

Wu et al., 202

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## **EFFECT OF DIFFERENT UV EXPOSURE ENERGY ON POLYIMIDE-BASED NONVOLATILE RESISTIVE PHOTOMEMORY DEVICE**

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### **Abstract**

*Recently, many researchers pay attractive attention to organic memory technology. Polyimide film was used as the resistive switching layer of nonvolatile photomemory in this study. In order to improve the performance of the device, different wavelengths of Ultraviolet (UV) light were used to operate the device, and its impact on the polyimide film was discussed. In this paper, three different UV light bands, UVA, UVB, and UVC, are used to switch devices between low resistance state (LRS) and high resistance state (HRS). It can be seen from the results that all three kinds of*

*energies of UV light can transform the polyimide film from HRS to LRS successfully. According to the data, after 1s of UVB irradiation, the LRS current of polyimide-based photomemory device is the largest, and the data retention ability is also the best, the second is to irradiate UVA, and the last is to irradiate UVC. The results of the optical properties and electrical properties are coincidental. Therefore, different UV energies can affect this photomemory device.*

### **Keywords**

Nonvolatile, Organic, Photomemory, Polyimide, Resistance, Ultraviolet

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## **1. Introduction**

With the in-depth study of organic materials, the conductivity of organic materials has opened up new research fields for people, and a large number of organic semiconductor materials have emerged. It has even been found that many performances of organic semiconductor materials are better than inorganic semiconductor materials. For example, the material is easy to obtain, low in manufacturing cost, capable of low-temperature processing, and has good absorption characteristics in the visible light region, and the emission spectrum can cover the entire visible light region, and even extend to the UV and near- infrared (NIR) light regions. Therefore, in today's various devices, organic materials are undoubtedly the focus of much attention (C.-C. Chen, Chiu, Sheu, & Wei, 2008; F.-C. Chen, 2018; Ouyang et al., 2017; Palma & Duart, 2017).

Optical manipulations are non-destructive. In addition to being able to operate the device in a wide range and improve the operating efficiency, it can also improve the performance of the device (Gemayel et al., 2015; Wakayama, Hayakawa, & Seo, 2014; H. Wu et al., 2021; Zhou et al., 2017). In recent years, the rapid development and transmission of optical signals have led to the development of many optoelectronic devices, such as photodetectors, phototransistors, and photodiodes (Cheng, Yang, & Hsu, 2009; Dini, Calvete, & Hanack, 2016; Wang et al., 2019; Yang & Ma, 2019).

With the rapid development of artificial intelligence (AI) technology, photodetectors can be combined with other components to perform calculations on data, so it is also widely used in image processing (Lei et al., 2015; Nalwa, 2020). However, if photodetectors remove the light, the data cannot be stored, and non-volatile memory is needed as an auxiliary. In order to solve the above problems, the research and development of photomemory with storage characteristics has become a trend that has attracted much attention (H. Chen, Liu, Hu, Al-Ghamdi, & Fang, 2015; Fang & Hu, 2017).

The storage mechanism of most photomemories is based on the Charge Trap Type (C.

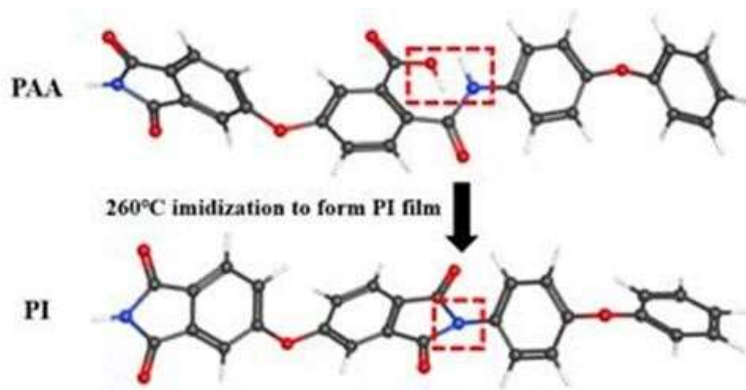
Huang et al., 2017). With down scaling of the device, the photomemory reduces the memory window ratio due to the reduction of charge carrier traps, and the excessive erase voltage causes RC delay (Jia et al., 2019; Yin, Akey, & Jaramillo, 2018). Recently, Wu et al. developed a polyimide (PI)-based non-volatile resistive photomemory (C.-C. Wu, Chen Jr, & Yang, 2022). They use PI as the resistive layer of resistive memory (Hsiao et al., 2015). The PI film is photosensitive to UV light, and its molecular structure can be changed by UV light irradiation. The high-energy-gap aromatics are transformed into low-energy-gap quinoids so that the PI film can switch between HRS and LRS (Costa, Taveira, Lima, Mendes, & Santos, 2016). The conduction mechanism of this photomemory is Charge Transfer. Its device size depends on the size of the electrodes. Therefore, there will be no device scaling limitations (Ismail et al., 2016; Tseng et al., 2007; Zhou et al., 2018).

