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BOOST FOR MAINTENANCE OF MINI-SOLAR MODULES QUALITY DUE TO ACID RAIN*

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Abstract

The impact of acid rain on the potential induced degradation (PID) and subsequent recovery of mini-solar modules was investigated over varying durations. The acid rain with a pH of 4 was prepared and immersed mini-solar modules (12.5 cm x 7.2 cm) in it for 2, 4, and 5 days. The initial degradation of the mini-solar modules was assessed through photocurrent measurements under different lighting conditions. Following this, we subjected the modules to a recovery process, annealing them for 30 minutes at 50°C, and reevaluated their performance through photocurrent measurements. Additionally, the surface characteristics of these modules were explored using electroluminescence images during different daytime settings. This entire procedure was repeated for double degradation and recovery. Our experimental findings suggest that a simple low-temperature method can effectively restore degraded mini-solar modules to their original state.

Keywords: potential induced degradation (PID), acid rain, solar modules, recovery

Introduction

High energy efficiency, a low rate of degradation, cost effectiveness, and a long lifespan of more than 30 years must be necessary for common solar cells. If the PV modules are not resisting degradation, the mechanism may result in losses of 20 % in less than a year [1]. PV modules have experienced degradation and failure in recent years, leading to PID and performance losses in a short amount of time[2-3]. It is remarkable for quality control in solar cells with regard to PID [4]. PID was generally described as a loss of power behavior that results from N-ion migration in solar modules [5-6]. In its most significant form, the shunting of solar modules in PID-affected regions caused an instantaneous reduction in solar modules [7]. A new and difficult credibility issue for solar modules has been identified as one of the degradation mechanisms, PID, which deteriorates the photovoltaic performance of crystalline Si-based solar cells over an extended period of time [8-10]. Actually, various factors such as high-temperature and high-humidity can cause the PID phenomenon to reduce the performance of PV modules and lead to their failure states [11-12]. This paper described the photocurrent and electroluminescence images of the acid rain-induced PID and recovery of mini-solar modules.

Preparation of acid rain

The artificial acid rain was prepared according to the ratio of sulfuric acid (H_2SO_4): nitric acid (HNO_3): hydrochloric acid (HCl) (5:1:1). The mixed solution was adjusted to pH-4 by pH meter. The mini-solar modules were kept in a glass jar filled with acid rain for 2 days (sample 1), 4 days (sample 2), and 5 days (sample 3) to be degraded. These degraded solar modules were recovered by annealing at a low temperature of 50 ^{0}C for 30 min. This above processes were done repeatedly for double degradation and double recovery. The artificial acid rain preparation was shown in Fig 1.

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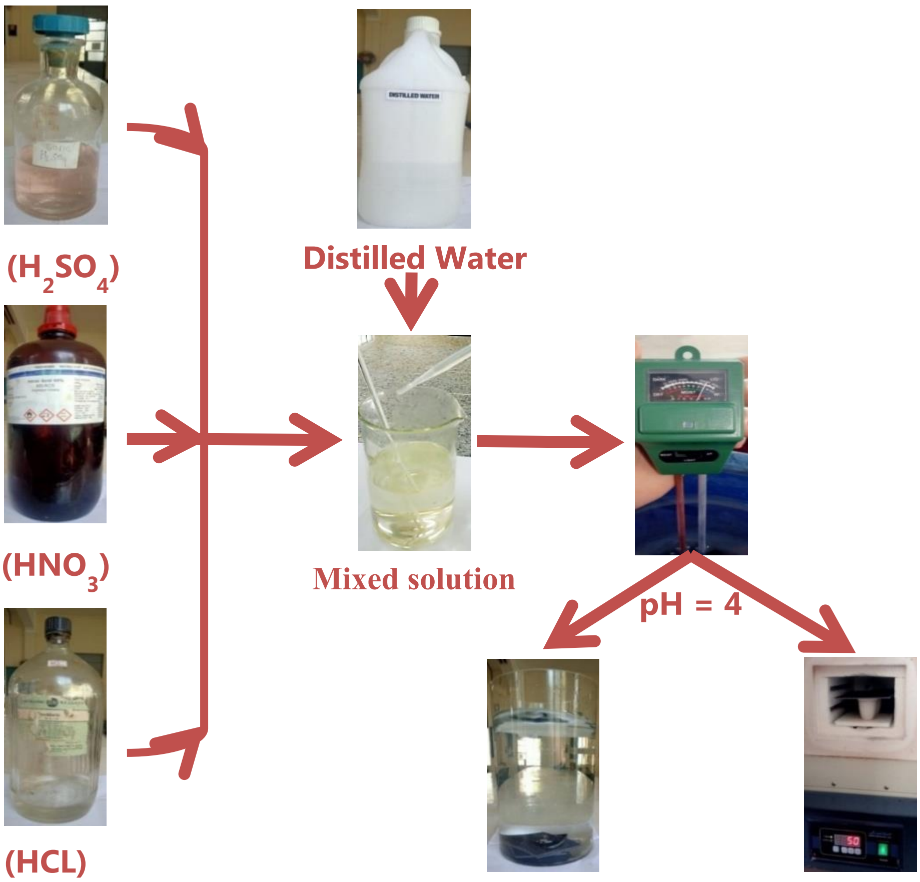
Photocurrent and EL Measurements

