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Photocapacitor Integrating Solar Energy Conversion and Energy Storage

Authors : Jihuai Wu, Zeyu Song, Zhang Lan, Liuxue Sun

Abstract : Solar energy is clean, open, and infinite, but solar radiation on the earth is fluctuating, intermittent, and unstable. So, the sustainable utilization of solar energy requires a combination of high-efficient energy conversion and low-loss energy storage technologies. Hence, a photo capacitor integrated with photo-electrical conversion and electric-chemical storage functions in single device is a cost-effective, volume-effective and functional-effective optimal choice. However, owing to the multiple components, multi-dimensional structure and multiple functions in one device, especially the mismatch of the functional modules, the overall conversion and storage efficiency of the photocapacitors is less than 13%, which seriously limits the development of the integrated system of solar conversion and energy storage. To this end, two typical photocapacitors were studied. A three-terminal photocapacitor was integrated by using perovskite solar cell as solar conversion module and symmetrical supercapacitor as energy storage module. A function portfolio management concept was proposed the relationship among various efficiencies during photovoltaic conversion and energy storage process were clarified. By harmonizing the energy matching between conversion and storage modules and seeking the maximum power points coincide and the maximum efficiency points synchronize, the overall efficiency of the photocapacitor surpassed 18 %, and Joule efficiency was closed to 90%. A voltage adjustable hybrid supercapacitor (VAHSC) was designed as energy storage module, and two Si wafers in series as solar conversion module, a three-terminal photocapacitor was fabricated. The VAHSC effectively harmonizes the energy harvest and storage modules, resulting in the current, voltage, power, and energy match between both modules. The optimal photocapacitor achieved an overall efficiency of 15.49% and Joule efficiency of 86.01%, along with excellent charge/discharge cycle stability. In addition, the Joule efficiency (ηJoule) was defined as the energy ratio of discharge/charge of the devices for the first time.

Keywords : joule efficiency, perovskite solar cell, photocapacitor, silicon solar cell, supercapacitor
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