text{Sb}_2\text{Br}_9$ single crystals were synthesized by inverse temperature crystallization process with precursor solution at three different growth temperatures at 60, 80, and 100 °C. According to photoluminescence (PL), it could be seen that the three kinds of $\text{MA}_3\text{Sb}_2\text{Br}_9$ single crystals with different growth temperatures have a very narrow PL emission peak at the wavelength of 523-527 nm, and FWHMs of 39.9, 42.4, 47.9 nm. The PL intensities of single crystals at the three growth temperatures were different. Among them, the $\text{MA}_3\text{Sb}_2\text{Br}_9$ single crystal grown at 60 °C has a highest

PL intensity, followed by 80 °C, and 100 °C was the lowest. MA₃Sb₂Br₉ single crystal with an optimum growth temperature of 60 °C present a low trap density of $2.63 \times 10^{11} \text{ cm}^{-3}$, high charge carrier mobility of $0.75 \text{ cm}^2 \text{ V}^{-1} \text{ s}^{-1}$, and excellent crystal structure and optical absorption properties. This MA₃Sb₂Br₉ perovskite-like photodetector exhibits low dark current of $8.09 \times 10^{-9} \text{ A}$, high responsivity of 0.113 A W^{-1} , and high detectivity of $4.32 \times 10^{11} \text{ Jones}$. On the other hand, recently, we also have fabricated an alcohol detector based on the MA₃Sb₂Br₉ film with transistor type. Here, MA₃Sb₂Br₉ films were spin-coated on the glass substrates with ITO pattern. X-ray diffraction (XRD) patterns, absorbance, and current voltage were employed to examine the characterizations of the MA₃Sb₂Br₉ films and devices. One diffraction peak at 29.9° corresponding to the cubic crystal (022) phase was observed. The position of absorption edge of MA₃Sb₂Br₉ film is around 500 nm. It is corresponding to the band gap of MA₃Sb₂Br₉ crystal. This MA₃Sb₂Br₉ perovskite-like alcohol detector exhibits high responsivity of 1.5 and 19.9 A W⁻¹ for 0.01% and 5 % alcohol, respectively.

Keywords: Perovskite-like; MA₃Sb₂Br₉; photodetector; alcohol detector.

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Biography of Presenting Author



Lung-Chien Chen received his Ph. D degree in the electrical engineering from the National Tsing Hua University, Hsinchu, Taiwan, in 1999. He has a professional career in industrial institution: Manager and Vice Assistance President in Formosa Epitaxy Photonic Incorporation (1999–2002). In 2002, he joined National Taipei University of Technology (Taipei Tech), Taiwan, as a faculty member of Department of Electro-Optical Engineering. Currently, he is a full Professor of Taipei Tech and his main research interests include compound semiconductor growth (GaSb, AlInGaP, III-nitrides, zinc oxide, and perovskites), material analysis, and device fabrication technology, light-emitting diodes (LEDs), photodetectors, and solar cells. He has authored or coauthored more than 160 journal papers and 5 books or book chapters. He is the holder of more than 21 patents in his fields of expertise. Prof. Chen is the Optica (former of Optical Society of American (OSA)) Senior member and the IEEE Senior member. He was elected as the fellow of Royal Society of Chemistry (RSC) in 2019. In 2021, Prof. Chen is on the Elsevier global top 2% of scientists list.

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