Molybdenum-doped bismuth vanadate photoanode for photocatalytic fuel cell

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Introduction

Photocatalytic fuel cell (PFC) is very attractive device for wastewater treatment with simultaneous electricity generation under sunlight. In such a system, electrons of the photoanode generated under illumination are transferred via the external circuit to the cathode to participate in reduction reactions and at the same time holes are released to be consumed in degradation of organic compounds [1]. $BiVO_4$ has been investigated as a promising photocatalyst due to its high photoactivity under visible light, moderate charge transport properties and relatively negative conduction band edge potential [2]. Metal-doping is widely used to enhance charge carrier generation and reduce recombination in $BiVO_4$ for catalyzing oxidation of organic compounds, inorganic species and water. Mo is a transition metal with half-filled orbital electronic configuration having six free electrons in its outer layer of electron structure, therefore Mo-doped $BiVO_4$ stands out for better n-type semiconductor and photoelectrochemical (PEC) properties. The aim of this work was to investigate how different amounts of doped-Mo (1%, 5% and 10%) influence the PEC performance of $BiVO_4$ coatings.

RESULTS

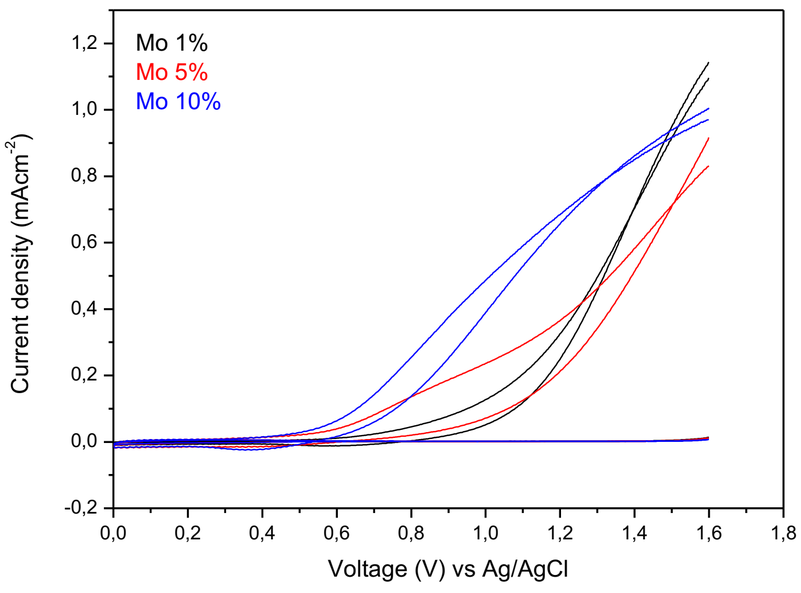

Fig. 1. Cyclic voltammograms (CV) of Mo-modified $BiVO_4$ samples in 0.5 M Na_2SO_4 solution in the dark and under illumination (potential scan rate 50 mVs^{-1}; intensity of illumination ~ 100 $mWcm^{-2}$).

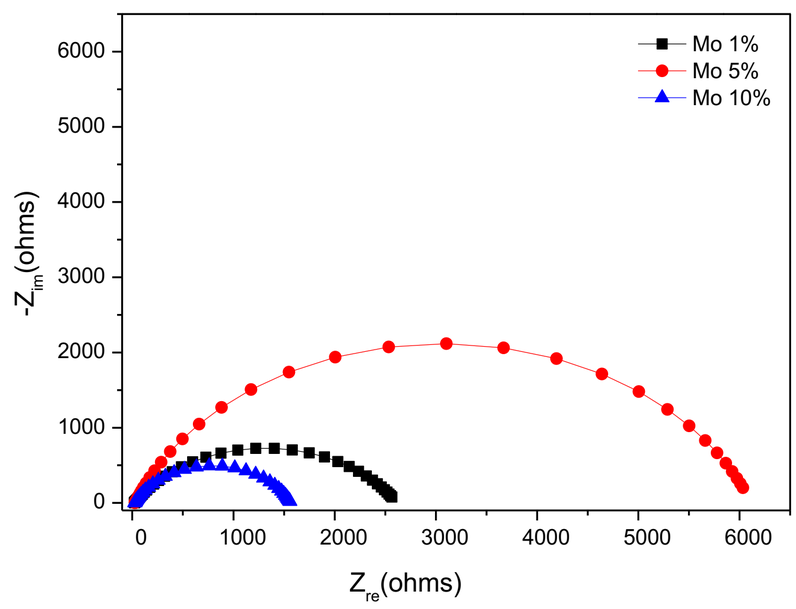

Fig. 2. Nyquist EIS plots of the differently doped Mo-$BiVO_4$ (1%, 5%, 10%) films in 0.5 M Na_2SO_4 solution.