Here, different wavelengths of UV light were used to perform device-switching operations and discuss the relative characteristics of the device after different UV irradiation.

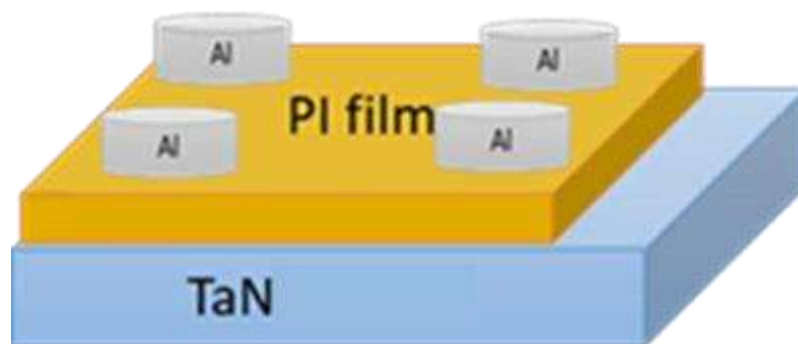
## **2. Materials and Methods**

First, 4,4'-Oxydiphthalic Anhydride (ODPA) was stirred with the N-methyl-2-pyrrolidone (NMP) solution for 30 minutes, then 4,4'-oxydiphenylamine (ODA) was added to the solvent, and stirred for 12 hours. To complete the preparation of PAA solvent. Next, the PAA solution was dropped onto the TaN for spin coating, and the spin coater pre-rotation speed was set to 1500 rpm for 5 seconds for the first time, and then 3000 rpm for 30 seconds. The device entered high temperature for dehydration and the cyclization reaction was heated to 260°C at high temperature, and baked for 30 minutes in nitrogen. During this period, the PAA underwent a dehydration reaction and cyclization reaction to form a polyimide solid film. This step is also known as imidization, which is shown in Figure 1. Finally, the polyimide film was pasted with a metal mask and put into a metal thermal evaporation system to complete the top electrode. The thickness of the top electrode was about 100 nm. The polyimide photomemory can be completed. Figure 2 illustrates a schematic diagram of the PI photomemory device.

Optical analysis was performed with a UV-vis spectrometer (Evolution 201, Thermo Fisher Scientific, Waltham, MA, USA). The current-voltage (I-V) characteristics were measured using the Keithley 4200A- SCS parameter analyzer (Tektronix, Beaverton, OR, USA).