The change in photocurrent as a function of light intensity was observed for the mini-module after degradation as well as recovery. Fig 2 (a-f) gave the variation of photocurrent and light intensity for all mini-modules under degradation-recovery and double degradation-double recovery were compared to those of mini-module at the initial state. From the characteristic curve, it was found that the photocurrent slightly increased with an increase in light intensity for all mini-modules. After degradation, the acid rain-induced affected a module, and the current nominally reached the initial state after recovery.

A high-resolution Electroluminescence (EL) camera was used for the characterization of the mini-solar modules. The EL images for degradation and recovery were described at Fig 3. The EL images for double degradation and double recovery were shown at Fig 4. As a result, no surface feature was found for all samples. The EL pictures of degraded mini-modules were changed a little on the module surface and the recovery nature could not be clearly shown by EL camera.

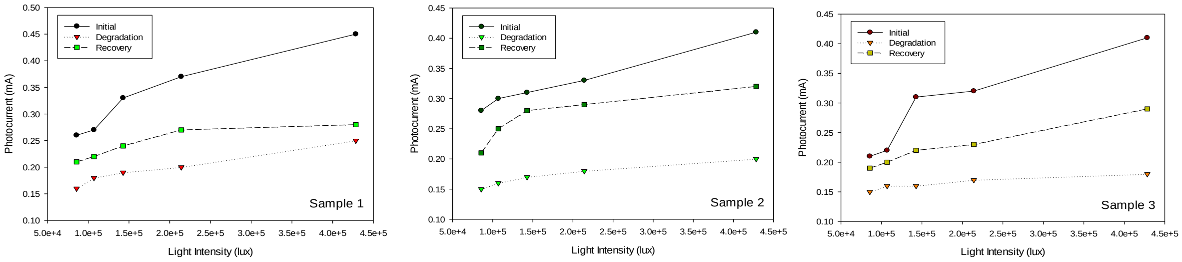


Keeping mini-solar modules in a glass jar filled with acid rain to be degraded

Recovery of degraded solar modules by annealing at low temperature (50^0C °) for 30 min

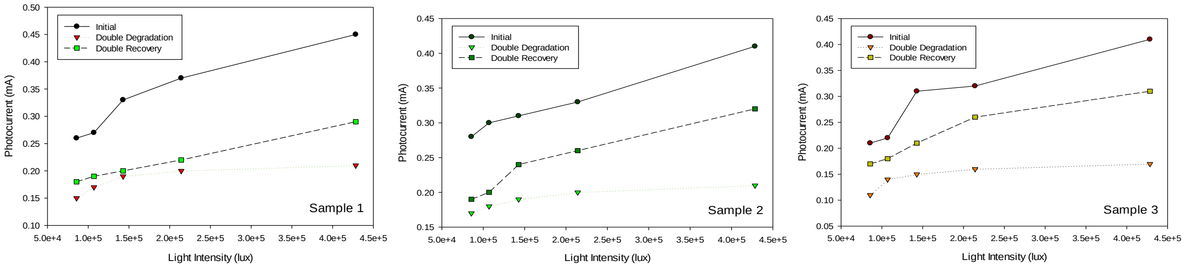
Figure 1 Acid rain preparation, Degradation, and Recovery

Degradation and Recovery



(a) (b) (c)

Double Degradation and Double Recovery



(d) (e) (f)

Figure 2 (a-f) Photo I-V characteristic curves corresponding to degradation-recovery and double degradation-double recovery of mini-solar modules

