PREPARATION AND CHARACTERIZATION OF THE MESA ISFET

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Introduction

Although the ISFET is commercially available nowadays, the encapsulation of ISFETs is still a problem. The commercially available ISFETs are encapsulated by a labour-intensive and expensive process.

Initially, packaging techniques used in IC technology were adapted to the packaging of ISFETs. However, the packaging of ISFETs has additional problems because the gate area has to remain unprotected and because ISFETs are used in electrolyte solutions which are, from the electrical point of view, hostile environments. Therefore, several new packaging techniques have been developed in the last decade [1, 2, 3]. Most of these techniques have still the disadvantage of their unsuitability for large scale production.

A different concept to reduce the problems of the packaging procedure is adaptation of the sensor geometry [4, 5]. These new geometries make them easier to encapsulate but they give rise to additional problems during ISFET fabrication. Therefore, most ISFETs are still encapsulated by hand.

This paper presents the fabrication and the characterization of the mesa ISFET. The three-dimensional structure of the mesa ISFET reduces the encapsulation problems because the gate area can be kept more easily free from encapsulant. Even encapsulation by hand becomes easier and less time consuming. The characteristics of the mesa ISFET are compared with the characteristics of the non-mesa ISFETs which were produced by the standard fabrication process.

Design and fabrication

Figure 1 shows the novel three-dimensional structure of the ISFET. In this structure the gate area is on top of a mesa (80 μm high) while the contact pads are

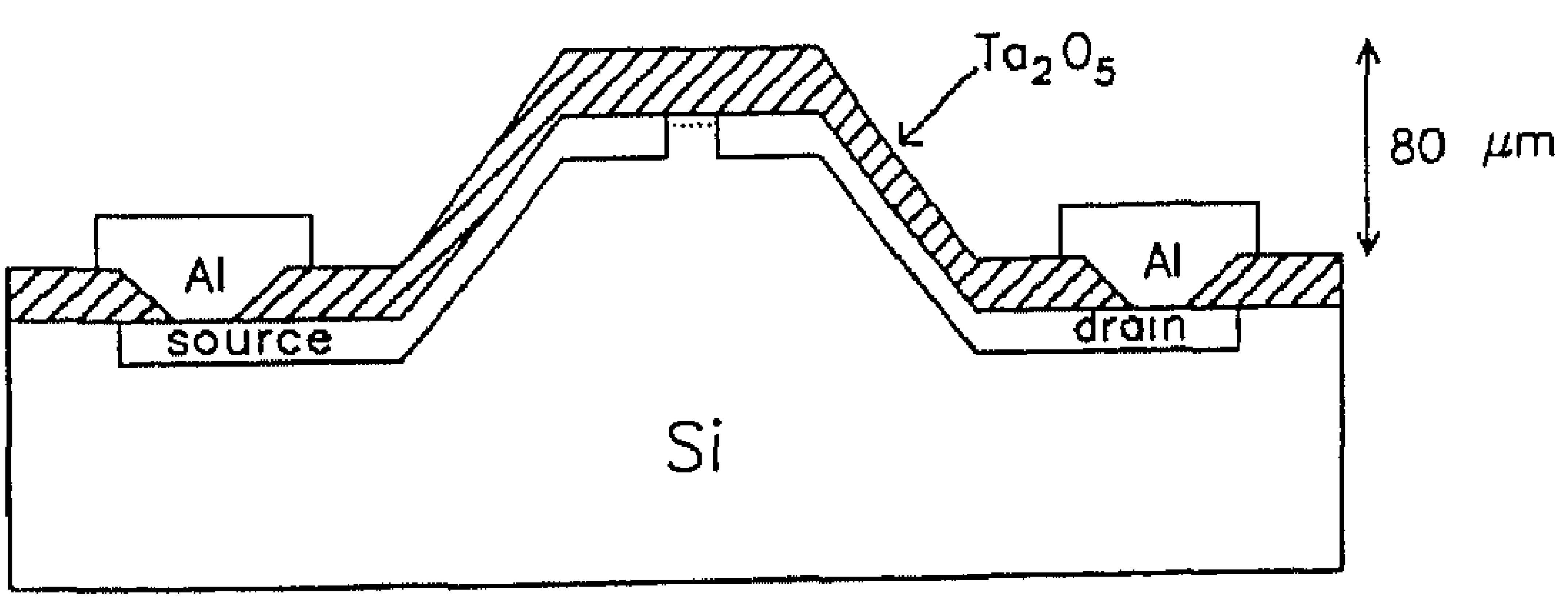

Figure 1 *Cross-sectional view of the mesa ISFET.*

on the lower part of the device. Clearly, the height of the mesa can be adapted for specific applications. For example, the mesa can be glued in a hole of a foil with backside contact leads to be attached to the chip contact pads. The new geometry has the additional advantage that it enables a flat packaging that prevents solids to deposit in the gate area.

The fabrication of the mesa ISFET requires only one additional step, formation of the mesa, compared to the standard fabrication process. The mesas are formed by anisotropic etching with a KOH-isopropanol (IPA) solution. This highly concentrated solution was not stirred to prevent the formation of hillocks. We choose to use IPA to reduce the undercutting of the corners instead of a compensation structure for the corner since the latter approach would only be sufficient for one depth.

After preparation of the mesa, the ISFETs were made by the normal fabrication process [6]. Photolithography on three-dimensional structures is often a problem due to poor step covering and delineation problems. Muñoz et al [7] showed that the use of photosensitive polyimides can solve these problems. Normal (non-mesa) ISFETs were produced according to the standard procedure using conventional photoresist.

Results and discussion

The use of a KOH-IPA etching solution gave mesas with an acceptable degree of convex corner undercutting. The amount of hillocks was minimal when the solution was not stirred.

