Optica Applicata, Vol. XXIX, No. 1–2, 1999

Spectral response of integrated-optic ammonia sensor

ZBIGNIEW OPILSKI, PAWEŁ KARASIŃSKI, ALEKSANDER OPILSKI

Institute of Physics, Technical University of Silesia, ul. Bolesława Krzywoustego 2, 44–100 Gliwice, Poland.

The paper presents the structure of measurement stands for spectral measurement of sensor layers sensitive to the presence of ammonia vapours in the atmosphere surrounding them. Also the structure of a waveguide sensor model for detection of ammonia vapours has been presented, together with measurement results involving such a sensor.

1. Introduction

The main aim of the work was to construct a laboratory model of a waveguide sensor for detection of ammonia vapours. The concept for the construction of such a sensor is presented in Fig. 1. The strip multimode waveguide made with the use of planar technology is covered by the sensor layer whose function is to detect the

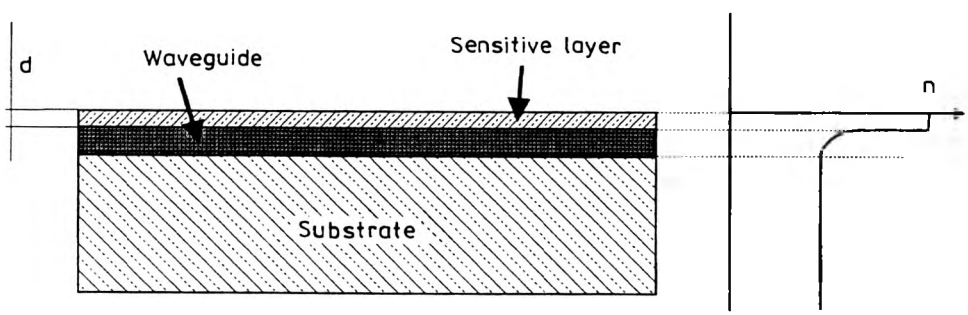

Fig. 1. Diagram of the investigated structure of the waveguide sensor layer.

presence of ammonia vapours. Adsorption of ammonia vapours through this layer results in the change of its transmission properties. Since the said layer is placed directly on the surface of the strip waveguide and is coupled optically with it by means of the evanescent field of waveguide modes, therefore the changes of sensor layer transmission must influence the spectral composition of light leaving the sensor [1]. The sensor is excited by the wide spectrum light, and the detector is placed at the sensor's output. Its function is to detect changes in the spectral composition of light leaving the sensor.

2. Structure of waveguide sensor for detection of ammonia vapours

The design concept of such a sensor is presented in Figure 1. The waveguide constructed for the purpose of our investigation was a strip multimode waveguide. It was made in soda-lime glass through the diffusion of silver from the melted $AgNO_3$ bath at temperature 300 °C over 4 h, and then the waveguide was subjected to thermal treatment at 450 °C over 1.5 h [2]. The diffusion was carried out through the mask of the window width of 20 μm. Standard telecommunication multimode waveguides were coupled to the strip. The strip was 22 mm long.

The waveguide was spin-coated with a mixture of polystyrene and bromophenol blue dissolved in chloroform. Using this method, the thickness of the coated layer was about 200 nm. The thickness of the layer is very small due to two reasons. Firstly, the changes of spectral properties effected by the presence of gas vapours are taking place only in the vicinity of the sensor layer's surface which gets into direct contact with these vapours. If the thickness were too great, the waveguide would not see spectral changes taking place on the opposite side of the layer. The second reason is connected with the attenuation effected by the presence of sensor layer and its influence on the light being propagated in the waveguide strip. The said layer is characterized by higher refractive index than the waveguide structure and by much higher attenuation. If the thickness of this layer were too great, then the principal part of waveguide mode energy would concentrate just in the sensor layer, where the attenuation is high. The said problem is graphically illustrated in Fig. 2, where the

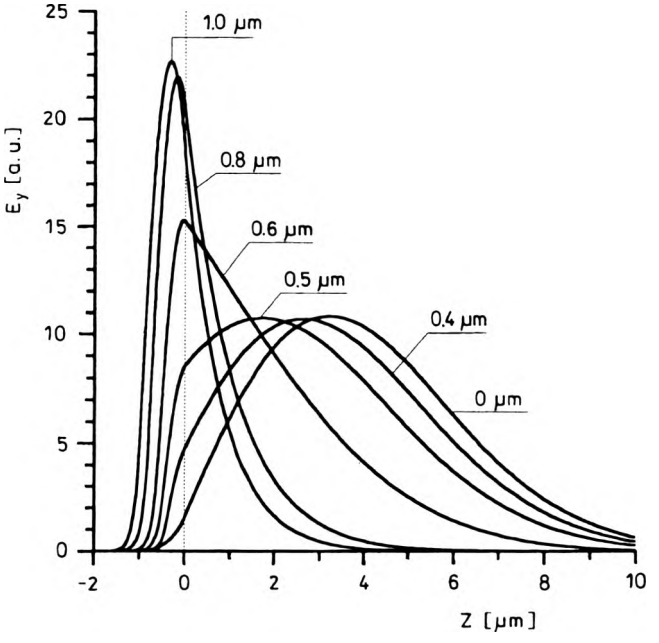

Fig. 2. Influence of the sensor layer thickness on the distribution of the electrical field of the zero order mode.

distribution of electrical field involving the zero order mode is presented. The location of glass surface is marked with the vertical broken line. The sensor layer is located on the left of the line. The thickness of sensor layer is the parameter of the curves.

