A NEW ENZYME TRANSDUCER COMBINATION: THE ENZYME TRANSISTOR

B. Danielsson, K. Mosbach
Chemical center, University of Lund
Lund, Sweden

I. Lundstrom
Applied Physics, Likoping Institute of Technology
Sweden.

L. Stilbert
Research Lab. Electronics, Chalmers University of Technology
Gothenburg, Sweden.

The p-channel Pd-MOS-transistor used resembles an ordinary field-effect transistor, but the gate metal is a catalytic metal, palladium, instead of e.g. aluminum, which makes it sensitive to hydrogen (1). It has also been found to respond to other hydrogen containing gases such as NH₃ (1) and H₂S (2). The practical sensitivity of the device is better than 1 ppm of hydrogen or 10 ppm of NH₃ in air. As a number of enzymic reactions produce these gases we investigated the analytical potential of a combination of such a specific transistor with enzymes.

The transistor was mounted approximately 5 mm above the reaction solution of 1-2 ml in a stopper made of teflon that fitted into a small glass vessel (Figure 1). Reagents could be added through a small hole in the stopper and mixing was accomplished by a small magnetic stirring disc.

When the transistor is exposed to hydrogen or gases containing hydrogen such as NH₃, the gas is dissociated on the catalytically active palladium surface. The hydrogen atoms diffuse rapidly through the palladium film and form a dipole layer at the palladium-silicon dioxide interface (Figure 1). If the current through the transistor is kept constant, the voltage across it will
Fig. 1. Schematic representation of the Pd-MOS-transistor. The NH₃-sensitive device was mounted in a small glass vessel as shown to the left in the figure. Encircled in the middle is a cross-section of the structure. To the right is illustrated the dissociation of NH₃ on the surface of the palladium layer and the diffusion of hydrogen atoms through this layer towards the SiO₂ (3).

change as a function of the hydrogen concentration and can easily be registered by a recorder. It has been shown that the threshold voltage is a function of the hydrogen concentration according to the equation:

\[
V = \frac{K_1[H_2]^{1/2}}{1 + k[H_2]^{1/2}},
\]

where \(k_1\) and \(k_2\) are constants (1).

For ammonia the situation is more complex and the voltage seems to be proportional to \([NH_3]^{1/3}\) at low NH₃ pressures and a cubic root dependence seems to fit with the standard curve shown in Figure 2. This curve was obtained by adding enough NaOH to NH₄Cl solutions of various concentrations to convert virtually all ammonia to NH₃(g).

In other experiments NH₃ was produced by the action of urease on urea in 0.1 M TRIS buffer pH 8.5. Here the threshold voltage increased linearly with time and it was found that the rate of the voltage increase \(dV/dt\) (the slope) could be used to determine the amount of urea present in the sample. Alternatively, using an excess of urea the urease activity could be assessed. Urea concentrations down to 0.1 mM were easily determined (3).

The Pd-MOS-transistor was also tested in a flow cell through which the effluent from an enzyme thermistor (3), containing