Highly Sensitive Ammonia Gas Detection with a Silica Toroid Microcavity Packaged in a Box

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Abstract

We demonstrate highly sensitive ammonia gas (NH₃) detection with a packaged silica toroid microcavity coated with 20-PAA/PAH multilayers. Our experiment shows that a detection sensitivity of 450 ppb is achieved.

Background: Sensing w/ a WGM microcavity

- Can realize downsizing and high sensitivity by using microcavity
  - w/ a cavity
  - w/o a cavity
  - Lights interact many times
  - Small size & sensitivity CAN coexist
  - Light interacts only once
  - Small size & sensitivity CANNOT coexist

Principal of microcavity sensor

- Optical microsphere
- Nanoparticles attached
- Cavity resonance shifts when nanoparticles attach to a microcavity

Surface treatment for sensitivity improvement

- Bare silica toroid microcavity is inactive with the ammonia
  - We used PAA/PAH multilayers to raise reactivity
    - PAA/PAH multilayers: Multilayer thickness changes in respect to pH
  - Method (ESA: Electric self-assembly)
    - PAA/PAH: organosilane (positive charge) + Ethanolamine (negative charge)
    - Make bilayers: ESA + EISA
    - Bake 1 hour at 100°C
  - Comparison before and after coating
    - Thickness of a layer: 20 nm~30 nm
    - Quality factor: 6.2 × 10⁵ ~ 7.5 × 10⁵

Results: Ammonia gas sensing

- Experimental setup
  - Experimental results
    - (a) Conc.: ~1.23 ppm
      - Error rate: 4.96 × 10⁻⁴%
    - (b) Conc.: 1.23 ppm
      - 450 ppb detection limit is achieved
      - 1.67 ppb detection resolution is achieved

Microcavity packaging

- Apply UV curable polymer
- Alignment
- UV light irradiation

- UV curable polymer does not cover the silica toroid microcavity
  - We can measure the resonance after a several month

Conclusions

- We experimentally demonstrated highly sensitive and practical ammonia gas (NH₃) detection with a packaged silica toroid microcavity with PAA/PAH multilayers, and obtained a lower detection limit and higher detection resolution than other types of ammonia gas sensors.
- Because the Q factor of the silica toroid microcavity in this study was not high, we can expect to fabricate a more highly sensitive ammonia gas sensor by using a silica toroid microcavity with a higher Q factor.

Acknowledgements

Grant-in-aid from the Ministry of Education, Culture, Sports, Science and Technology (MEXT), (KAKEN 15H05429)