Fiber-optic sensor based on an organic phosphor for detecting UV radiation in the A range

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Synthesis and characterization of the photoactive composition

The synthesis of the photoactive composition was carried out in two stages. Firstly, an organic phosphor 1,3,5-triphenyl-4,5-dihydro-1H-pyrazole (Sigma Aldrich, mass concentration 98%) and an organic solvent dimethylformamide (EKOS-1, mass concentration 99.9%) were stirred vigorously and exposed to the action of ultrasound waves at normal conditions until a homogeneous and low-viscous (10^{-3} Pa·s) solution was formed. Secondly, the solution was mixed with a polymer material based on epoxyacrylate DeSolite 3471-3-14 under identical conditions in order to provide the viscosity of the solution about 10 Pa·s.

The solution was prepared in a few concentrations. Mass fractions of substances are shown in Table.

Fig. 1 demonstrates photoluminescence excitation spectra and photoluminescence emission spectra of the coating based on the photoactive composition synthesized from the solution 1.

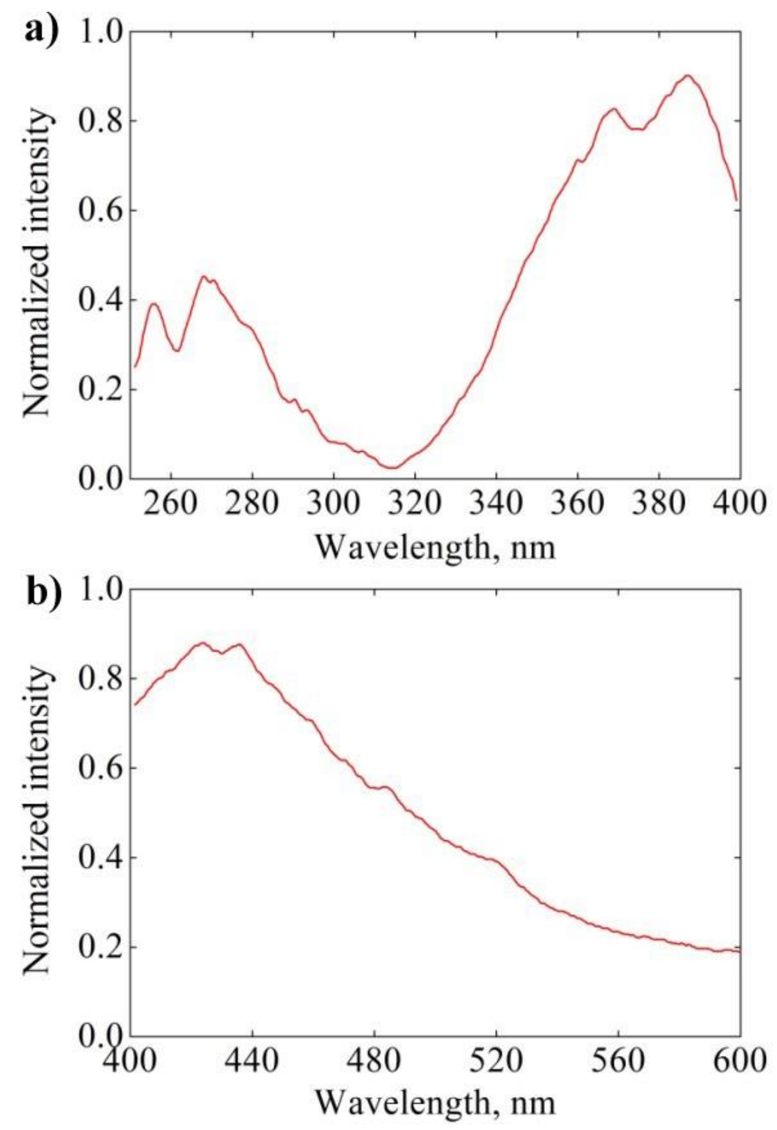

Figure 1. Photoluminescence spectra of the synthesized photoactive composition: a) excitation, b) emission

