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Plasmonic Gas Sensor

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1. Introduction

Gas detection is an important field of medical gas sensing from exhalation, bio-markers of disease can be detected without any medical intervention. In case of environmental sensing in landfills, detection of greenhouse effect gases, exhaust fumes from cars, monitoring of industrial processes, the gases concentration should be monitored continuously in real time with 1 ppm precision or better.

The non-dispersive infrared (NDIR) absorption method is widely used for gas sensing, because of its simplicity and high sensitivity. NDIR is based on the single-wavelength detection of a molecular vibrational mode; however, because of the small extinction cross-sections of these modes, a long optical path (in a gas cell) is required, and sensors become relatively large or require optical folding of the light path.

We have already demonstrated surface-enhanced infrared absorption (SEIRA) with metal hole array (MHA) micro-structures[1]. A strong absorption enhancement appeared on the transmission peaks, due to the electromagnetic field enhancement in the MHA holes. Here we apply the MHA structures for the gas sensing application to increasing the sensitivity and reducing the size cost of NDIR system[2].

2. Experiments

The fabrication of the designed MHA has been done via standard lithography and lift-off processing. The structures were defined by standard contact photolithography using mask projection. Both side polished Si substrate were coated by COAT200 (Tokyo Ohka Kogyo Co. Ltd.) to obtain a hydrophobic surface for increasing the adhesion strength of photoresist. Then, a positive type photo-resist (OFPR-500, Tokyo Ohka Kogyo Co. Ltd.) was spin-coated at 3000 rpm for 60 s. Structures are fabricated at 2×2 cm^2 area with uniform shapes. The series of hole diameter c and period a combinations are designed as (c, a) = (1.4, 2.9), (1.5, 3.1), (1.6, 3.3), (1.7, 3.5), (1.8, 3.7), (1.9, 3.9), (2.1, 4.2), and (2.3, 4.6) μm, respectively. Especially for the SF_6 (which is the target gas of this work) gas detection, (1.6, 3.3) setup was well matched the gas vibrational peak and MHA transmission.

For NDIR gas sensing, SF_6 gas was used as the target gas. Several concentrations of gases are injected into the 2 cm gas cell. MHA structures on Si substrate was used as the window. Light source and detection were used commercially available for NDIR and 10 μm of wavelength detection.

3. Results and Discussions

We have performed three different configurations for comparison. The configurations and its gas sensing results are shown in Fig. 1. Firstly, both MHA patterns were located on the inward wall of the window (black-framed picture). Secondly, one MHA mirror was flipped over with bare Si facing the gas cell interior red-framed; in the third configuration, both MHAs were facing outside the cell (blue-framed). The response of gas concentration was drastically changed by their window configurations. Especially both MHAs are faced to the SF_6 gas, its lowest detection limit has reached to the 5 ppm. From this result, the enhancement by the MHA critically affects to the gas sensitivity.

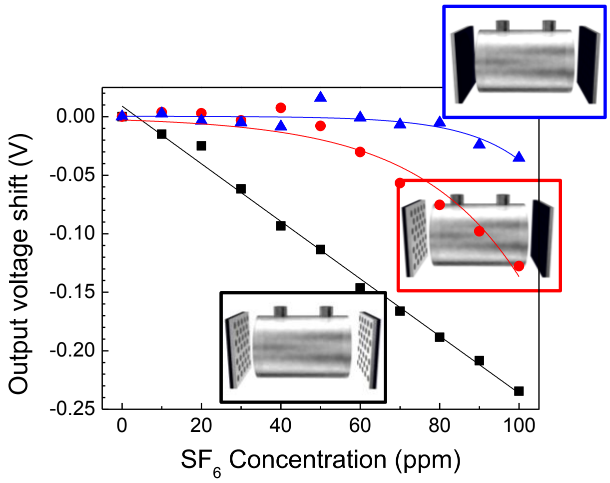

Fig. 1 The response to the SF_6 gas concentration with different three configurations of MHA windows.

4. Conclusion

In this study, we demonstrate SEIRA with MHAs for gas sensing. With the MHA, gas sensitivity drastically increased. The surface area of MHA, which is facing to the target gas and light pass, are important for the sensing ability. Therefore customizing there configuration and electromagnetic field enhancement, ppb or less gas sensing would be expecting.

References

[1] Y. Nishijima et. al, Opt. Mater. Express, 2, 1367-1377 (2012).
[2] Y. Nishijima et. al, Opt. Mater. Express, *in press* (2013).