**Figure 1:** Schematic 260°C Imidization to Form the PI Film  
(Source: J. S. Huang, Liu, Chen, Tseng, &Yang, 2022)



**Figure 2:** Schematic Diagram of the Device Structure  
(Source: Self Own Illustration)

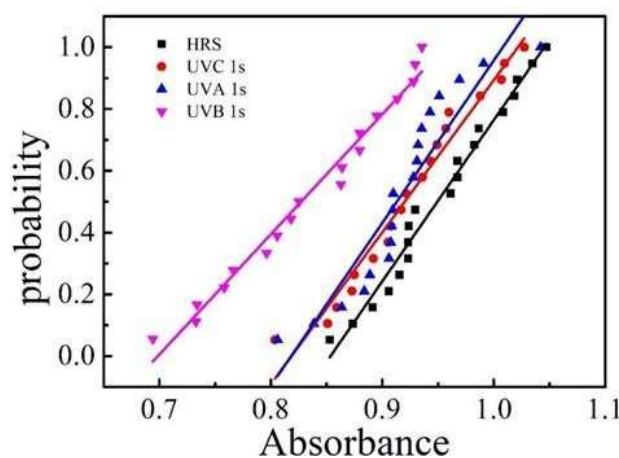
### 3. Results and Discussion

#### 3.1. Optical Characteristics

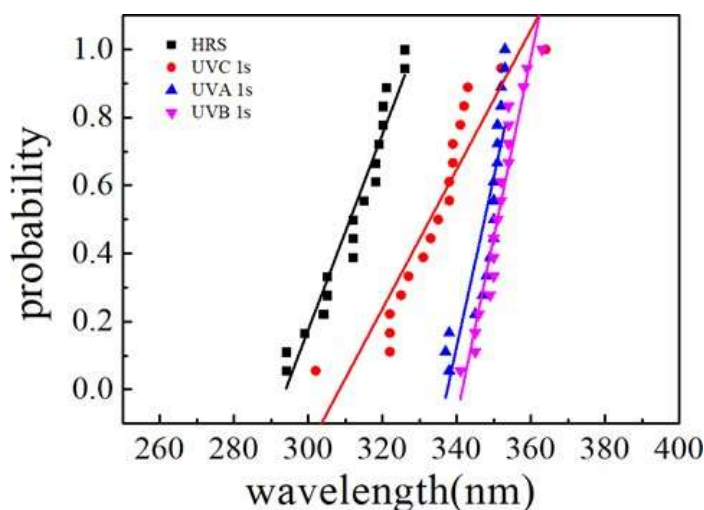
In order to know the influence of different UV light on PI thin films, the optical properties of PI thin films were measured by UV-vis spectroscopy. Figure 3 shows the maximum absorption of the PI film in the initial state, after 1 s of UVA irradiation, after 1 s of UVB irradiation, and after 1 s of UVC irradiation. The absorption of the aromatic PI is about 0.9 ~1.0. After irradiating UVB, its absorption drops to 0.7~0.9, which is an obvious change. Although the absorption of the PI film decreases after UVA and UVC irradiation, the magnitude is very small. Figure 4 illustrates the wavelengths corresponding to the absorption peaks of PI films in the initial state, after 1 s of UVA irradiation, after 1 s of UVB irradiation, and after 1 s of UVC irradiation. The absorption peak wavelength of aromatic PI falls at about 345nm. However, after irradiating

with UVB light for one second, its absorption peak wavelength gradually shifts to the right (redshift), and the maximum can even reach about 365nm. In addition, after the PI film is irradiated with UVA and UVC light, its absorption wavelength also has a red shift phenomenon. The redshift phenomenon is attributed to the conjugate effect of the unsaturated bonds in the quinoid PI (Cheng et al., 2009). This means that the number of aromatic PI converted into quinoid PI gradually increases, resulting in a decrease in the energy band gap of the film. Figure 5 shows the chemical structures of quinoidPI and Aromatic PI (C.-C. Wu et al., 2022).

In terms of the energy of UV light, UVC has the highest energy. However, the data results showed that the PI film changed the most after UVB irradiation. This is attributed to the best absorbance of PI film at 290-320 nm, as shown in Figure 6, but UVC wavelength ranges from 100nm to 280 nm. Therefore, the film has poor absorption capacity for UVC.

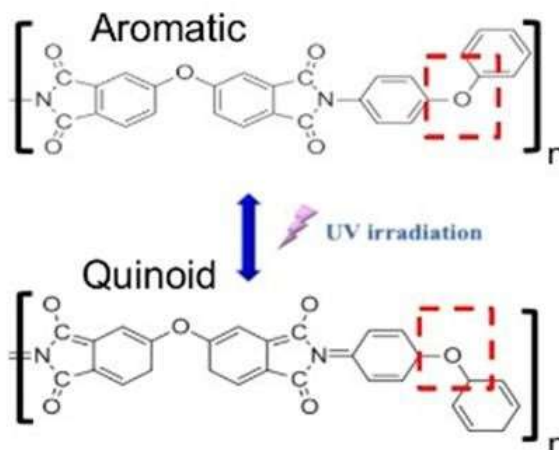


**Figure 3:** *The Wavelength of the Maximum Absorption Peak of PI Film in the UV-Vis Region*  
(Source: Self Own Illustration)



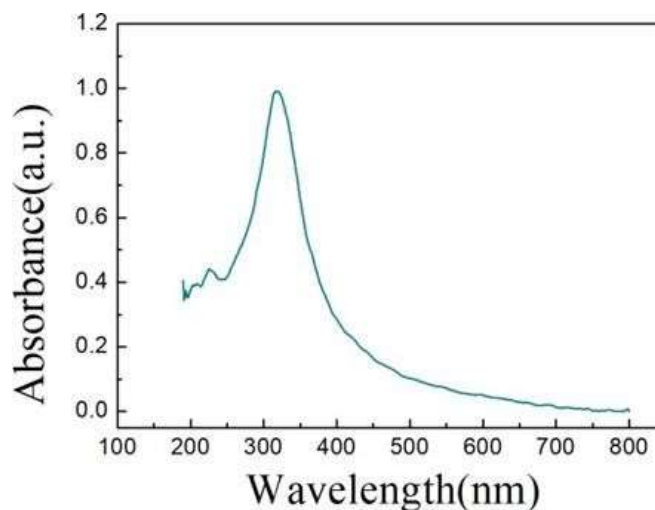
**Figure 4:** *The Wavelength of the Maximum Absorption Peak of the PI Film*