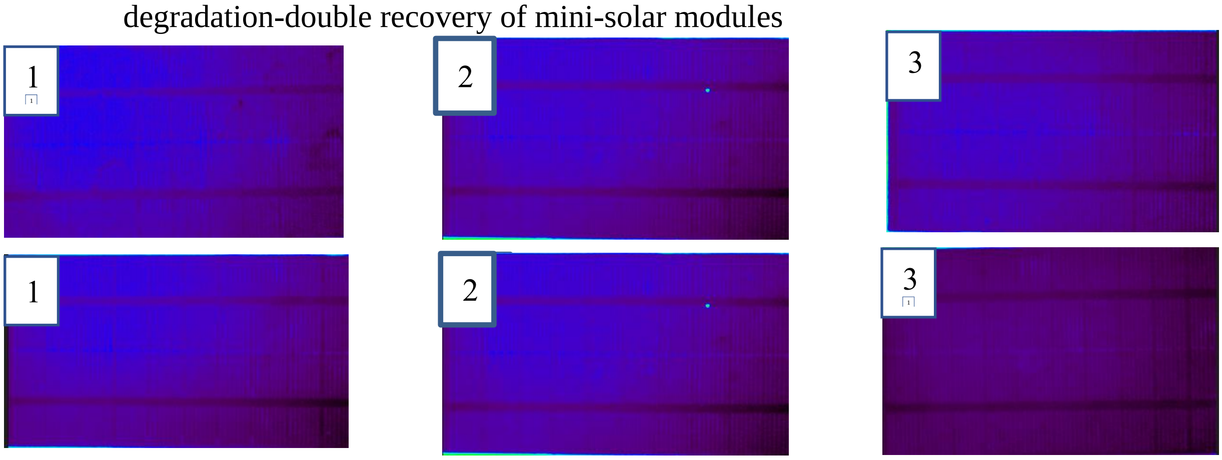


Figure 3 EL images before and after recovery of mini-solar modules

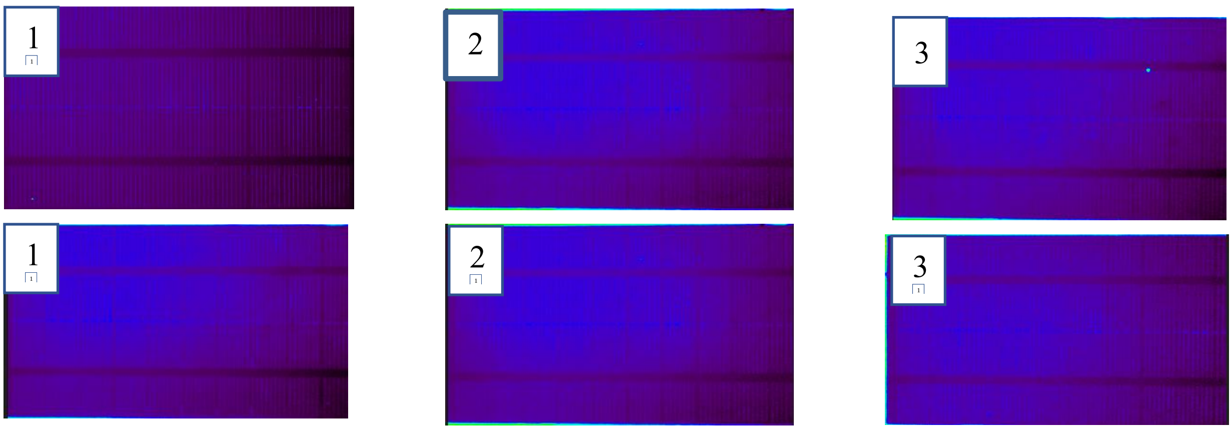


Figure 4 EL images for double degradation and double recovery of mini-solar modules

Conclusion

In contrast to this research, it is important to maintain solar cells over the extended period of time. The I-V characteristics were demonstrated under 1 sun illumination. However, surface damage may be the result of long term PID stress. Degradation must be prevented because acid rain caused damage to the mini-solar module. The purpose of this research was to explain the process of recovering from acid rain-induced solar cell degradation. In this study, photocurrent and EL images were used to analyze PID and recovery with regard to time enhancement under acid rain.The mini-module's photocurrent delivery was decreased due to degradation caused by acid rain. The degradation mechanism is shown by the losses evolution observed on the I-V curves. The findings of this research show that PID increases as the immersed in acid rain time increases. According to EL, the PV solar modules have been affected by the degradation mechanism. Degradation under I-V curves increased further as the amount of time immersed in acid rain increased. Using I-V curves and EL images, different characteristic states (initial, degradation, recovery, double degradation, and double recovery) of solar modules were defined and characterized in relation to acid rain immersion. The simple method under low-temperature treatment is straightforward for recovering damaged solar modules.

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