Thin-film laser for ammonia and hydrogen chloride vapor

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ABSTRACT

This investigation is devoted to the study of the sensory abilities of the selected fluorophore (Nile red) in the laser mode. The results of a study of the generation characteristics of a polymethylmethacrylate film doped with Nile Red in the presence of ammonia and hydrogen chloride vapors are presented.

INTRODUCTION

Among a wide variety of molecular chemical sensors, luminescent sensors attract the attention of researchers due to their ease of creation and low cost, high sensitivity and speed of response to the presence of a detectable substance (analyte). When an analyte molecule meets an organic sensor molecule in an electronically excited state, a complex is formed with the transfer of an electronic charge towards the analyte. The luminescence intensity of the sensor molecule decreases [1].

The transition from the fluorescence mode (spontaneous emission) to the threshold lasing mode (transition from enhanced spontaneous emission to stimulated emission) is one of the ways to increase the sensitivity of optical molecular sensors [2]. In work [3], the response time decreased by a factor of 4.

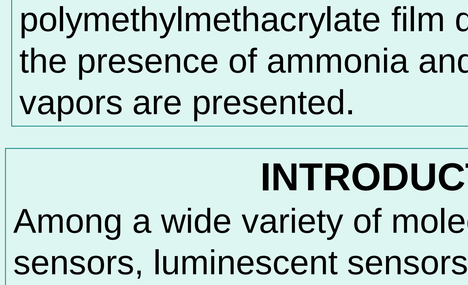

Fig.1. The structural formula of Nile Red

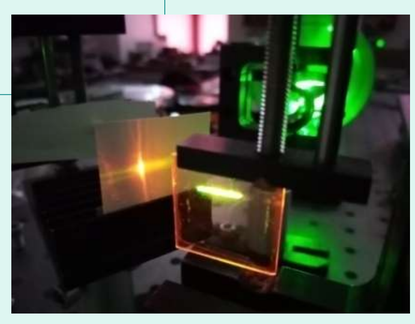

Fig.2. The thin film based Nile Red

EXPERIMENTAL PART

In this work, the dye Nile red (NR) was used as a fluorophore-sensor. This dye is able to quickly respond to changes in the chemical composition of the environment. To excite this fluorophore, it is convenient to use the second harmonic of a Nd3+:YAG laser because the absorption bands of this compound lie near the wavelength of this harmonic (λ=532 nm) [2]. Ammonia (NH3) and hydrogen chloride (HCl) were as analyte (Fig.1).

To fabricate thin-film samples, the chosen fluorophore was dissolved in tetrahydrofuran or toluene with a concentration of 10–3 M, and the obtained solutions were deposited on microscope glasses, which were preliminarily coated with hydrolysed tetraethoxysilane by spin-coating (Fig.2).

The generation characteristics were studied in a sealed cell, which was purged with analyte vapor mixed with inert gases. Registration of the generation intensity was carried out for 0, 10, 20, and 30 seconds after the addition of analyte vapors.