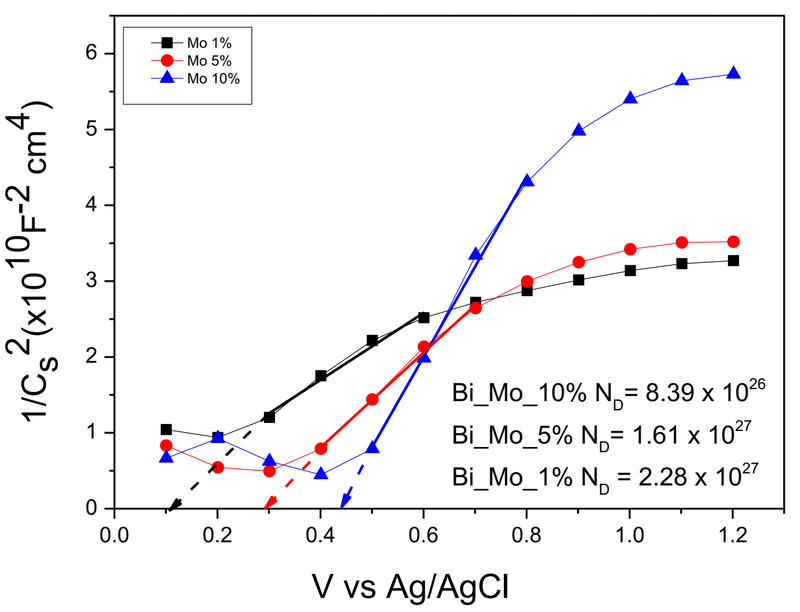

Fig. 3. Mott Schotkky plots of Mo-modified (1%, 5%, 10%) $BiVO_4$ films in 0.5 M Na_2SO_4 solution.

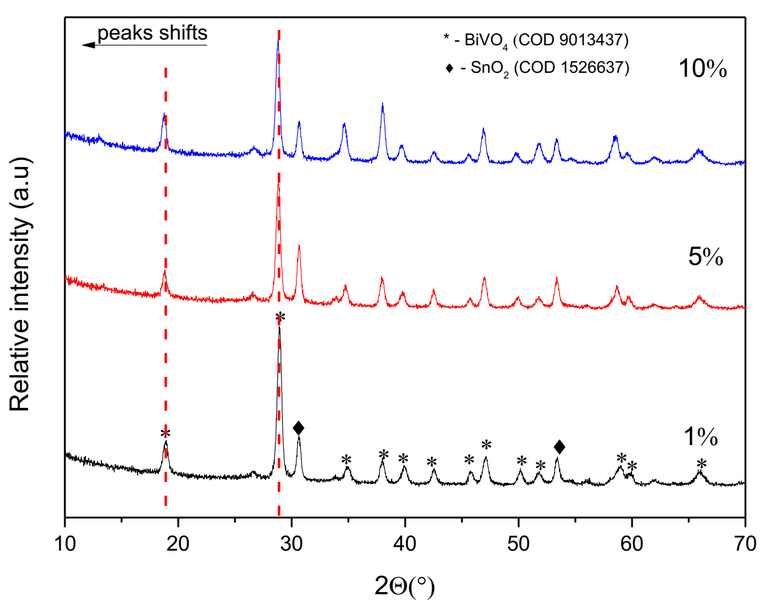

Fig. 4. XRD patterns of 1%, 5%, 10% Mo-$BiVO_4$ samples.

