Ultraminiature pH ISFET with back side contacts and Ta_2O_5 gate material for use in a guidewire tip

A.Prak[1], H.H. van den Vlekkert[1] and M.-A. Levine[2]

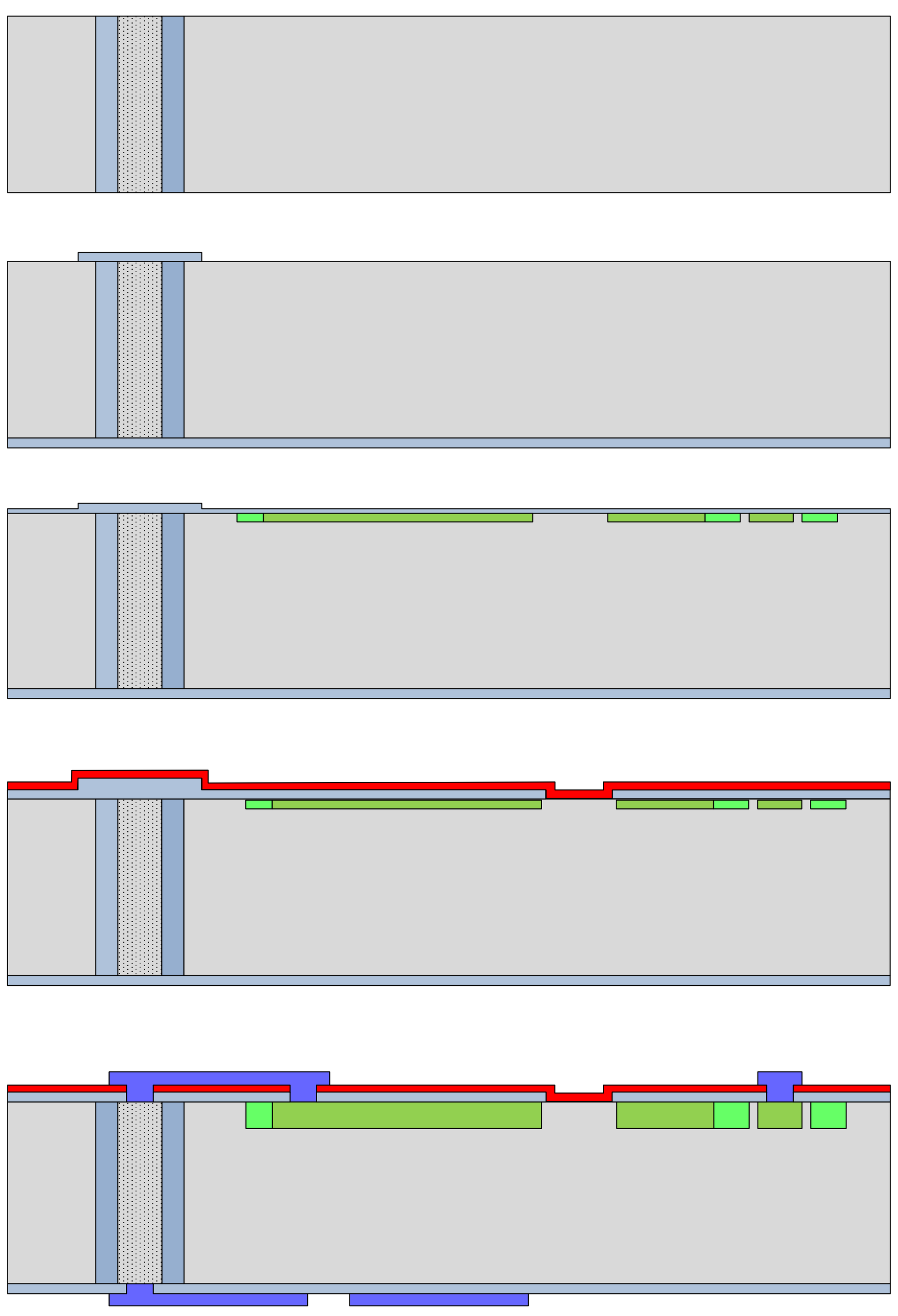
[1] LioniX International, Enschede, the Netherlands

[2] Makaha Medical LLC, Pottstown, PA 19465, USA

Introduction

We fabricated ISFETs (ion sensitive field effect transistors) with backside contacts and a Ta_2O_5 gate. The chip fits in a guidewire tip with an internal diameter of 0.3 mm which will be inserted into the brain vasculature to monitor patients suffering from stroke. Because of its small size the ISFET needs back side contacts. Most back side contacted ISFETs reported in literature have been fabricated by some form of KOH etching. Our requirements of a very small footprint and a CMOS compatible process forced us to explore the possibilities to realize TSVs (through silicon via's) by DRIE (deep reactive ion etching). We used IceMos TSV process to realize the back side contacts. This process is based on through wafer DRIE, thermal oxidation of the via sidewalls and a polyfill process with phosphourous solid state doping. The size of the fabricated chips is 0.23 x 1.00 x 0.20 mm^3 (w x l x t) which results in approx. 20.000 chips on a single 100 mm wafer. As far as we know this is the smallest ISFET chip ever made.

