

Mind the nanogap: Fast and sensitive oxygen gas sensors

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Mind the Nanogap: Fast and Sensitive Oxygen Gas Sensors

Oxygen gas sensors are crucial in many technological fields

Applications: Industrial, Biomedical, Environmental

Nanogap gas sensors based on ceria offer great performance...

...but they are challenging to fabricate for gaps smaller than 100 nm

Introducing robust 20-nm nanogap oxygen gas sensors

Bottom-contact type also available! (Cerium oxide film with optimal thickness, Pt, SiO₂, Si)

Top-contact type (Platinum/Platinum electrodes, Cerium oxide layer, Silicon dioxide layer, Silicon substrate)

Oxygen gas molecules inhibit electron hopping

Resistance, R (GΩ) vs. Time (S) graph showing selectivity towards oxygen (O₂) and faster response time compared to H₂ and CO.

- Selective towards oxygen
- Faster response time

- Lower operating temperature than microgap sensors
- Stable even after six months
- Easily reproducible gap distance (20 nm)

This nanogap gas sensor is promising for general gas-sensing platforms

- Wearable sensors
- Industrial gas control systems
- Environmental monitoring

20-nm-Nanogap oxygen gas sensor with solution-processed cerium oxide
Phan et al. (2021) | 10.1016/j.snb.2021.130098
Sensors & Actuators: B. Chemical

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Credit: Tokyo Tech

Oxygen (O₂) is an essential gas not only for us and most other lifeforms, but also for many industrial processes, biomedicine, and environmental monitoring applications. Given the importance of O₂ and other gases, many researchers have focused on developing and improving gas-sensing technologies. At the frontier of this evolving field lie modern nanogap gas sensors—devices usually comprised of a sensing material and two

conducting electrodes that are separated by a minuscule gap in the order of nanometers (nm), or thousand millionths of a meter. When molecules of specific gases get inside this gap, they electronically interact with the sensing layer and the electrodes, altering measurable electric properties such as the resistance between the electrodes. In turn, this allows one to indirectly measure the concentration of a given gas.

Although nanogap gas sensors bear many more attractive properties than the closely related microgap gas sensors, they have proven much more difficult to mass produce reliably for gap distances in the order of tens of nanometers. At the Laboratory for Materials and Structures of Tokyo Tech, a team of scientists led by Dr. Yutaka Majima is seeking ways to fabricate better nanogap sensors. In their latest study, which was published in *Sensors & Actuators: B. Chemical*, the team presents a new strategy to produce nanogap oxygen gas sensors using platinum/titanium (Pt/Ti) electrodes and a cerium oxide (CeO_2) sensing layer.

Two sensor designs were tested by Prof. Majima and his team. In the bottom-contact design, the CeO_2 sensing layer is first deposited onto a silicon substrate and the two Pt/Ti electrodes are laid on top of the CeO_2 through [electron beam lithography](#) (EBL). With EBL, one draws custom shapes on a resist film using a focused beam of electrons with extreme precision. This then allows for the selective etching or evaporation of Pt/Ti regions, thus giving shape to the nanogap electrodes. The other design (top-contact) was produced using EBL as well, but the CeO_2 was applied on top of the Pt/Ti electrodes as a thin coating layer.

With this fabrication strategy, the team managed to reliably produce stable Pt nanogaps as small as 20 nm, which was unprecedented in the literature. Both sensor designs exhibited similar and highly promising performances, as Dr. Majima remarks: "For a gap separation of 35 nm, our nanogap O_2 gas sensors exhibited a fast response time of 10 seconds at a relatively low operating temperature of 573 K (300 °C); this

[response time](#) is approximately three orders of magnitude shorter than that of microgap sensors under the same measurement conditions." Moreover, their procedure offers better scalability than those for previously developed nanogap gas sensors.

In addition to the sensor designs, this study provided important insights on the electron hopping mechanisms by which O₂ molecules modulate the resistance between the Pt electrodes in the presence of CeO₂ at the nanogap. Taken together, the results of this study are paving the way to better gas-sensing devices, as Dr. Majima concludes: "Our nanogap gas sensors could be promising candidates for the development of a general gas-sensing platform with a low operating temperature." In due time, nanogap gas [sensors](#) shall surely find their way into more fields of application, including wearable biomedical devices, industrial condition monitoring, and environmental sensing.

More information: Trong Tue Phan et al, 20-nm-Nanogap oxygen gas sensor with solution-processed cerium oxide, *Sensors and Actuators B: Chemical* (2021). [DOI: 10.1016/j.snb.2021.130098](https://doi.org/10.1016/j.snb.2021.130098)

Provided by Tokyo Institute of Technology

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