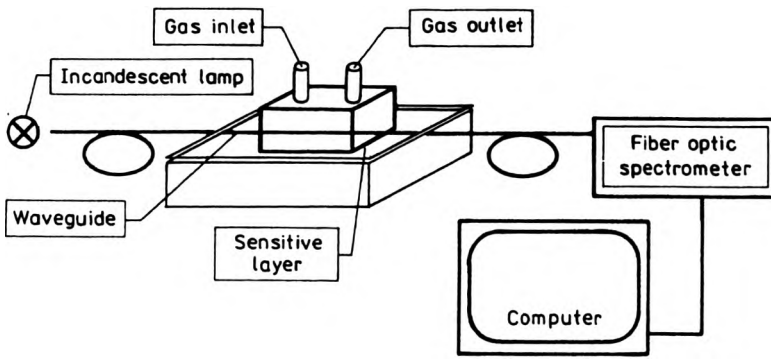

Fig. 3. Measurement system.

The measurement system of the waveguide gas sensor is presented in Fig. 3. A mixture of gases was introduced into the system, the composition of which was determined in the system with a computer controlled gas mixing set-up. An incandescent lamp, which provides a wide spectrum, was used as a light source. A waveguide spectrometer was used as a detector. Its structure was based on a microspectrometer manufactured by the firm microParts furnished with a CCD array. The said spectrometer works in the spectral range from 380 to 780 nm with the spectral resolution of 12 nm. Light is introduced to the spectrometer by means of a multimode waveguide fibre 105/125 μm terminated with a ST connector. The spectrometer uses the parallel interface (printer's output) to communicate with the computer.

3. Measurement results

In Figure 4, we can see the feedback provided by the sensor to the periodic action exerted by air and ammonia vapours of the concentration 11.8 ppm at temperature 21 °C. As shown by the spectral characteristic of the strip waveguide, there is strong attenuation of light having the wavelength lower than 600 nm. The presence of ammonia vapours results in the following: drop in light intensity and change in the location of the maximum of spectral characteristic with respect to the wavelength. Both of the said effects can be used to detect ammonia vapours.

Figure 5 provides the results of light intensity measurements for two selected wavelengths during the periodic action of air and ammonia vapours of the concentration 11.8 ppm at temperature 21 °C. The wavelengths were selected in such a way that the measurement taken on one of them could create a reference for the other case. It can be observed that the interaction of ammonia with the layer is

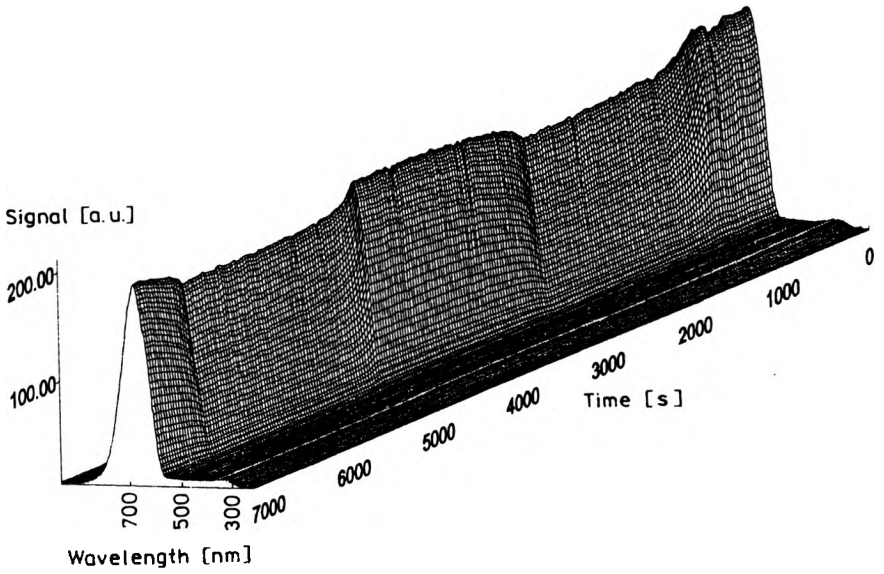

Fig. 4. Evolution involving the light spectrum leaving the sensor effected by the periodic action of air and ammonia vapours of the concentration 11.8 ppm.