Process



Wafer cross section after realization of TSV's (Icemos) and backgrinding (Optim Wafer Service).

After SiO_2 TEOS deposition (diffusion barrier and isolation).

After implantation the source/ drain areas and the channel stopper.

After growing the gate oxide and deposition of Ta_2O_5.

After etching contact holes and aluminum deposition on front side and back side.

Fig 1. Fabrication process of the ISFET with back side contacts.

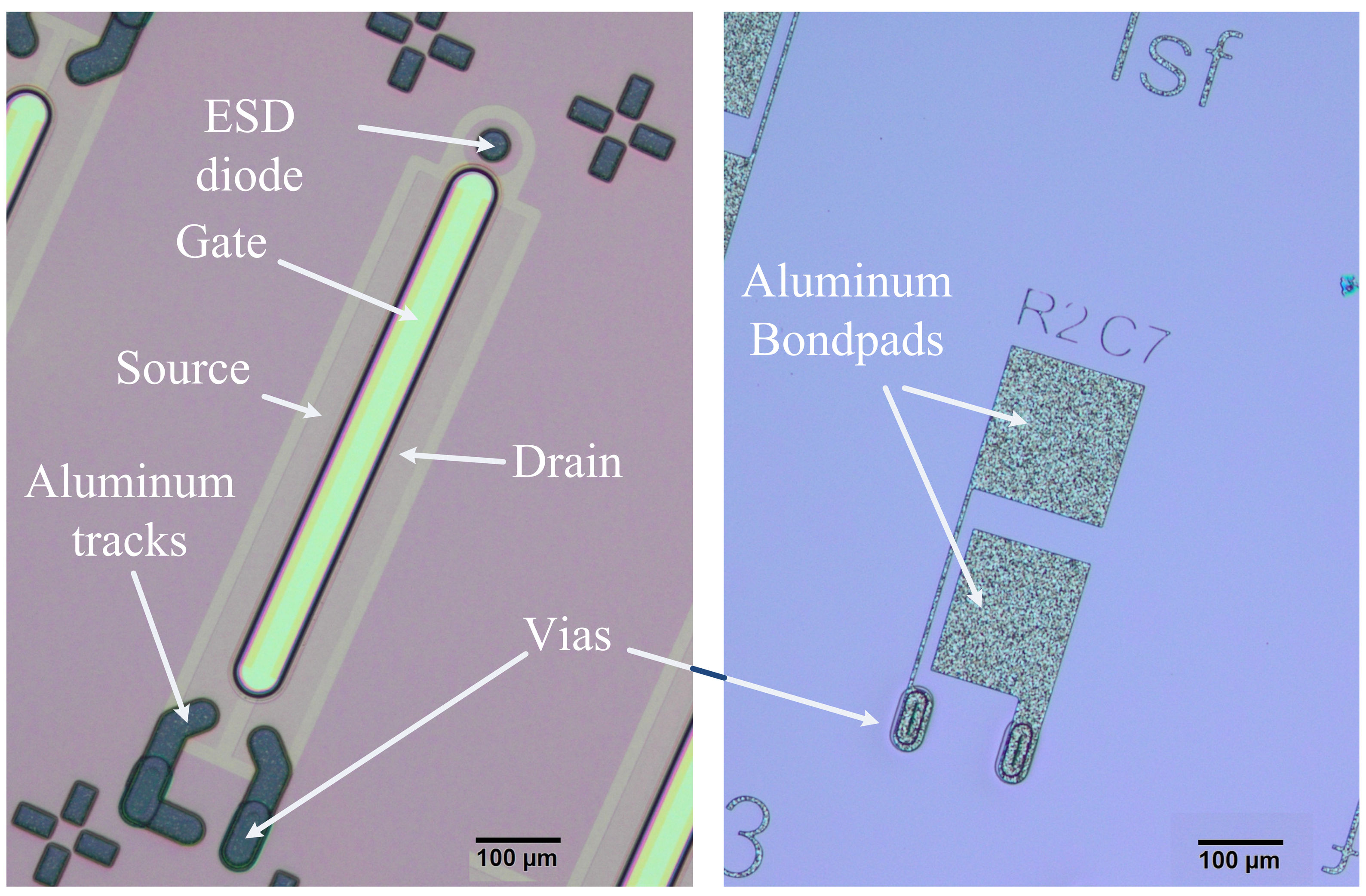


Fig 2. Photographs of the ISFET. Front side (left) and backside (right)

Results

The FETs were not working as we expected. After investigating the process and equipment carefully, we found that a cross contamination had occurred in one of the furnaces, resulting in a slight n-doping on the surface of the wafer, including the channel area of the FET which is supposed to be p-doped. In the past we have fabricated identical Ta_2O_5 ISFETs without vias which not suffered from this problem, and therefore we will show the results of those MOSFETS and ISFETs. We expect to obtain the same results from the wafers with vias once the cross-contamination issue has been solved.