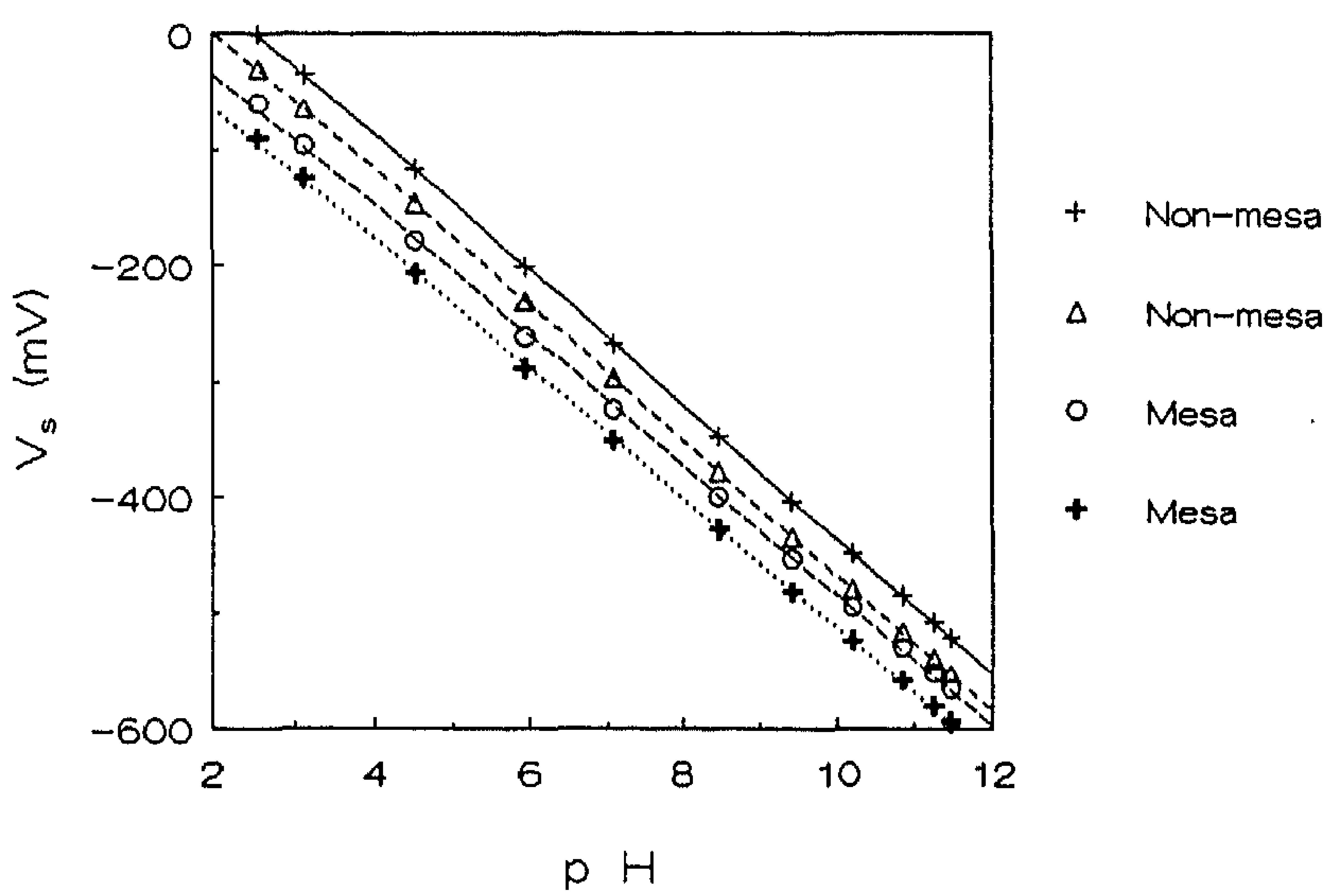

Figure 2 *The sensitivity of mesa and non-mesa ISFETS.*

The use of the photosensitive polyimide HTR 3-200 as a photoresist gave the best results with respect to step covering. However, it was necessary to use two layers of this polyimide to cover the sharp edges of the mesa. A hard bake at 300 °C was necessary for the polyimide to withstand the HF etching solution. The photosensitive polyimide was removed by H_2O_2/H_2SO_4 at 120 °C.

Figure 2 shows the pH response of both types of ISFETs. The sensitivity of both types is nearly the same. The sensitivity of 57 mV/pH for the mesa ISFET is predicted by the theory.

The I_d-V_{GS} characteristics of both types of ISFETs are taken to determine the treshold voltage. This treshold voltage was shifted from 1.5 V for the non-mesa ISFET to 2.4 V for the mesa ISFETs. This shift is no problem for the use of the mesa ISFETs.

The initial drift of the mesa ISFETs is higher than the initial drift of the non-mesa ISFETs. The more important long-term drift of the mesa ISFET is also higher than the drift of the non-mesa ISFET. This long-term drift of the mesa ISFET is 0.8 mV/hr (non-mesa ISFET 0.02 mV/hr). The higher drift rates of the mesa ISFET can be caused by several reasons. A probable explanation is that the silicon and the silicon dioxide are contaminated with potassium causing a larger drift. Further research using non metal containing etchants is necessary to find the origin of the higher drift rate and to reduce the drift rate.

Conclusion

From the obtained results it can be concluded that the fabrication of the mesa ISFET is possible. The chemical and electrical characteristics of the mesa ISFET are the same as the characteristics of the non-mesa ISFETs. However, the drift rate of the mesa ISFET is higher than that of conventional ISFETs, which may be due to the preceding etch process may influence.

Acknowledgement

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