INFLUENCE OF ULTRAVIOLET RADIATION ON SURFACE ELECTRIC POTENTIAL OF THE P(VDF-TrFE 70:30) FILMS DEPOSITED ON GLASS SUBSTRATE

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Abstract. *Ultraviolet (UV) radiation is able to cause biological changes at the cellular and molecular level. These biological structures are nano- and micro-sized, so to study the effect of UV radiation, detector is required, commensurate with their size. Ferroelectric P(VDF-TrFE 70:30) films deposited on a glass substrate were examined as a possible sensor of UV radiation. Changes in surface electric potential of the P(VDF-TrFE 70:30) films under UV radiation were investigated by Kelvin force microscopy. The hypothesis was proposed that UV radiation was well absorbed by the glass substrate changing its surface charge. This charge changed polarization of the films leading to changes in their surface electric potential. It was found that after 6 minutes of UV irradiation surface electric potential of the P(VDF-TrFE 70:30) films decreased and no changes were observed further increasing irradiation time. However, surface electric potential of the bare glass substrate continued to decrease increasing irradiation time. It was also found that surface electric potential of the P(VDF-TrFE 70:30) films relaxed to its initial value within half an hour after the irradiation was stopped. The relaxation obeyed exponential law. Ability of the examined P(VDF-TrFE 70:30) films deposited on the glass substrate to change their polarization upon application of external DC bias voltage was also checked by Piezoresponse force microscopy. The DC bias was used as a model for electric charge induced on the surface of glass substrate during UV irradiation.*

Keywords: *P(VDF-TrFE) films, surface electric potential, ultraviolet radiation, dosimetry, Kelvin force microscopy*

I. Introduction

Polyvinylidene fluoride (PVDF) and its copolymer poly(vinylidene fluoride-trifluoroethylene) [P(VDF-TrFE)] are polymers well-known for their ferroelectric properties [1].

In their piezoelectric form, PVDF and P(VDF-TrFE) find use in transducer devices where mechanical energy is converted into electrical energy and vice versa. These polymers can be used in a variety of sensors and actuators such as artificial muscles and organs, medical imaging, blood-flow monitors, microphones, smart skins, underwater acoustic transducers, seismic monitors, fluid pumps and valves, surface acoustic wave devices, robots, and tactile sensing devices [1, 2]. Ability of PVDF and P(VDF-TrFE) to change their polarization upon application of an external electric field is used in nonvolatile memory and data-storage devices [3].

Application of the P(VDF-TrFE) films consisting of 70% vinylidene fluoride (VDF) and 30% trifluoroethylene (TrFE), or P(VDF-TrFE 70:30), as a possible sensor of ultraviolet (UV) radiation was studied in the current research. The films were deposited on a glass substrate. P(VDF-TrFE 70:30) films were fabricated using Langmuir-Blodgett technique. Size of the samples was 1x1 cm. 10 and 11 monolayer (ML) thick P(VDF-TrFE 70:30) films were available. The films were made in Shubnikov Institute of Crystallography of the Russian Academy of Sciences in collaboration with Sergey G. Yudin, leading researcher.

It has been hypothesized that UV radiation is absorbed by the glass substrate, inducing electric charge on its surface. The induced electric charge in turn changes the polarization of the P(VDF-TrFE) film (Fig. 1). Changes in the polarization result in changes of surface electric potential of the film. Examination of the surface electric potential was performed by Kelvin force microscopy. Atomic force microscope Solver P-47 PRO was employed for measurements.

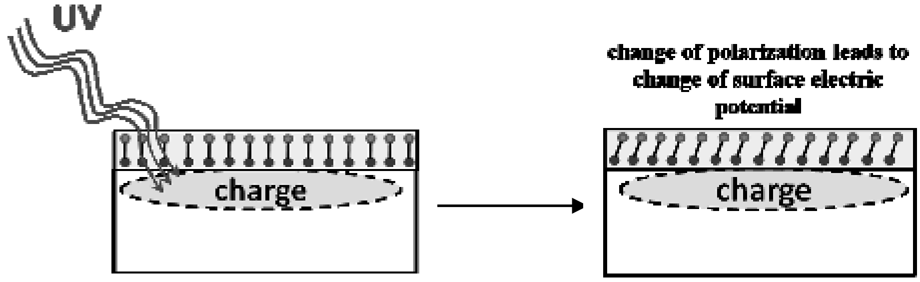

Fig. 1. The hypothesis was proposed that electric charge was created due to the absorption of UV radiation in the glass substrate. This charge changed polarization and surface electric potential of the P(VDF-TrFE) film.

The P(VDF-TrFE 70:30) films were UV irradiated with HAMAMATSU PHOTONICS Lightningcure 5 series xenon-mercury lamp L8222-01 (250 – 400 nm). The UV irradiation of the films was performed inside the atomic force microscope. The films were irradiated at a distance 40 cm between the film surface and the output of optical fiber of the UV lamp. This distance was chosen to avoid heating of the films. According to the Hamamatsu Photonics datasheet, the intensity of UV radiation at this distance was about 250 mW/cm^2. Surface electric potential of the P(VDF-TrFE) films was measured before and after irradiation. Bare glass substrate was irradiated as a reference and its surface electric potential was measured as well.