(Source: Self Own Illustration)



**Figure 5:** Chemical Structure Diagram of the PI Molecules in their Aromatic and Quinoid Forms

(Source: C.-C. Wu et al., 2022)



**Figure 6:** UV-Vis Spectrum of the PI Films

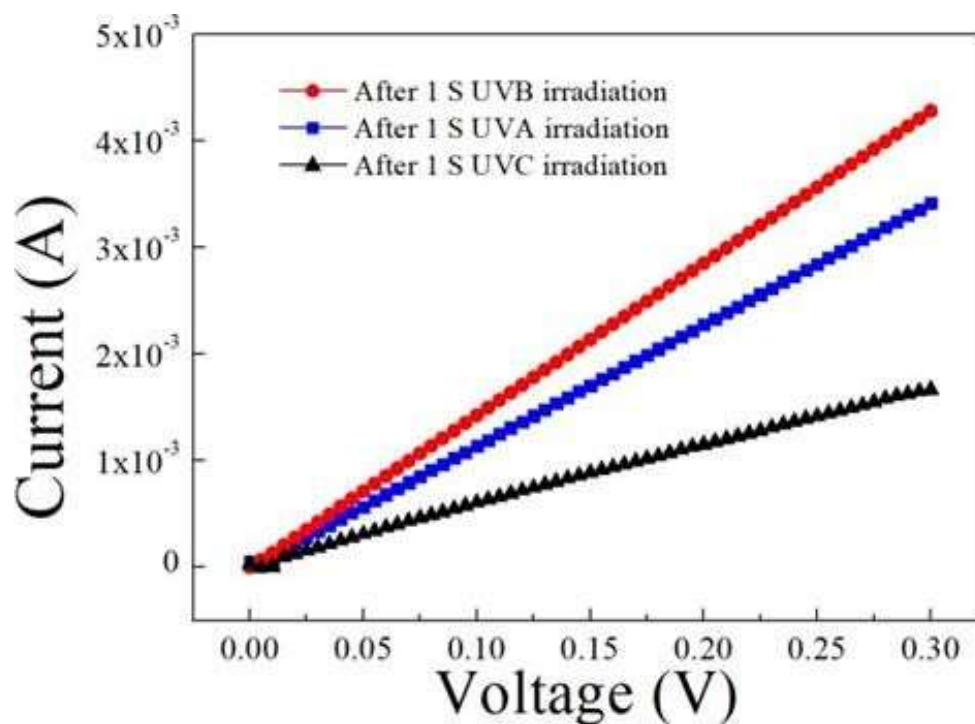
(Source: Self Own Illustration)

### 3.2. Electrical Characteristics

This paragraph mainly focuses on the electrical measurement results and analysis of the components, including the current in the LRS and the data storage capacity of the photomemory. The main current conduction mechanism of the device in HRS is hopping conduction, while the current conduction mechanism in the LRS is ohmic conduction (C.-C. Wu et al., 2022). Figure 7 shows the I-V characteristics of the device after irradiating UVA, UVB, and UVC for 1 second. It can be calculated that the resistance values of the LRS are 0.00342, 0.00428, and 0.00167 respectively. Table 1 shows the difference in current and resistance in LRS after different UV light

