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I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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STRUCTURAL AND OPTICAL CHARACTERIZATIONS OF METHYL AMMONIUM LEAD HALIDE PEROVSKITE EMBEDDED POLYMER FILMS

NURUL AIN BINTI MANSHOR

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ABSTRAK

Sel suria perovskite (PSCs) yang menggunakan methylammonium plumbum iodida ($MAPbI_3$) sedang dikaji secara intensif oleh komuniti penyelidik teknologi hijau. Hal ini kerana banyak kelebihan yang sel suria perovksite ditawarkan, seperti (i) kebolehan diproses dengan mudah dan kos yang lebih rendah, (ii) kemungkinan boleh dibina dalam pelbagai reka bentuk peranti, (iii) kecekapan di bawah keadaan cahaya rendah, dan (iv) kecekapan penukaran tenaga sel suria(~ 22%).Walaubagaimanapun, kestabilan sel suria perovskite sangat lemah dan hanya beberapa jam beroperasi di kawasan persekitaran normal, sel suria perovskite menunjukkan tanda-tanda histerisis dalam pencirian arus-voltan apabila dijalankan secara keadaan hadapan dan songsang pincang. Hipotesis dalam kajian ini menunjukkan kestabilan operasi yang lemah adalah kerana sifat ion methylammonium yang tidak stabil dalam kristal dan kestabilannya boleh menyebabkan PSC stabil. Polimer sintetik adalah sangat stabil di bawah keadaan atmosfera dan liputan polimer terhadap $MAPbI_3$ boleh menjadi satu kaedah yang berkesan untuk meningkatkan kestabilan sel suria perovskite. Dalam kajian ini,empat filem dihasilkan (i) $MAPbI_3$ tulen tanpa PVP, (ii) $MAPbI_3$ dalam 5 wt.% PVP, (iii) $MAPbI_3$ dalam 10 wt.% PVP, (iv) $MAPbI_3$ dalam 20 wt.% PVP. Kristal $MAPbI_3$ terlarut didalam DMF telah dicampurkan dengan polymer diatas dan membentuk filem di atas salutan 500 nm TiO_2 plat kaca dengan kaedah salutan putaran. Sifat-sifat struktur dan optik filem dikaji mengikut fungsi masa (sehingga 2000 h) di dalam keadaan cerah dan gelap menggunakan X-ray pembelauan (XRD), Fourier-mengubah spektroskopi inframerah (FTIR), Imbasan mikroskop elektron (SEM), Spektrofometer Ultra Lembayung-Nampak (UV-Vis), dan photoluminescence spektroskopi (PL). Kemerosotan kecil kestabilan sel suria perovskite yang disimpan di dalam persekitaran gelap dapat diperhatikan manakala kemerosotan drastik terhadap filem sel suria yang terdedah kepada cahaya disebabkan permukaan TiO_2/perovskite reaktif dan kecacatan permukaan TiO_2. Kestabilan filem sel suria perovskite yang diliputi PVP menyumbang kepada kestabilan struktur perovskite $MAPbI_3$ dan juga memberikan penambahbaikan permukaan TiO_2/perovskite. Arus suntikan boleh dihasilkaan melalui campuran polimer dengan $MAPbI_3$ dengan menghasilkan sel suria yang lengkap menggunakan gabungan ini dan memberikan ruang penyelidikan yang cerah pada masa depan untuk menghasilkan sel suria perovskite yang lebih stabil dan mempunyai kecekapan yang tinggi.

ABSTRACT

Perovskite solar cells (PSCs) made using methylammonium lead iodide ($MAPbI_3$) perovskite is currently under intensive investigation by the clean and sustainable energy research community. This is because many advantages they offer, such as (i) solution processability and hence lower cost, (ii) feasibility to be fabricated in diverse device designs, (iii) workability under low-light conditions, and (iv) high photovoltaic conversion efficiency (~22%). However, their operational stability is very poor, only few hours under normal operating conditions, and they show a hysteresis in their current – voltage characteristics when the measurements are done at forward and reverse bias conditions. It is hypothesized in this research that the poor operational stability is due to the volatile nature of the methylammonium ions in the crystals and stabilizing them could lead to stable PSCs. Synthetic polymers are very stable under atmospheric conditions and encapsulating the $MAPbI_3$ perovskites in a polymer could be an efficient method to improve their stability. Following this argument, this thesis describes synthesis and characterization of $MAPbI_3$ embedded polyvinylpyrrolidone (PVP) polymeric films. In this research work, four films were produced (i) pure $MAPbI_3$ with 0 wt.% PVP, (ii) $MAPbI_3$ in 5 wt.% PVP, (iii) $MAPbI_3$ in 10 wt.% PVP, (iv) $MAPbI_3$ in 20 wt.% PVP. 20 wt.% of PVP reported retained its optical and structural characteristics in dark for ~2000 h and ~800 h in room light which is noticeably higher than pure perovskite film which fully degraded in 600 h in dark and less than 100 h when exposed to light. The $MAPbI_3$ crystals dissolved in DMF were dispersed in the above amount of polymers and developed into films on 500 nm TiO_2 coated glass plates by spin coating. The structural and optical properties of the films as a function of time (up to 2000 h) under light and dark were studied by X-ray diffraction (XRD), Fourier-Transform Infrared spectroscopy (FTIR), Scanning Electron Microscopy (SEM), Ultra-Violet Visible (UV-Vis) absorption spectrometry, and Photoluminescence spectroscopy (PL). Minor degradation in perovskite films stored in humid dark environment were observed whereas upon exposure to light, the films undergo a drastic degradation, primarily owing to the reactive TiO_2/perovskite interface and also the surface defects of TiO_2. The superior stability of PVP incorporated perovskite films are attributed to improved structural stability of $MAPbI_3$ and also the improved TiO_2/perovskite interface upon incorporating a polymer matrix. A charge injection from the polymer embedded perovskite films has also been confirmed by fabricating solar cells using them; thereby providing a promising future research pathway on stable and efficient perovskite solar cells.

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