Biosensors Based On Standard Dielectric Materials

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Ion sensors have many applications in the biomedical field. Specific examples are the measurement of K^+ and H^+ for ischemia monitoring during cardiac surgery [1], or for the evaluation of organ viability for transplantation. Miniaturized sensors based on silicon technologies have many advantages for this application field, such as allowing the use of small analyte quantities and the possibility of sensor integration on micromachined structures such as needles [2] (Fig. 1). Biomedical monitoring often requires single-use disposable biosensors, in which case the manufacturing volumes can be high but the unitary cost must be very low. Silicon technologies can be compatible with a low manufacturing cost for high volume fabrication, but this is only true if a standard manufacturing process is used.

Solid-state ion microsensors are usually based on ion-sensitive field-effect transistors (ISFET) or on microelectrodes. The operation of both devices is based on charge-exchange processes between a dielectric layer and the ions in a liquid solution. Achieving a long-term stability in ISFET devices requires the use of specific dielectric materials, such as tantalum oxide, which are not standard in microelectronics technology. However, in disposable monitoring applications the devices only operate during a limited time period, and in this case standard materials can be used.

In this work we discuss a number of ion sensor devices which have been fabricated using standard microelectronic dielectric materials for biomedical applications. We discuss the requirements imposed on the properties of dielectric materials by their use in ion sensor devices, and how these requirements are fulfilled by standard dielectric materials, such as silicon dioxide and nitride.

Sensitivity and selectivity of ISFETs to ions other than H^+ require the use of additional dielectric layers, usually polymeric, with some ionic conductivity. We show how standard polymers such as PVC can provide good sensor properties for biomedical measurements [2] (Fig.2). The same polymeric materials can allow obtaining ion-insensitive reference ISFETs (REFETs) which can be used for differential mode measurements [3]. An alternative approach to induce ion sensitivity in ISFETs is the modification of the inorganic dielectric layers by ion implantation [4].

Ion sensor devices sensitive to pH can also be fabricated in a commercial CMOS process [5] (Fig. 3), which allows the integration of sensors and signal-processing circuitry in the same silicon chip. In this case the dielectric materials that have been optimized for integrated circuit fabrication are used as ion-sensitive layers.

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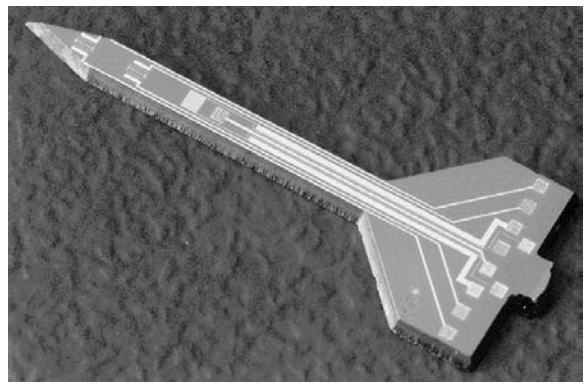

Fig. 1. Silicon needle with integrated ISFET ion sensors

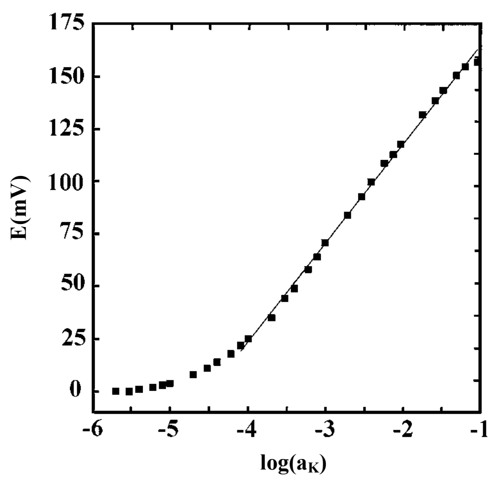

Fig. 2. K^+ response of an ISFET with polymeric membrane

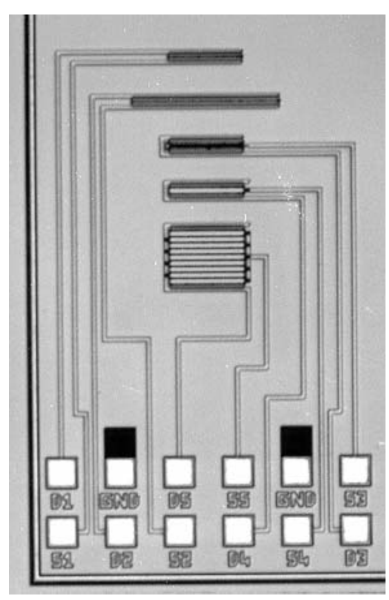

Fig. 3. ISFET sensors fabricated in a commercial CMOS process