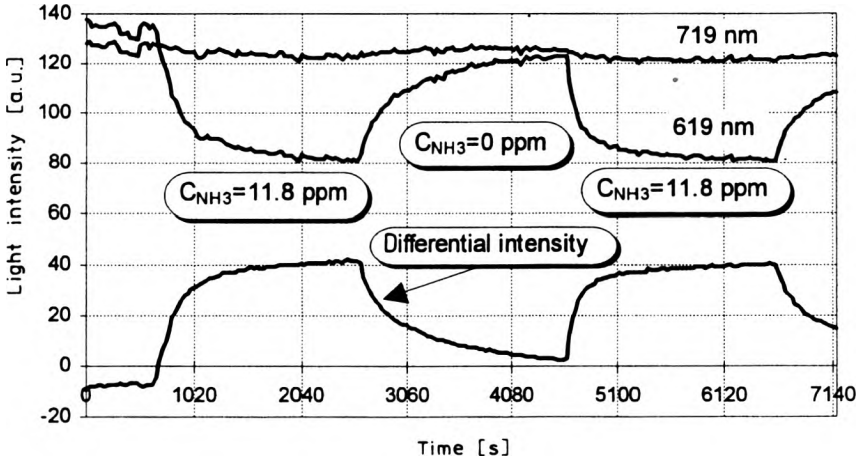

Fig. 5. Changes in light intensity for the selected wavelengths caused by the presence of ammonia vapours.

clearly evident at the wavelength of 619 nm. Due to the presented detection method we can at least partially eliminate the influence caused by the changes of light intensity and attenuation of waveguide channel.

The measurement system makes it possible to follow the displacement of the maximum of light spectrum effected by the influence of gas adsorbed by the sensor layer. The spectrometer applied together with the software controlling it allows us to detect the changes of spectral characteristic maximum with the resolution much

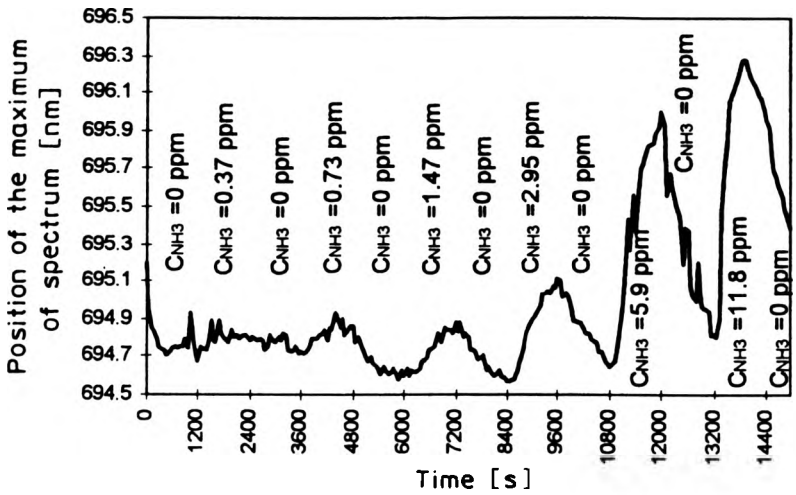

Fig. 6. Influence of ammonia concentration on the position of spectrum maximum of the sensor layer.

below 1 nm. It turns out that the position of the maximum of spectral characteristic is the function of the concentration of the gas being measured. Figure 6 presents changes in the position of the maximum during the periodic action of ammonia on the sensor layer. The sensor was subjected to the activity of ammonia whose concentration was increasing gradually from 0.37 ppm to 11.8 ppm. The aim of these measurements was to estimate the sensitivity threshold of the method under investigation. As can be observed, the threshold can be estimated at the value of about 1 ppm. Another important parameter is the sensitivity of the displacement of the spectral charactersitic maximum with respect to gas concentration which effected this displacement. This sensitivity can be estimated at the value of about 0.2 nm/ppm. It should be emphasized that the time needed to regenerate the sensor layer is long.

Similar measurements were carried out in the presence of SO_2 and NO_2, with the concentration of gas vapours ranging from 0 to 160 ppm. The results obtained are indicative of the fact that the sensor layer is much less sensitive to the presence of these gases. The sensitivity in question was estimated at the value of about 0.0018 nm/ppm. It constitutes about 1% sensitivity rating to ammonia.

4. Summary

The paper presents the structure and results of spectral measurements involving a laboratory model of the waveguide strip ammonia sensor. The sensor's sensitivity ratings to the presence of ammonia vapours, SO_2 and NO_2 vapours were determined. Comparative studies involving these sensitivity ratings indicate that the sensor exhibits high selectivity to the presence of ammonia vapours.

Acknowledgements — This work was carried out under the Research Project BW-430/RMF-1/98.

References

[1] KLEIN R., VOGES E., Anal. Chem. **349** (1994), 394.
[2] OPILSKI A., ROGOZIŃSKI R., BŁAHUT M., KARASIŃSKI P., GUT K., OPILSKI Z., Opt. Eng. **36** (1997), 1625.

Received October 20, 1998