

Development of an acid moisture detection method in photovoltaic modules

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Abstract

Formation of acetic acid through the penetration of moisture into ethylene vinyl acetate (EVA) in photovoltaic (PV) modules is cited as a main reason for their failure. Currently, there is no effective method for the detection of acid moisture in PV modules. Hence, we propose a method for detecting acid moisture using a pH-sensitive dual wavelength fluorescent dye, which indicates pH by the ratio of dual peak wavelength fluorescent spectra. Through this study, we have confirmed that a device with fluorescent dye can detect acid moisture by the shift of fluorescent spectra.

1. Introduction

The exhaustion of fossil fuel and rising need for clean renewable energy has led to the widespread use of photovoltaic solar power generation [1]. The cost of generating solar power is higher than that of other types of power, and the reduction of this cost has been attempted by improving conversion efficiency and extending duration of use. In this study, we focus on the latter method [2].

It has been reported that the main cause of degradation of photovoltaic (PV) modules is the production of acetic acid in ethylene vinyl acetate (EVA), which is used as an encapsulant of PV modules [3]. Under prolonged atmospheric exposure of PV modules, moisture penetration occurs through the edges and backsheet and spreads in EVA. It is believed that acetic acid is synthesized through the reaction of EVA with water. This acetic acid produced by moisture penetration has the potential to cause corrosion of cells, and other malfunctions. In order to prevent the expanding degradation of PV modules, it is necessary to detect the formation of acetic acid in EVA as early as possible. Currently, however, there is no effective method for detecting acetic acid in PV modules, partly because of their design, which consists of a tight space sealed with glass plate and backsheet.

In this study, we focus on the pH shift induced by the production of acetic acid in EVA. Detection of pH change in EVA was devised with a pH-sensitive fluorescent dye used in biological fields. Our proposed method is non-destructive and simple because the fluorescence of the dye can be measured from outside the glass plate of the PV module.

2. Materials and Methods

In this study, a dual-wavelength pH-sensitive fluorescent dye, SNARF-4F[®](Invitrogen)[4], was used for the detection of pH change in EVA. Fluorescent emission spectra of SNARF-4F are shown in Fig. 1 as a parameter of the dye solution's pH value. This figure shows that the dye has two peak wavelengths (587 nm and 650 nm), and that the ratio of two peak fluorescent intensities (fluorescent intensity ratio: FIR) changes in the pH range of 5.0–8.4. FIR is defined by the ratio of fluorescent intensities at 587 nm and 650 nm (I587/I650) [5].

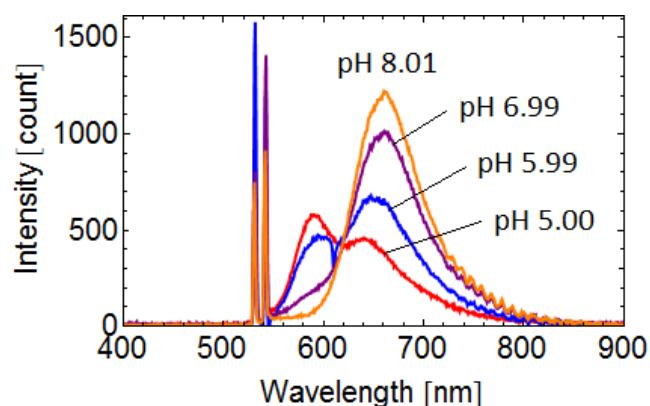


Fig. 1 Fluorescent emission spectra of SNARF-4F at various pH values

Although the fluorescent dyes used in biological applications are generally liquid solutions, it is necessary to use a solid fluorescent dye for installation in PV modules. It was, therefore, necessary to confirm that a dry dye was able to measure the pH value. A dry test piece was produced by dropping SNARF-4F solution (0.02 mM, 20 μ l) on filter paper and heating it at 85°C for 90 min. FIR of this filter paper was measured at every 1.0 pH value from pH 5.0 to 8.0 by using a 532 nm YAG-SHG laser as excitation light and a spectrometer (Ocean Optics, QE-65000).

It was confirmed that a dry test piece of SNARF-4F is effective for the detection of acetic moisture. For this purpose, a test piece was prepared by dropping dye solution on a microscope cover glass and heating it at 85°C for 90 min. The experimental setup for generation of acetic moisture is

shown in Fig. 2. Acetic moisture was formed by bubbling in acetic acid solution (10%). The dry test piece was exposed to high humidity (RH = 85% at temperature of 24°C) of acetic moisture. While a specimen was exposed to acetic moisture, fluorescent spectra of SNARF-4F were measured by a reflective optical fiber probe every 30 s. Time response of FIR to acid moisture was calculated from the fluorescent spectra.