Number of the solution	Substances used to synthesize the photoactive composition		
	1,3,5-triphenyl-4,5-dihydro-1H-pyrazole, g	Dimethylformamide, g	Epoxyacrylate, g
1	0.1	0.5	0.5
2	0.1	2	2
3	0.4	2	2

Sensor design and results

The first FOS prototype consisted of a horizontally oriented silica capillary with 0.8 mm inner diameter and 26 mm length, filled with the photoactive composition from the one end (Fig. 2). The capillary was filled by pumping the composition under pressure through a plastic pipe, hermetically connected to the capillary. The length of the filled capillary segment was about 10 mm. After filling, the pipe was disconnected, and the face end of the capillary was sealed by a cap made of the UV resistant plastic to prevent leakage of the composition during its curing. From the other capillary end a silica optical fiber 100 mm in length was inserted close to the photoactive composition. In order to transfer the converted portion of radiation at wavelength λ = 440 nm the multimode fiber with a pure silica core and thin fluorosilicate cladding was used. The core diameter and numerical aperture of the fiber were equal to 200 μm and 0.22 respectively. Then the construction with the optical fiber rigidly fixed inside the capillary was exposed in the UV furnace at a radiation dose of 0.5 J/cm^2 for 30 seconds.

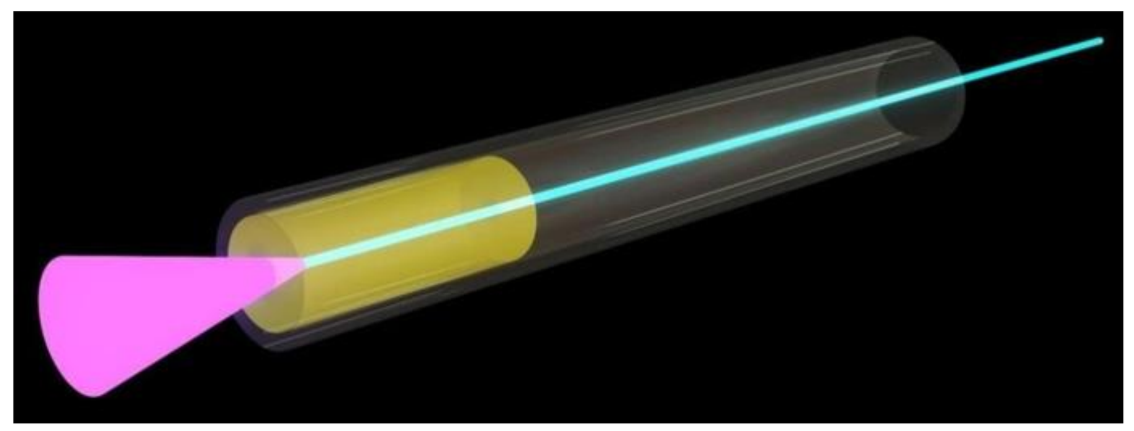

Figure 2. Scheme illustrating the FOS construction with a purple cone of radiation from a xenon lamp at the input

Experimentally, the FOS potential to be implemented as a UV-A radiation sensor was evaluated by measurement of the optical signal amplitude at wavelength of 440 nm with an increase of the UV radiation power at wavelength of 365 nm. As a result of experimental verification, it was revealed that dependence of the FOS optical signal amplitude on the launched UV radiation power has a linear character with a confidence interval of approximation of 98% (Fig. 3). Thus, according to the determined linear dependence, it is possible not only to detect the UV radiation in the environment but also to qualify changes of its relative power.

