Micromachined silicon hotplate arrays with integrated gas sensitive MOS capacitors

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In a companion paper we report on micromachined gas sensor arrays containing four different kinds of metal oxide gas sensing layers deposited on four independently heatable silicon hotplates. These hotplates have been formed by employing silicon-on-insulator (SOI) technologies for producing the thermally insulated sensor platforms. Such sensor platforms not only provide for low heating power consumption and small thermal response times (5-10 ms) but also open up new degrees of freedom for producing miniaturized silicon gas sensing devices.

In the present contribution we should like to extend on our SOI approach showing that gas sensitive MOS capacitors with catalytically active Pt electrodes can be integrated into SOI heater platforms to form sensor arrays. Such low heating power gas sensing devices could not previously be realized using the normally employed silicon-oxinitride membrane technologies.

Silicon MOS gas sensors have first been reported by Lundström in 1973 and have become known as selective H_2 gas sensors. This same group has later shown that SiC MOS devices can also be very good hydrocarbon sensors when operated at elevated temperatures above 400°C. This latter possibility is a consequence of the increased catalytic activity of the noble metal electrodes at these elevated temperatures and the ability of the SiC to retain semiconducting properties in this temperature range.

Recently we have shown that the gas sensing properties of such devices can be systematically altered by perforating the catalytic gate electrodes (see Fig.1): devices with dense Pt electrodes only allow H_2 and hydrocarbon species to be detected from which H atoms can be abstracted at the catalytic Pt surface. Perforated Pt electrodes, on the other hand, allow all kinds of molecular species to adsorb at open patches of SiO_2 as molecular dipoles. Such dipolar absorption yields a much wider range of gas sensitivities as typically observed with metal oxide gas sensors. Unlike this latter kind of sensors, however, no response to ozone and a very small response to water vapor has been observed with MOS devices.

Building on these previous results we have integrated MOS capacitors with catalytically active Pt electrodes to arrive at a fully microelectronics compatible silicon gas sensing technology. Attempting to make the full range of gas sensing possibilities of SiC MOS capacitors available to Si MOS gas sensors, hotplate-integrated MOS gas sensors were operated in a pulsed temperature mode. In this mode of operation the devices are repeatedly switched between high-temperature chemical sampling (T ~ 400°C) and low-temperature electrical read-out (T ~ 30°C) modes. Employing this kind of operation and making use of dense Pt gate electrodes, H_2 and a range of more stable hydrocarbon species (ethane e.g.) could be detected via quenched in CV-shifts measured at room temperature. Using the same kind of sensor operation principle, CO and NO_2 could also be detected using devices with less dense or systematically perforated gate electrodes.

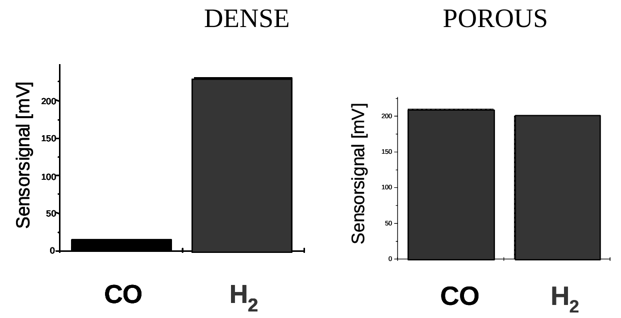

Fig.1: Gas response of SiC MOS capacitors operated at a constant temperature of 400°C using dense or porous Pt gate electrodes.

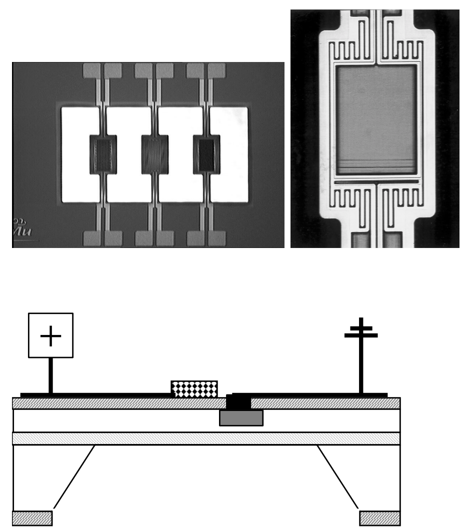

Fig.2: (a) view onto a silicon hotplate chip with three independently heatable hotplates with integrated Si MOS gas sensors; (b) detail view onto a single hotplate displaying Pt heater meanders and a catalytic gate MOS capacitor; (c) cross section through the hotplate chip. The platinum gate in the middle is maintained at positive potential, the back electrode is grounded.

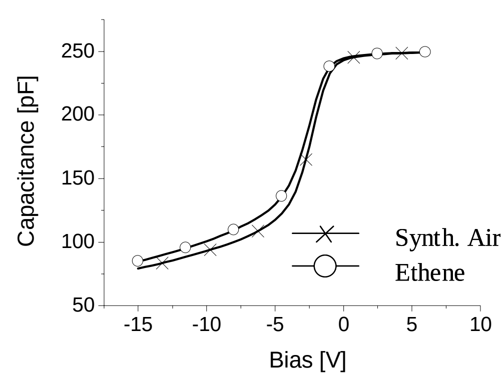

Fig.3: CV-curves measured on a Si MOS capacitor at room temperature after quenching from a high-temperature chemical sampling phase (400°C) in synthetic air (x) or in synthetic air containing a small concentration of ethane (o). Concentrations down to 100ppm can be detected.

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