To test the ferroelectric properties of the P(VDF-TrFE 70:30) films, piezoresponse force microscopy mode of AFM was employed.

II. Results

AFM topography image of the P(VDF-TrFE 70:30) films deposited on glass substrate is shown in Fig. 2.

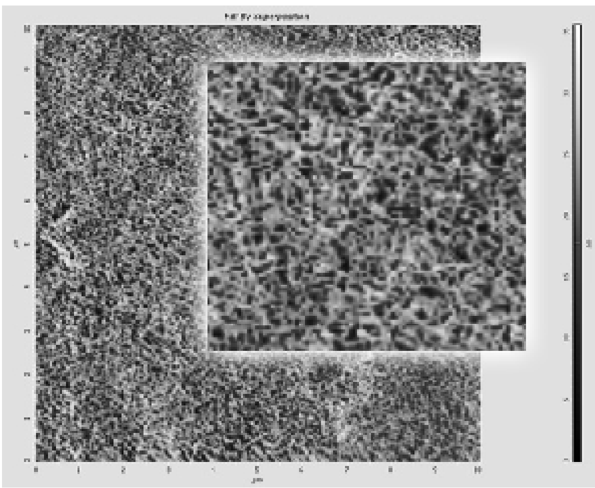

Fig. 2. AFM topography image of the 10 ML P(VDF-TrFE 70:30) film. Scan size 10x10 μm. The color gradation on the vertical Z-axis is from 0 nm (dark regions) to 35 nm (light regions).

To test the ferroelectric properties of the samples, piezoresponse force microscopy mode of

AFM was used. DC bias voltage +5 V and -5 V was applied to the 11 ML thick P(VDF-TrFE 70:30) film during scanning. The applied DC bias voltage changed piezoresponse Z-amplitude and piezoresponse phase of the film (Fig. 3). Piezoresponse phase image clearly identifies regions with different polarization states which have resulted from the different polarity of the applied bios voltage. This experiment proved that external electric field changed polarization of the examined P(VDF-TrFE 70:30) films. The external DC bias voltage applied in this experiment was used to model electric charge induced on the surface of glass substrate during the UV irradiation (Fig. 1).

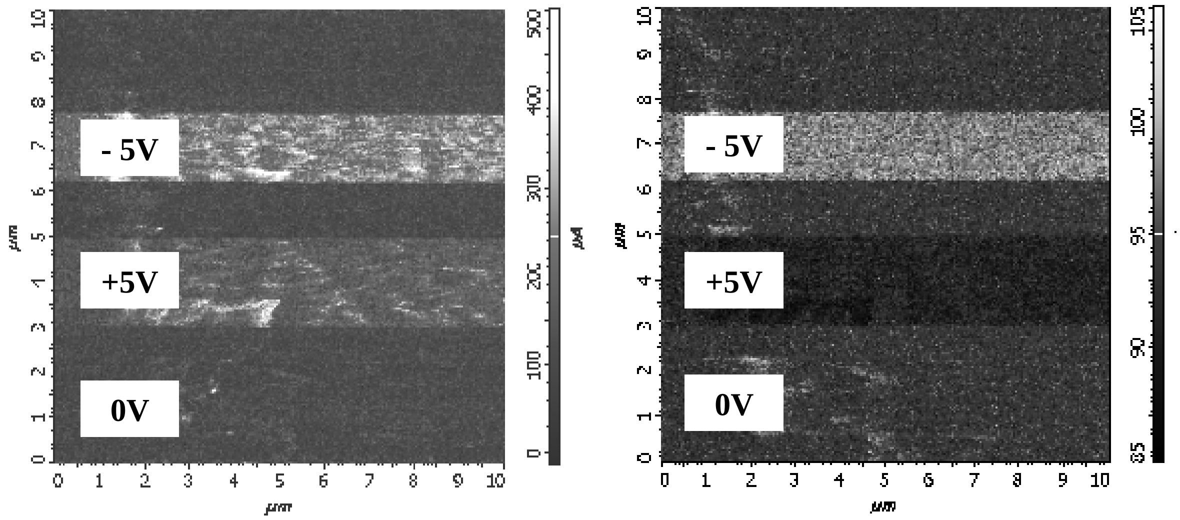

Fig. 3. Piezoresponse Z-amplitude (on the left) and piezoresponse phase (on the right) images of the 11 ML P(VDF-TrFE 70:30) film. DC bias +5V and -5V was applied during scanning.