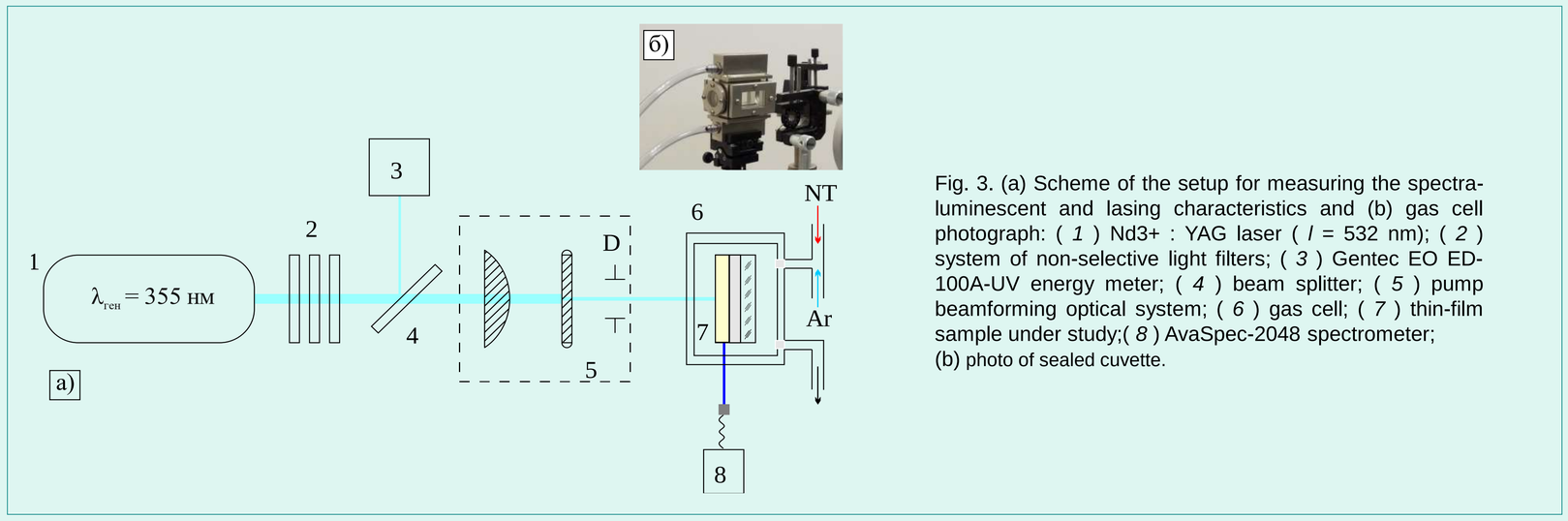

Fig. 3. (a) Scheme of the setup for measuring the spectra-luminescent and lasing characteristics and (b) gas cell photograph: (*1*) Nd3+ : YAG laser (*l* = 532 nm); (*2*) system of non-selective light filters; (*3*) Gentec EO ED-100A-UV energy meter; (*4*) beam splitter; (*5*) pump beamforming optical system; (*6*) gas cell; (*7*) thin-film sample under study;(*8*) AvaSpec-2048 spectrometer;
(b) photo of sealed cuvette.

RESULTS AND DISCUSSION

The lasing spectra of NR films in HCl and NH3 vapours are presented in figures 4 and 5. Generation spectra of polymethylmethacrylate (PMMA) films doped with NR were obtained at a wavelength of 602 nm.

As a result of the studies, the spectra of generation of sensor films under the influence of analyte vapors were obtained. After the interaction of a PMMA film from a solution of tetrahydrofuran doped with NR with HCl vapor for 10 seconds, the generation intensity dropped by 64%; after another 30 seconds the generation broke down

The intensity of generation of a PMMA NR film from a toluene solution decreased in the presence of NH3 vapor by 70% within 10 seconds, and after 20 seconds the generation broke down (Fig.5).

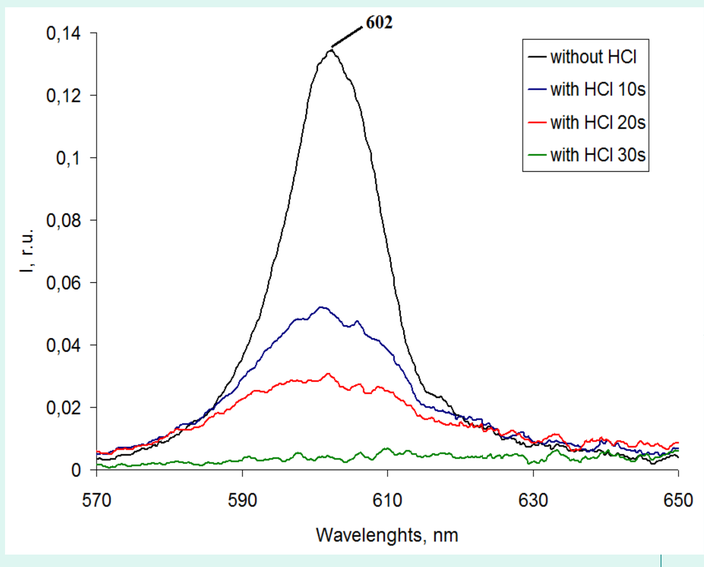

Fig.4. Lasing spectra of of a PMMA film from a solution of tetrahydrofuran doped with NA with HCl vapor

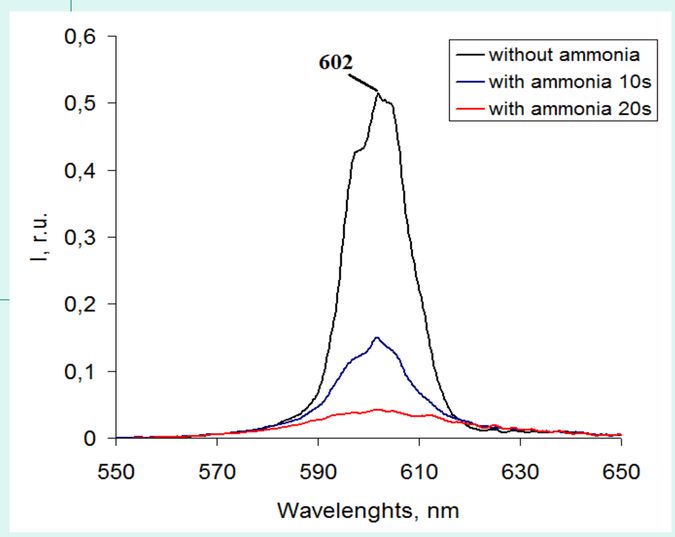

Fig.5. Lasing spectra of of a PMMA film from a solution of toluene doped with NR with NH3 vapor

CONCLUSION

Thus, the Nile Red laser dye has promising sensory abilities for the recognition of ammonia and hydrogen chloride vapors. The possibility of creating solid-state photoexcited laser sensors for the detection of selected analytes is shown.

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