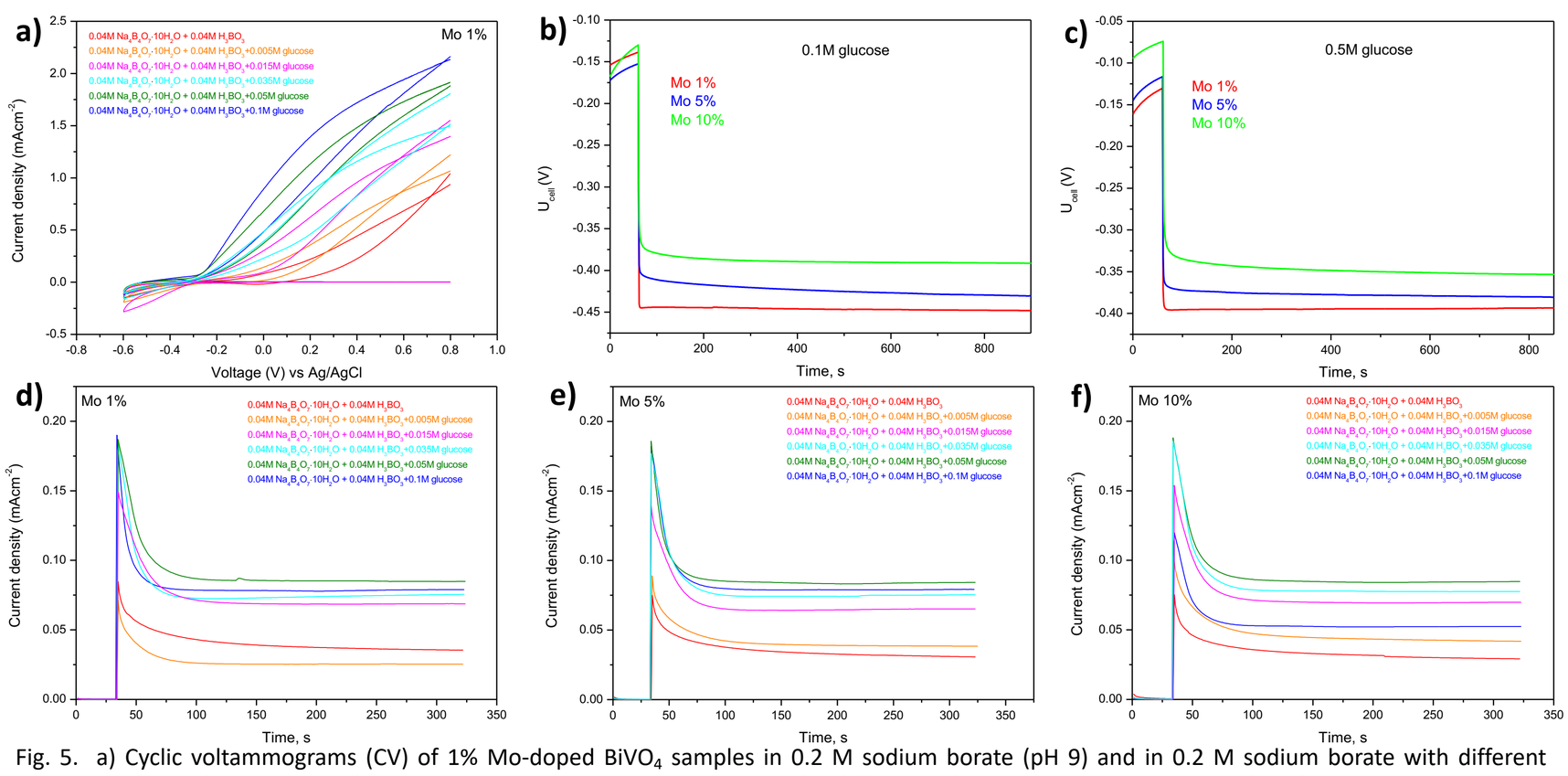

Fig. 5. a) Cyclic voltammograms (CV) of 1% Mo-doped $BiVO_4$ samples in 0.2 M sodium borate (pH 9) and in 0.2 M sodium borate with different concentration of glucose under illumination. Open circle potential (OCP) of the differently doped Mo-$BiVO_4$ in 0.2 M sodium borate containing b) 0.1 M, c) 0.5 M glucose. Chronoamperometry (CA) tests of d) 1% Mo-$BiVO_4$; e) 5% Mo-$BiVO_4$; f) 10% Mo-$BiVO_4$ in 0.2 M sodium borate (pH 9) and in 0.2 M sodium borate with different concentration of glucose under illumination.

Conclusions

- Mo-doped n-type $BiVO_4$ films were successfully synthesized on conducting glass substrate (FTO) using sol-gel synthesis technique.
- XRD showed that peaks shifts to the lower 2θ° values with increasing amount of Mo, implying expansion of the lattice due to doping effect of element with higher ionic radius (Fig. 4).
- Mo-doping had significant effect to photoelectrochemical properties of $BiVO_4$ coatings: the slope of photocurrent is steeper with increasing amount of Mo in the $BiVO_4$ structure due to more efficient generation and transport of charge carriers (Fig. 1).
- Electrochemical impedance spectroscopy showed that sample doped with 10% of Mo has the lowest charge transfer resistance (Fig. 2). Mott–Schottky analysis revealed increasing flat band potential with increase in Mo content in $BiVO_4$, whereas the density of charge carriers was estimated to be about 10^{27} cm^{-3} for all coatings (Fig. 3).
- Photocatalytic fuel cell experiments were performed using CV, CA and OCP measurements in solution containing different concentrations of glucose. It was found that glucose concentration strongly influences the photoresponse of the coatings. The highest photocurrent was obtained in the solution containing 0.05 M glucose (Fig.5 a, d, e, f).
- Results showed that obtained coatings can be successfully used for photocatalytic fuel cell under illumination at OCP.

References:

1. L. Xia, J. Bai, J. Li, Q. Zeng, X. Li, B. Zhou. Applied Catal B, Environ. 186 (2016) 224-230.
2. Y. He, R. Yuan, M.K.H. Leung. Mater. Lett. 236 (2019) 394–397.