DESIGN AND FABRICATION OF AN SOI-CMOS LARGE-SCALE INTEGRATED CIRCUIT FOR BIOELECTROCHEMICAL SENSING

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Recent advances in the electronics industry show an increasing interest in the potential to apply complementary metal-oxide-semiconductor (CMOS) technology in the development of sensors to various applications, such as in the biotechnology and medical fields [1]. CMOS with large-scale integrated (LSI) circuits are particularly attractive for the measurement of biological and chemical substances through bioelectrochemical measurements [2]. In this study, we present a novel platform technology for micro- (MEMS) and nano-electromechanical systems (NEMS) based on a silicon on insulator (SOI) CMOS structure made in LSI foundry and post-processed in open cleanroom facility [3]. As an example, a high-density active switched microelectrode array (MEA) with advanced transistor performance for high-throughput applications is presented.

The CMOS circuit consists of an array of microelectrodes individually controlled by transistors closely embedded and integrated into it by LSI technology. A CMOS circuit has been developed with an array 16 × 20 microelectrodes. Each microelectrode is 44 µm × 36 µm, with a 51 µm pitch, which provides a sensing array of approximately 1.02 mm × 0.81 mm. The system is fabricated using SOI substrates, which means that the transistors are fabricated with a very thin silicon film placed on an ultra-thin insulation layer of silicon oxide positioned on top of the silicon substrate. Thanks to this configuration, faster switching speed and better performance of the transistors can be achieved. Electrical characteristics of the system have been performed and results are shown in Fig. 1. The device provides a maximum drain current (Id,max) of 1.0 mA at both a gate voltage (Vg) and maximum drain voltage (Vd,max) of 1.8 V. The maximum extrinsic transconductance (gm,max) is 1.0 mS and the threshold voltage (Vth) is around 0.5 V. As the transistor is about 5 µm in width, we can obtain a current flow of 200 µA/µm and an electrical conductance of 200 µS/µm.

Post-processing steps can be performed on the original device on both the LSI layer and the silicon substrate as shown in Fig. 2. The structure of the device can thus be modified, which offers the possibility to adapt and use the circuit for various applications. From this perspective, the LSI surface and the back side substrate can be etched to build microchannels through the microelectrodes. Aluminum has also been be deposited on the LSI layer to build circuit lines that can later be used for making the connection to the microelectrodes easier. A summary of the incremental processing steps involved in the fabrication of a device for bioelectrochemical applications using our CMOS circuit is presented in Fig. 3. As a result, the described SOI-CMOS LSI circuit can allow the fabrication of devices for various applications. In this regard, a novel particle counter can be fabricated with a large array of vertical through-holes to achieve a higher density of sensing channels [4][5]. The technology can then be easily extended to the fabrication of sensors for concentration and size distribution of a suspension of nano- and micro-particles by flowing a solution of biological cells. In this research, we thus reported the characteristics, fabrication process and potential implications of a novel SOI-CMOS MEMS platform for chemical and biological applications.

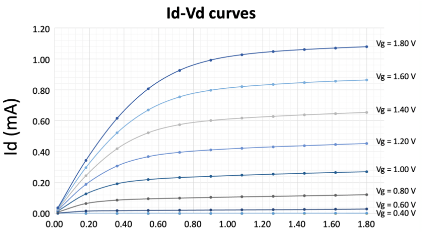

Figure 1. Electrical characterization of integrated transistor: Id-Vd curve

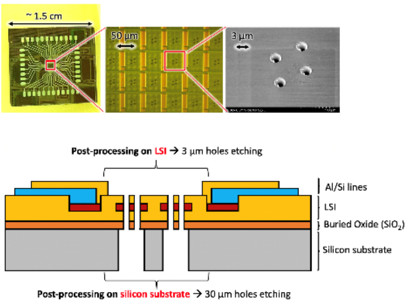

Figure 2. Fabrication of SOI-CMOS LSI circuit: (a) example of holes etching process on LSI; and (b) schematic view of the microsystem after processing

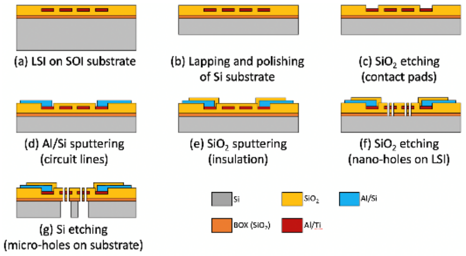

Figure 3. Process flow of nano- and micro-holes fabrication on SOI-CMOS circuit for counting

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