Silicon Microphone Development at Infineon Technologies

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Abstract

This paper shows how Silicon condenser microphones are processed in a standard six inch BiCMOS line at Infineon Technologies. Innovative surface and bulk micromachining processes have been developed to realize the microphone functionality. Basically, the microphone consists of a thin poly-Silicon membrane electrode which has distance of about 2µm to a highly perforated counter electrode. Monolithically integrated microphones as well as two chip solutions have been developed. Especially the hybrid integration opens up a wide spectrum of applications in terms of signal conditioning. Microphones have been realized with sensitivities of up to 45mV/Pa at 2.5V bias without amplification. These microphones show superior noise equivalent sound pressures of only 25dB(A).

Introduction

The material properties and the concept of condenser microphones leads to important advantages compared to standard electrets microphones. Silicon microphones do not degrade due to temperature and humidity. They withstand temperatures higher than 300°C, are highly shock resistant and show little variations in performance due to the batch processes. This is important in particular for microphones in array solutions. Mounted into SMD (Surface Mount Device) packages automatic manufacturing and reflow soldering of the devices is allowed. A further motivation is the ability to share BiCMOS technology for low cost and high volume production.

The development in a standard 150mm BiCMOS line environment is mandatory at Infineon [1]. Additional surface [2] and bulk [3] micromachining processes that are well established for pressure sensor products have been combined to a process flow for silicon microphones. Superior acoustical and electrical performances as well as signal conditioning have been published [4].

Technology Development

Figure 1 shows the structure of the microphone. Step by step the front side of the microphone is fabricated. The optional JFET can be integrated into the process flow using three additional layers. The cavity on the back side is etched after the front is finished. The final step is the release of the membrane by sacrificial etch of the oxide between the electrodes.

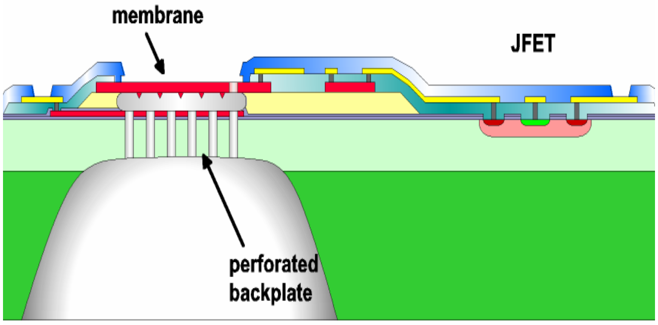

Figure 1: **Schematic drawing of a silicon condenser microphone, here with an additional JFET.**

Starting with an epitaxy on a silicon wafer, the first poly-silicon layer is deposited, implanted and structured. It forms the perforated counter electrode of the microphone.

Then the trenches are etched into the substrate and filled with an oxide. Additional oxide layers are deposited, which serve as sacrificial layer and define the gap between the two condenser plates.

Sensitivity enhancing corrugation rings and anti-sticking-bumps inside the membrane are defined by etching their negative form into the sacrificial oxide. Subsequent deposition of poly-Silicon atop then realizes these functions inside the membrane. The geometry of the anti sticking bumps can be defined very well using the right combination

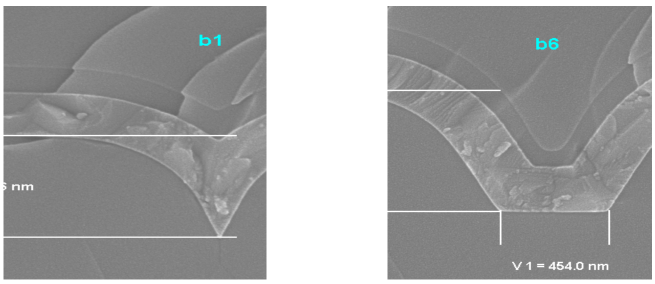

Figure 2: **Anti-sticking bumps inside the membrane with different tip area**.

of etch depth and width. Figure 2 shows the poly-Silicon layer embedded in sacrificial oxide layers. To guarantee low adhesion of the anti sticking bumps they should have a small tip radius.