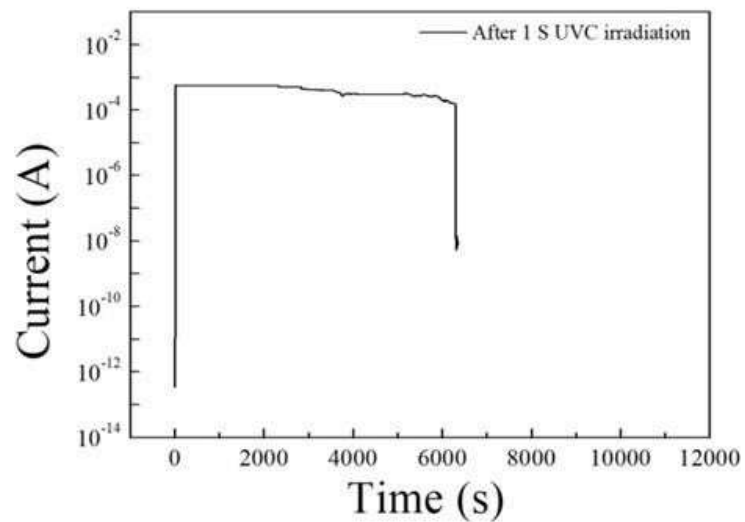
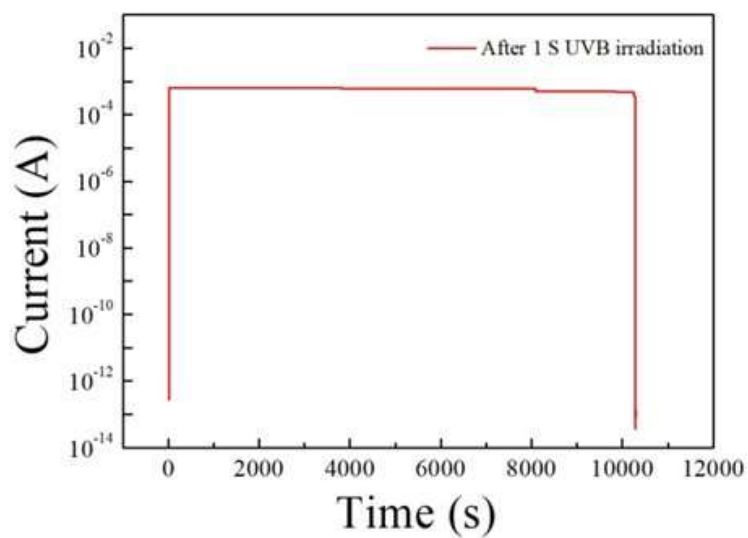
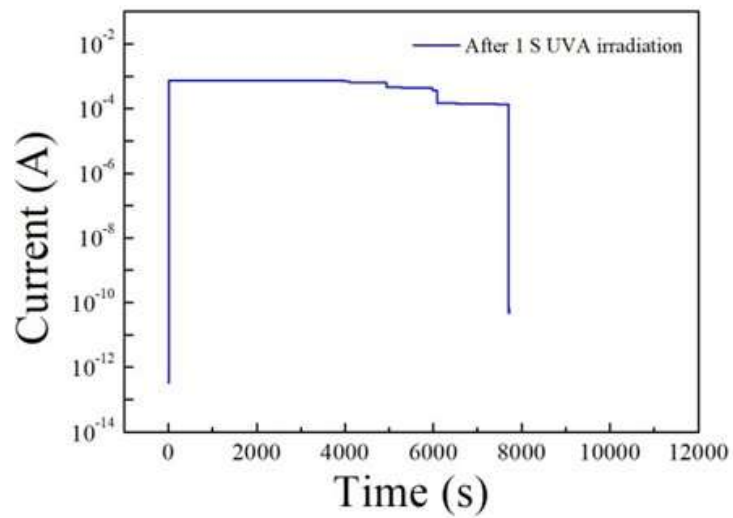
irradiation, and the photoresponse of the optical storage device can be clearly seen.

The data retention ability represents the time that the photomemory can retain the light information after receiving the light source without applying a bias voltage. The effect is known as persistent photoconductivity (PPC). After irradiating UVA, UVB, and UVC light for 1 second, the data retention ability of the device at room temperature is shown in Figure 8a-c. The data retention time after UVA irradiation is about 7500 seconds, while the data retention time is about 10200 seconds after UVB irradiation, and 6100 seconds after UVC irradiation. The device is switched by three different ultraviolet light irradiations, all of which have very excellent data storage capabilities. In addition, the measurement results of the electrical and optical properties are consistent with each other. The magnitude of the current value in the LRS is related to the conduction path of the device. Therefore, the data retention capability of the device is also affected by the number of conduction paths.



**Figure 7:** *I-V Curve of the Device in LRS (UVA, UVB, UVC irradiated for 1 s)*

*(Source: Self Own Illustration)*





**Figure 8:** The Data Retention Time of the Photo Memory after 1 S of (A) UVA, (B) UVB, (C) UVC Irradiation  
(Source: Self Own Illustration)

**Table 1:** The Polyimide Photomemory with Current and Resistance Values in Lrs after Different Illumination

	Irradiate 1 s		
	Voltage (V)	Current (A)	resistance ( $\Omega$ )
UVA	0.3	0.00342	87.7
UVB	0.3	0.00428	70.1
UVC	0.3	0.00167	179.6

(Source: Self Own Illustration)

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