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The Influence of O_2 Plasma Treatment to NiO_x Layer for Perovskite Solar Cells

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Abstract

We fabricated perovskite solar cells (PSCs) with inverted p-i-n planar structure using NiO_x film as a hole-transporting layer. Since the surface of NiO_x film fabricated by sputtering is hydrophobic, O_2 plasma treatments on the surface in various conditions were performed for improving the wettability of NiO_x surface. Maximum efficiency of the NiO_x-based device in the optimized O_2 plasma condition reached 12.3%.

1. Introduction

In recent years, perovskite solar cells (PSCs) have been attracting interest concerning both fundamental research and practical application for low-cost and high-efficiency solar cells [1-3]. There are many reports of PSCs with inverted p-i-n planar structure due to the merit of low-temperature process and hysteresis-less property [4-6]. A NiO_x film is one of the typical hole-transporting layers (HTLs) for inverted-type PSCs. However, the surface of NiO_x film fabricated by sputtering is too hydrophobic to form uniform perovskite film by spin coating on the surface (without treatment in Fig. 2).

In this work, in order to improve the wettability of NiO_x surface, O_2 plasma treatments on the surface in various conditions were performed. We investigated physical properties of O_2 plasma-treated NiO_x films and the influence of the treatment to NiO_x films as HTLs for PSCs.

2. Experimental

As shown in Fig. 1, solar cell devices composed of an inverted planar type of ITO/NiO_x/Perovskite/PCBM/LiF/Al were fabricated. The NiO_x film was deposited by magnetron sputtering [7]. The NiO_x surface was hydrophilized with O_2 plasma treatment apparatus (HARRICK PLASMA PCD-32G). The perovskite layer was fabricated by an antisolvent method [8], which is a well-known process to form smooth film by dropping a poor solvent during spin coating of a mixed solution of methylamine hydroiodide (MAI) and lead (II) iodide (PbI_2). After that, the $PC_{60}BM$ layer was formed by spin coating of the chlorobenzene solution. Finally, the LiF interlayer and Al electrode were formed by vacuum evaporation.

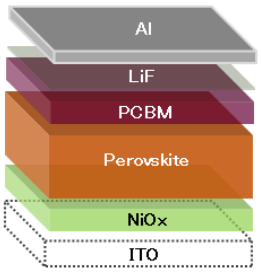


Fig. 1 Device structure of inverted planar type using NiO_x for the HTL.

3. Results and Discussion

As shown in Fig.2, wettability is greatly improved by O_2 plasma treatment. Contact angles of water on the NiO_x surfaces with the treatment under various conditions reached around 15 °. As a result, the treatment made it possible to form the perovskite layer on the NiO_x layer by spin coating.

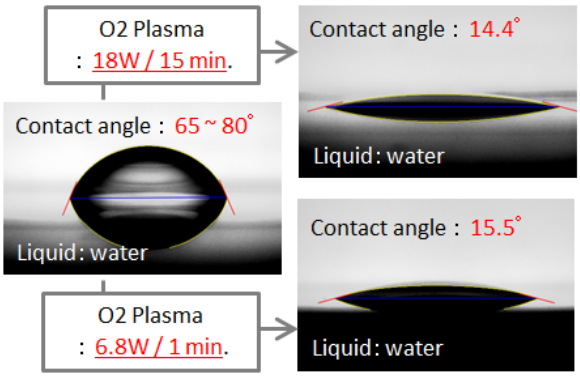


Fig. 2 Contact angles of water on the NiO_x surface without and with O_2 plasma treatment.

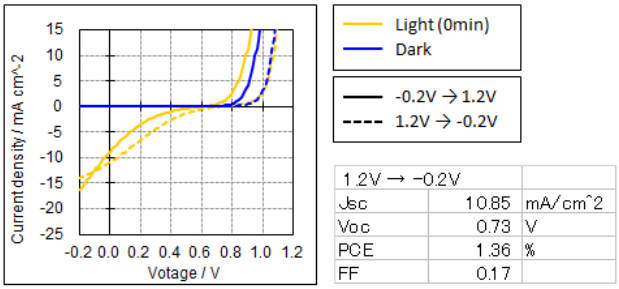
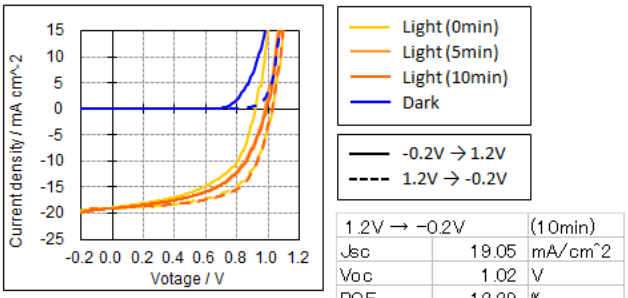


Fig. 3 *J-V* characteristics of the device with the O_2 plasma treatment on the NiO_x surface under normal condition (RF power: 18W / 15 min).

In the case of the O_2 plasma treatment under normal condition (RF power: 18W / 15 min), which is standard for ITO surface cleaning in our laboratory, the color of the NiO_x film slightly varied from transparence to blackish transparence and the contact angle was 14.4 °. *J-V* characteristics of the

device showed low *FF*, resulting in low PCE (Fig. 3).

In the case of the O_2 plasma treatment under weak condition (RF power: 6.8W / 1 min), there was no color change of the NiO_x film and the contact angle was 15.5 °. Fig. 4 shows *J-V* characteristics of the device. In particular, *FF* drastically improved by changing to the weaker O_2 plasma condition. The maximum PCE showed 12.3%.



1.2V → −0.2V		(10min)
Jsc	19.05	mA/cm^2
Voc	1.02	V
PCE	12.29	%
FF	0.63	

Fig. 4 *J-V* characteristics of the device with the O_2 plasma treatment on the NiO_x surface under weak condition (RF power: 6.8W / 1 min).

These results indicate that NiO_x films are sensitive for O_2 plasma treatment and the stronger treatment has a negative influence on electronic states of NiO_x as HTL for PSC.

For further investigation of physical properties of NiO_x films without and with the O_2 plasma treatment, we have performed and analyzed photoelectron yield spectroscopy, x-ray photoelectron spectroscopy and electrical conductivity measurements of the NiO_x films.

4. Conclusions

We investigated the influence of O_2 plasma treatment to NiO_x layer for PSCs. The treatment made it possible to form the perovskite layer on the NiO_x layer by spin coating. We found that NiO_x films are sensitive for O_2 plasma treatment and the stronger treatment has a negative influence on electronic states of NiO_x as HTL for PSC. Maximum PCE of the device in the optimized O_2 plasma condition reached 12.3%.

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