Also the second poly-Silicon layer is implanted and structured. The doping concentration of the membrane poly-Silicon defines -together with the thickness- the sensitivity of the microphone.

Gold pads and lines are realized for the purpose of reliability. A passivation film protects the microphone, but has to be removed above the membrane and the pads. Then, the wafer is thinned and bulk micromachined from the back side using the technology of the piezoresistive pressure sensor.

In a final step the sacrificial oxide in the trenches and between the electrodes is wet etched through the trenches and finally dried using a supercritical CO_2 drying tool.

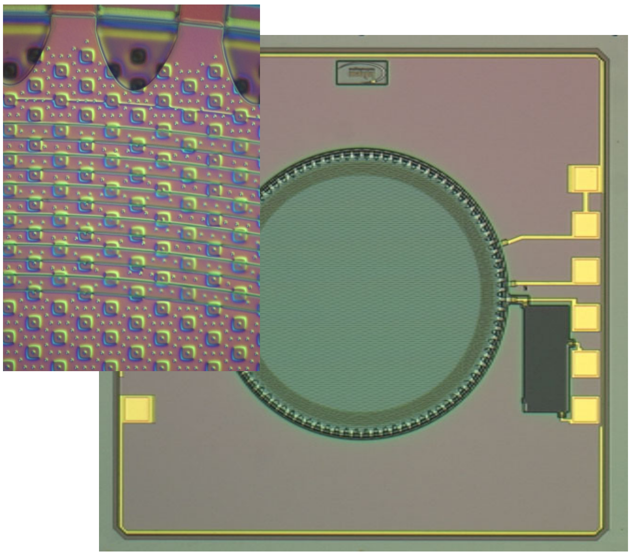

Figure 3: **Top view of a microphone without a JFET. The inset shows the corrugation ring and the anti-sticking bumps in detail.**

In Figure 3 a top view of a microphone chip is presented which is used together with different amplifiers. The inset shows in detail the opening of the membrane, giving sight to the backplate with its perforation. Also six corrugation rings can be seen. They increase the sensitivity of the microphone. The little dots in the inset photo are the anti-sticking bumps. They prevent sticktion of the membrane to the backplate due to humidity or electrical overload.

Acoustical Performance

For three microphones, the sensitivity and the frequency response is plotted in Figure 4. The sensitivity reaches up to 45 mV/Pa with an applied bias voltage of 2.5 V. The sensitivity is adjusted with different doping levels of the membrane layer. The doping level and annealing process of the membrane correlates with its residual stress. The flat frequency response is an important property for good microphones but can only be achieved with medium sensitivity otherwise damping of the perforation starts to low pass the sound.

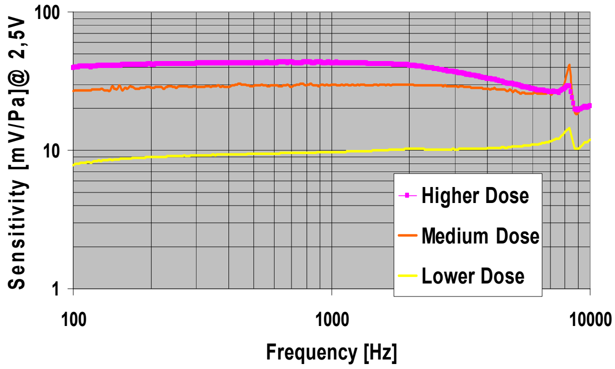

Figure 4: **Sensitivity of three microphones with different doping concentration of the membrane.**

Conclusion

The silicon microphone development at Infineon Technologies leads to condenser silicon microphones with very good acoustical performances. Sensitivities up to 45mV/Pa have been reached without additional amplification. We implemented into the membrane corrugation rings for sensitivity enhancement and anti-sticking bumps to prevent in-use sticking.

Acknowledgement

These new developments have been supported by the nationally funded project 'Silicon Microphones for Array Applications' (BMBF 16SV1273).

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