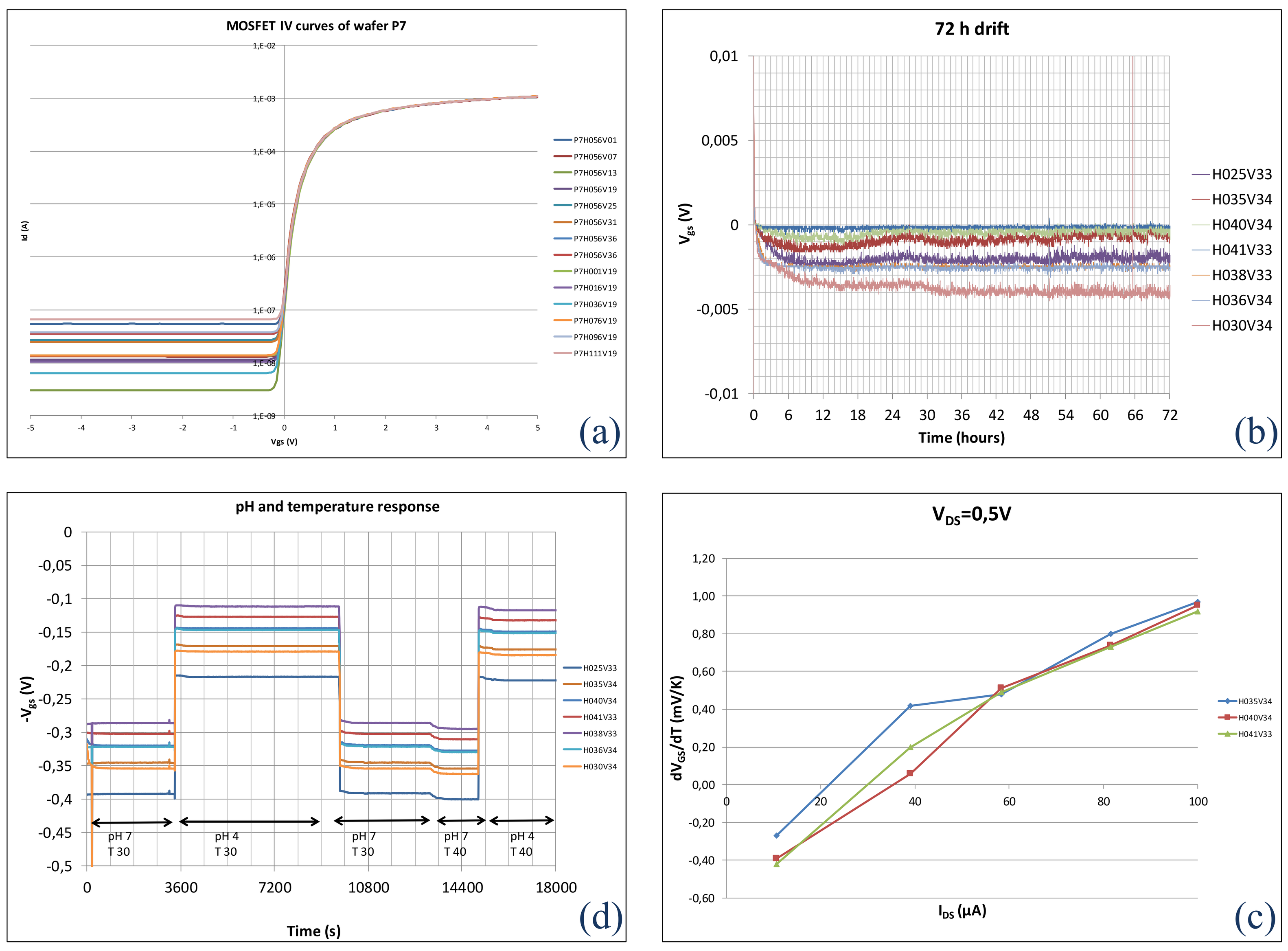


Fig 3(a) V_{gs}-I_d of MOSFETs at V_{ds}=0.5V; (b) Drift of ISFETs in pH 7 at V_{ds}=0.5V and I_d=100 µA; (c) pH and temperature response at V_{ds}=0.5V and I_d=100µA; (d) dV_{gs}/dT at V_{ds}=0.5V.

Table 1. ISFET characteristics

Parameter	Value
Sensitivity (pH 4-10, T=30˚C)	58.8 ± 0.2 mV/pH
Offset (pH 7, T=30˚C)	332 ± 50 mV
Drift (0 to 6h)	0.2 ± 0.2 mV
Drift rate (6 to 72h)	< 0.02 mV/h
Isothermal current (dVg/dT =0)	Id = 20 µA

Conclusions

We fabricated miniature ISFETs with backside contacts to be used in a guidewire tip which will be inserted into the brain vasculature of patients suffering from stroke.

The first process run of these ISFETs was only partially successful because a cross contamination issue in one of the furnaces occurred and caused a shallow doping of the n-type in the p-channel, preventing the ISFETs to work.

Measurements on ISFETs from a similar wafer with an identical ISFET process, but without the vias show very good characteristics: Sensitivity 59 mV /pH at 30 ˚C, drift < 0.02 mV/h after stabilization of 6h and an isothermal operating point at Ids = 20 µA.