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Micromachined Chemical Sensors

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We succeeded in making a variety of miniature oxygen electrodes. In upgrading the oxygen electrode to a really practical level, the most serious problem is electrochemical crosstalk between electrodes, which adversely affects the sensor's response. To eliminate crosstalk, we make a novel miniature oxygen electrode.

The oxygen electrode chip is 2×15 mm. The electrode was made by bonding a glass substrate with detecting electrodes and a grooved silicon substrate. To reduce electrochemical crosstalk, we made cavities that accommodate the electrolyte solution only around each electrode. We connected these cavities with long narrow grooves that match the electrode. Each groove was connected to long narrow grooves to eliminate electrochemical crosstalk between electrodes. The working electrode area was etched completely through to the other side. We used an FEP membrane as the oxygen-permeable membrane. We stuck the membrane to one side of the silicon substrate. The electrolyte solution was incorporated via the grooves near the pads after the oxygen electrode was complete. The electrolyte solution was incorporated in the small cavity simply by immersing the chip in the electrolyte solution, putting the beaker in a chamber, and pumping out the air. A gel electrolyte could be used instead of a liquid electrolyte. We applied −0.6 V (vs Ag/AgCl) to the working electrode. The oxygen electrode gave clear response curves. The 90% response time averaged 30 s, and residual current at zero oxygen concentration was negligible. Generated current was plotted against the dissolved oxygen concentration at 25 °C. We obtained very good linearity. Although the output current was very stable, we always observed a sudden increase in current when the electrode broke down. The lifetime was extended to 30 h by impregnating the electrolyte in a gel.

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A miniature glass electrode was made using similar techniques. A Ag/AgCl reference electrode was formed on a 7740 glass substrate. The container for the electrolyte solution was made by anisotropically etching a silicon substrate. It has a through-hole with a fusion bonded glass membrane. The glass membrane on the sensitive area consists of 20-μm thick 7740 glass and 2.5-μm thick sodium–calcium glass. These two substrates were bonded by field-assisted bonding. The inside of the cavity was filled with an electrolyte solution. The electrolyte was buffered 0.5*M* KCl with a pH 7.20. If the electrode was well isolated electrically from the outer solution, a clear response curve was always obtained. The response time was less than 5 s. Electrode potential was plotted against pH. The gradient of the line was about −30 mV/pH at 25°C.

Some applications require a transducer, which is thrown away after only one measurement. To make an extremely inexpensive sensor, we used a polyester film as a substrate, a paraffin film to delineate the sensitive area and to attach the gas-permeable membrane, recycled paper to impregnate the electrolyte, and FEP as the gas-permeable membrane. Each chip is 5×25 mm. We incorporated the electrolyte solution by permeating it from one side of the paper. The 90% response time was 1.8 min and a good linear relationship was observed in its calibration curve.