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Property of prepared N719 dye using gamma-irradiation and its dye-sensitized solar cell application

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1. Introduction

Solar photovoltaic cells, dye-sensitized solar cells (DSSCs), capable of directly converting sunlight into electrical power, are one of the most promising devices in the search for sustainable and renewable sources of clean energy. In particular, dyes used as a sensitizer in DSSCs are very important to increase the efficiency including a light harvesting portion (broad spectrum, increased absorbance), acidic ligands (ex; carboxylic or phosphonic acid) to attach to the semiconductor surface, and ligands to increase the solubility in the solution and reduce aggregation between dyes in DSSCs. Also, dyes have to possess thermal and chemical stability. In the present study, we tried to develop an advanced dye, using the interaction between the dye and gamma-irradiation. We also describe the preparation of structurally changed dyes using gamma-irradiation and the results achieved. Specifically, a commercialized dye, N719 was investigated.

2. Methods and Results

In this section, dyes were prepared using gamma-irradiation, the results of which are described shortly.

2.1 Preparation and property of dyes via the gamma-irradiation

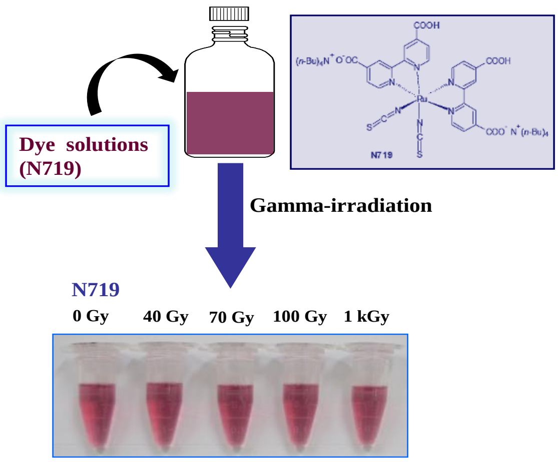

Fig. 1. Preparation and visible property of dye solutions by gamma-irradiation.

2.2 Optical property of prepared N719 dye solutions

The optical properties and band gap energy (eV) of N719 dye solutions by gamma-irradiation were shown in Fig. 2 and Table 1. While the optical spectrum is represented as correspondingly increased absorption peaks in accordance with the dose rate in the UV and visible wavelength fields, their band gap energy decreased values are shown. A red shift of N719 dye was occurred at a 1 kGy dose rate. Interestingly, these results were only shown in dye solutions through gamma-irradiation treatment. The absorption peak shape and band gap energy of N719 dyes might have an effect on the DSSC efficiency. It was indicated that dyes by gamma-irradiation treatment correlate with the DSSC efficiency through structural changes in the dye molecules.

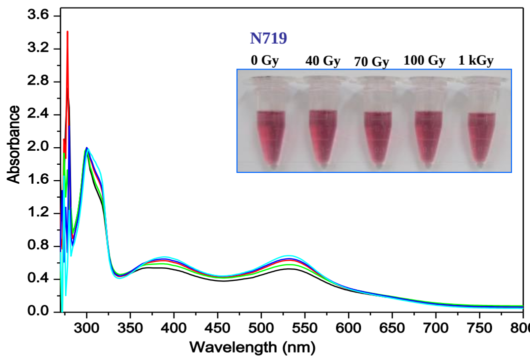

Fig. 2. Adsorption spectrum (270 nm to 800 nm) of prepared N719 dye solutions by gamma-irradiation. 0 Gy (black), 40 Gy (red), 70 Gy (light green), 100 Gy (blue), and 1kGy.

Table 1. Adsorption peaks of N719 dye solutions by gamma-irradiation and their band gap energy values.

Gamma-irradiation dose rate	Absorption peak (nm)	UV λ (edge)	Band gap Energy (eV)
0 Gy	524.9	585	2.12
40 Gy	524.8	596	2.08
70 Gy	522.3	592	2.10
100 Gy	524.8	590	2.10
1 kGy	510.8	574	2.16

2.3 FTIR study of prepared N719 dye solutions

The FTIR absorption spectra of the N719 dyes of gamma-irradiation treatment are shown in Fig. 3. Remarkably, the N719 dyes showed gradually increasing peak intensity at about 2400 cm^{-1} in accordance with the irradiation dose rate. The peak indicates the possible presence of a C-N or C-C triple bond and can be seen as carboxylic acid by the string, sharp carbonyl C=O peak.

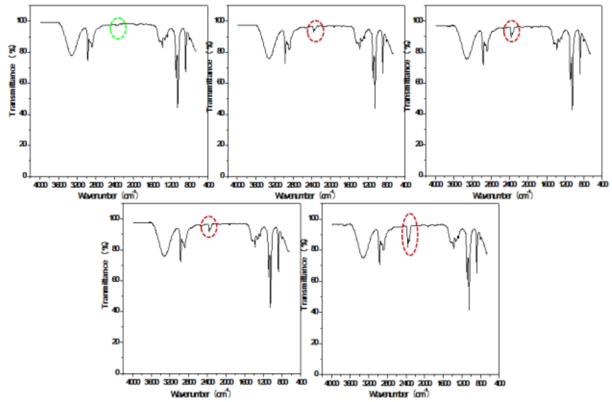

Fig. 3. FTIR absorption spectra obtained from N719 dyes by gamma-irradiation; 0 Gy (a), 40 Gy (b), 70 Gy (c), 100 Gy (d) and 1 kGy (e).

2.4 Application for DSSC analysis

The photovoltaic properties of gamma-irradiated N719 dye solutions in a DSSC analysis are shown in Table 2. The DSSC efficiency of N719 dyes has increased in accordance with the rise in gamma-irradiation dose to 100 Gy. A comparison of the *I-V* characteristics of a prepared cell using gamma-irradiated dye revealed that J_{sc} of the cell is sharply decreased at 1 kGy, while no large changes occur for an open-circuit voltage (V_{oc}), and the efficiency was shown as decreasing values.

Table 2. *I-V* performances parameters of DSSC with gamma-irradiated N719 dye solutions

Dose of irradiation	V_{oc} (mV)	J_{sc} (mA/cm^2)	FF (%)	η (%)
0 Gy	0.608	12.491	71.828	5.319
40 Gy	0.665	12.382	72.629	5.772
70 Gy	0.673	12.019	73.015	5.730
100 Gy	0.657	11.908	71.34	5.364
1 kGy	0.625	7.005	66.084	2.748

3. Conclusions

N719 dye solutions having different properties against non-treatment dyes were prepared from gamma-irradiation. The dyes constantly showed the same color (red pink) characteristics as 1Gy to the 1kGy of irradiation dose. Based on the optical property of the dyes, interesting structural characteristics were shown as a gradually increased absorption peak in accordance with the irradiation dose. The results might indicate that the dye structure was partially changed by an interaction between the gamma-irradiation. The DSSC efficiency of the dyes in terms of photovoltaic performance was clearly suggested from the reaction between the dyes and gamma-irradiation. In particular, the results suggest that the existence of an appropriate amount of OH-group in the dye molecules might control the effect on DSSC efficiency.

Therefore, it can be applicable to the needs for an appropriate sensitizer with certain added functions in DSSC using a radiolysis technique. In addition, it can be used effectively in various industrial fields and is applicable to diverse systems.

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