The Fig. 4 shows the changes of the surface electric potential of the 10 ML thick P(VDF-TrFE 70:30) film after UV irradiation. When the mode of Kelvin force microscopy was selected in the AFM microscope software program, the value of the average surface potential was displayed. The displayed value couldn't be considered as the absolute value of the surface electric potential of the P(VDF-TrFE 70:30) films, but it could be used to estimate changes in the surface electric potential, and in accordance with the hypothesis proposed above (Fig. 1), reflected changes in the P(VDF-TrFE 70:30) film polarization. For reference, the bare glass substrate was also irradiated and its surface electric potential was measured.

The results showed that surface electric potential of the P(VDF-TrFE 70:30) film decreased after 6 minutes of irradiation and did not change further with increase in the irradiation time. Surface electric potential of the glass substrate also decreased after UV irradiation. However, unlike the film, the value of the glass substrate surface electric potential continued to decrease increasing time of UV irradiation.

Explanation was proposed that despite the fact that UV radiation was still influencing the glass substrate after 6 minutes of irradiation changing the electric charge on its surface, this influence had no further effect on the polarization of the P(VDF-TrFE 70:30) film, which at that time already had arrived to saturation.

Measurements of the surface electric potential shown in Fig. 4 were performed every 10 seconds after the UV lamp was turned off (time on the horizontal axis). This was done to prove that the values of the surface electric potential measured by the Kelvin force microscopy were stable.

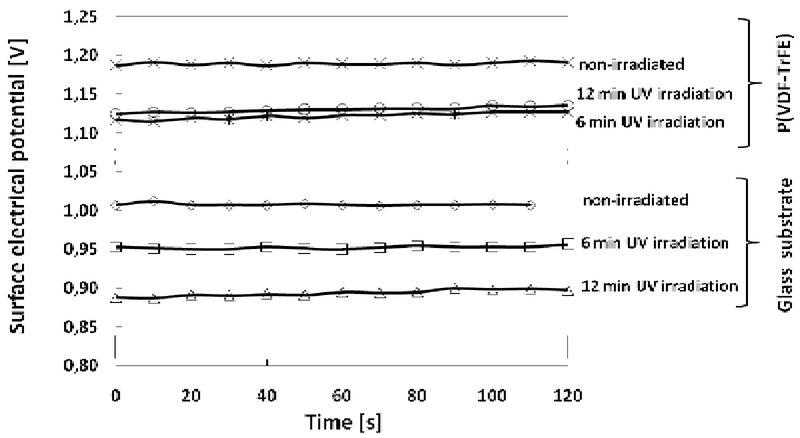

Fig. 4. Influence of UV radiation on surface electric potential of the 10 ML P(VDF-TrFE 70:30) film and the glass substrate.

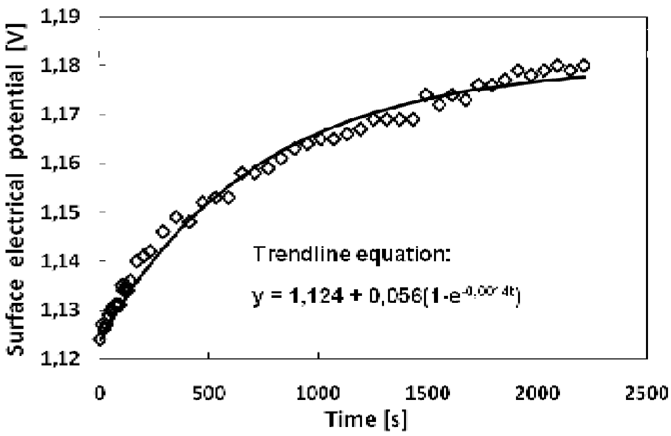

Fig. 5. Relaxation of surface electric potential of the 10 ML P(VDF-TrFE 70:30) film to its initial value after UV radiation was turned off.

Long-term changes in the surface electric potential of the 10ML thick P(VDF-TrFE 70:30) film after the UV radiation was turned off were investigated (Fig. 5). The film was UV irradiated during 12 minutes. After turning off the source of UV radiation, measurements of the surface electric potential were performed with 1 minute interval. The measurements revealed that the surface electric potential tended to return to its value present before the UV irradiation. Relaxation of the potential obeyed the exponential law (see the Trendline equation in Fig. 5). Relaxation occurred within half an hour.

III. Conclusions

Kelvin force microscopy measurements show that exposure to UV radiation decreases surface electric potential of the P(VDF-TrFE 70:30) films deposited on glass substrate. Presumably, this is because UV radiation is absorbed on the surface of the glass substrate, changing its surface charge, which, in turn, affects the P(VDF-TrFE 70:30) film changing its polarization. Surface potential of the film decreases to a particular value with increasing time of UV radiation, and then does not change. However, surface electric potential of the glass substrate continues to decrease with increasing irradiation time. After the UV radiation is turned off, the value of the potential of the P(VDF-TrFE 70:30) film relaxes to its initial value present before the irradiation. In our case, the relaxation occurs within half an hour.

Our studies suggest that the P(VDF-TrFE 70:30) films deposited on the glass substrate is a system sensitive to UV radiation. However, further investigations are required to examine the possibility to use these films as a sensor of UV radiation.

IV. References

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