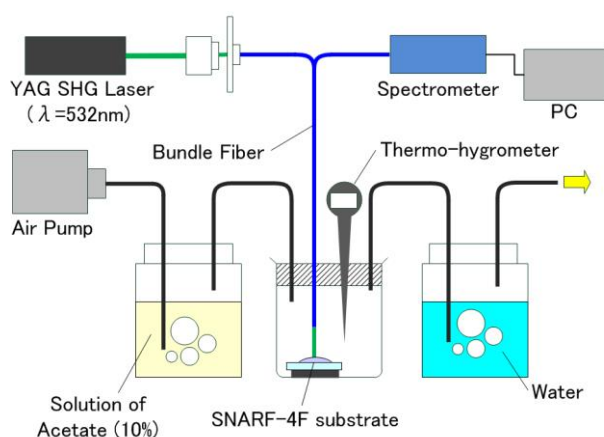


Fig. 2 Experimental setup

3. Results and Discussion

The pH value of dry SNARF-4F adsorbed on filter paper was adjusted by the addition of Tris buffer (1 mM) under controlled pH value. The FIR of the dry SNARF-4F test piece on the filter paper is shown in Fig. 3. This figure indicates that the FIR changed from 2.0 to 0.2 depending on the increase in pH value. In particular, the linear change in the FIR obtained from pH = 5.5–7.0 indicates that it is possible to detect a pH value shift by using the dry SNARF-4F test piece. Thus, dry SNARF-4F shows potential application for the detection of a pH value change in PV modules.

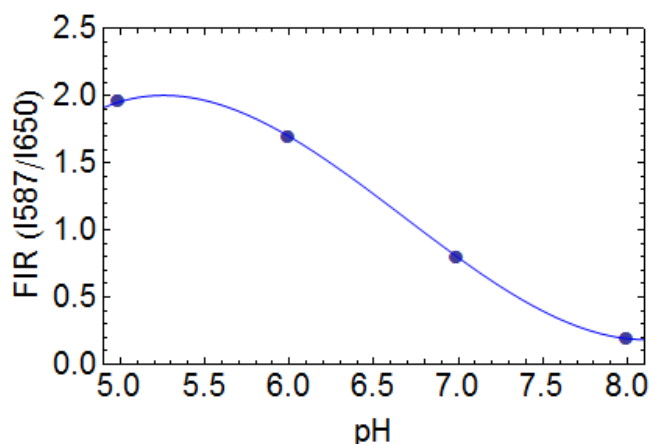


Fig. 3 FIR of dry SNARF-4F at various pH values

The experimental result of the FIR change of the dry cover glass test piece in a high-humidity chamber of acetic moisture is shown in Fig. 4. The figure indicates that the FIR monotonously increased from 0.5 at the start of the test to 1.6 at a time of 18 min. According to the calibration curve of FIR as a function of pH shown in Fig. 3, the pH value calculated by FIR changed from 7.3 to 6.1. This shift to an acid state shows the successful detection of acid moisture by the use of dry SNARF-4F test piece.

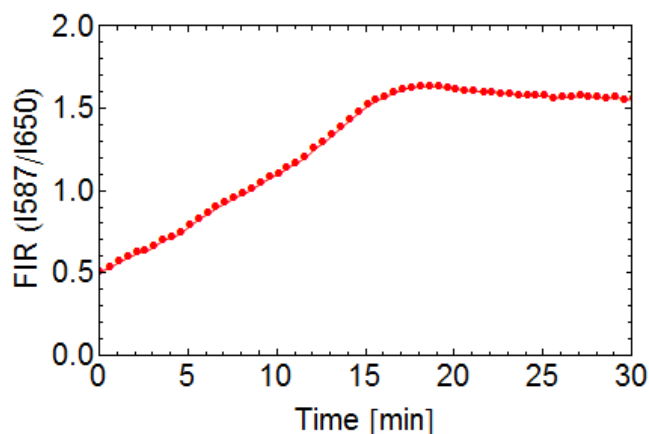


Fig. 4 FIR shift of dry SNARF-4F exposed in acid moisture

4. Conclusions

We have proposed a method that uses pH-sensitive dual wavelength fluorescent dye to detect acetic acid produced by EVA and water moisture in PV modules. The test piece of a dry fluorescent dye indicated the detection characteristics for a range of pH values, and was effective in the detection of acetic acid moisture. The experimental results suggest that our proposed test piece will be able to detect acetic acid moisture after installation in PV modules. Our proposed method represents a non-destructive and simple manner for evaluation of PV modules under exposure testing.

Acknowledgments

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