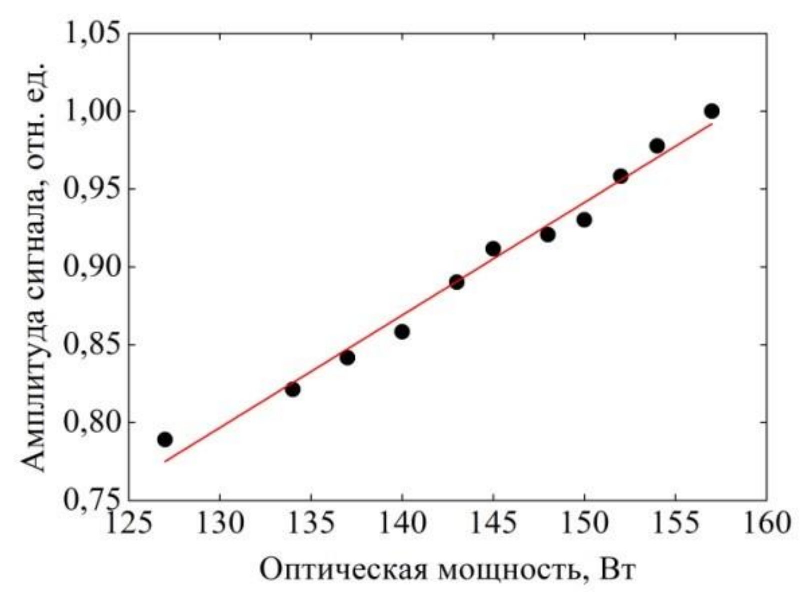

Figure 3. Dependence of the FOS optical signal amplitude on the UV radiation power.

After a successful experiment, it was decided to further simplify the design of the FOS. In its second version, we excluded a silica capillary from the construction to produce an optical element based on the fiber coated at one end with the same photoactive composition. For this, the multimode fiber with a core diameter and numerical aperture equal to 800 μm and 0.22 respectively of 40 cm in length was used. On the one end of the fiber the protective coating was removed by 1 cm and the photoactive composition was applied in this place.

To quantitatively confirm the visually registered effect of photoluminescence, spectral characteristic of the optical signal amplitude at the FOS output was measured. Fig. 4 demonstrates the measured characteristic.

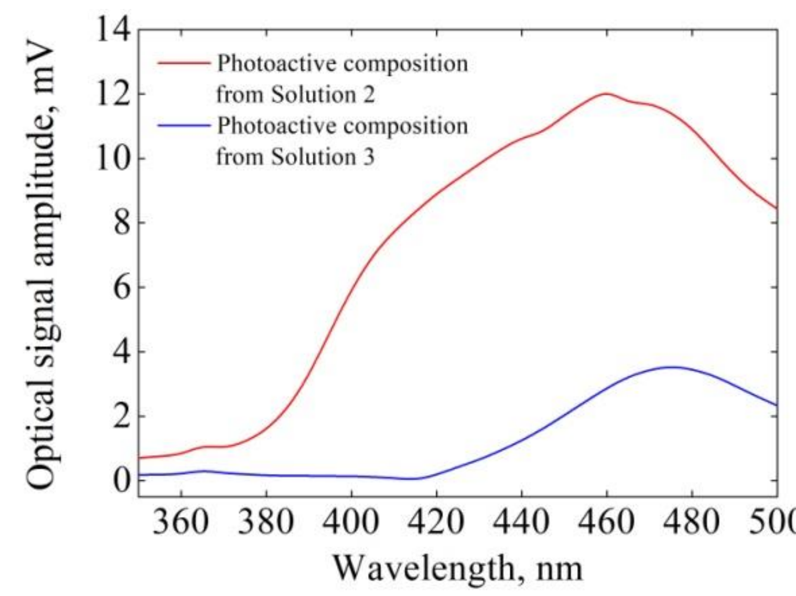

Figure 4. Measured spectral characteristic of the FOS optical signal amplitude

As can be seen from the curves in Fig. 4, a small peak is visible at wavelength of 365 nm which confirms the excitation of the photoluminescence. A further increase of the optical signal amplitude with a change in wavelength is due to the bandwidth of the optical cut-off filter.

Conclusion

Two types of luminescent fiber-optic sensors for detecting A-band UV radiation have been developed and experimentally studied.

The potential of the developed sensors to be used for the UV-A radiation detection was confirmed by the linear dependence of the optical signal amplitude at the sensor output on the UV radiation power. Among the benefits of the sensors there are an availability of raw materials and simplicity of fabrication, no need to change a construction of the fiber by partial removal of the cladding and/or deposition of coatings based on optically active materials, as well as an opportunity to function at considerably long distances far from sources of UV radiation.