IMEC's CMORE platform

SiGe-based MEMS

Technology

IMEC developed a poly-SiGe-based technology for the monolithic MEMS-IC integration. Poly-SiGe layers, with the materials properties which are desired for MEMS, can be deposited at significantly lower temperatures than poly-Si layers. Therefore SiGe is very suitable for above-IC microsystems, since it doesn't put any restrictions on the CMOS circuitry below. The successful realization of different SiGe-based integrated MEMS applications, convinced IMEC that poly-SiGe-based technology is indeed a generic MEMS technology enabling the realization of highly integrated miniature micro-mechanical systems with improved performance.

Applications

Based on its SiGe-based technology IMEC realized, together with its European project partners, gyroscopes on top of fully functioning CMOS circuits, for low-noise, high-resolution applications. A vibrating gyroscope was processed in a 10µm thick SiGe layer on top of a standard high-voltage (20V) 0.35µm CMOS ASIC with five aluminum wiring levels and standard passivation.

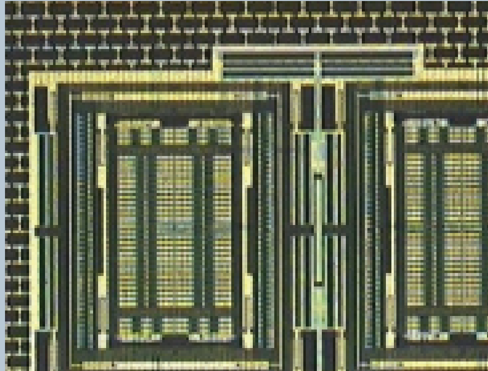
Further, IMEC's poly-SiGe based technology is used to make thin-film caps above MEMS devices forming an area-saving integrated 0-level package.

Another application are micro-mirrors, typically used for video projection systems, etc. The poly-SiGe technology allows integrating the micro-mirrors with the CMOS driving circuitry and gives good results in terms of micro-mirror flatness, uniformity and reliability. The SiGe structural layer developed for the micro-mirrors at IMEC is a micro-crystalline SiGe layer (µc-SiGe:H), which can be deposited at even lower temperatures (300 – 400°C) than the thick SiGe (450°C) used for the gyroscopes. Moreover, the small SiGe grains (max. 100nm diameter) ensure uniform and reproducible mechanical properties of the submicron hinges. Using µc-SiGe:H, IMEC produced micro-mirrors with sizes between 7.5x7.5µm² and 16x16µm² and sub-micron hinges ranging from 250 to 400nm. The thermal budget of the process flow was kept below a CMOS-compatible 420°C. The very flat mirrors (3nm cupping, 0.3nm surface roughness) showed no hinge creep over 20 days and no fatigue damage after 5x1010 cycles.

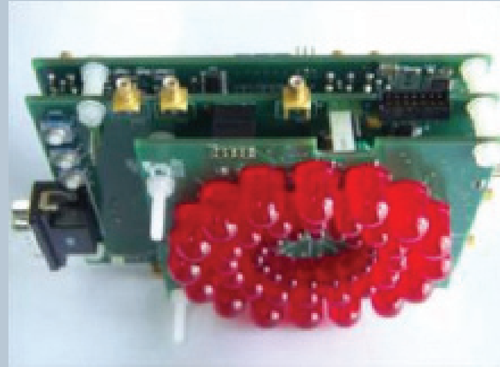
The process developed at IMEC has the potential to become a generic technology for different types of MEMS devices (e.g., resonators, accelerometers,…) processed on top of standard CMOS. Using the SiGe MEMS module multiple times enables multi-layer stack 3D MEMS structures like micro-motors or integrated 0-level packaged MEMS devices. In conclusion, this process ultimately enables the creation of highly integrated miniature systems with improved performance over the current state-of-the-art.

Technology advantages

Integrating MEMS (micro-electromechanical systems) with the driving and readout electronics on the same substrate improves the performance of the MEMS, allows for smaller packages and leads to a lower packaging and instrumentation cost. A promising approach for MEMS-IC integration is processing the MEMS above its integrated circuit. However, this limits the thermal budget for MEMS processing. IMEC's poly-SiGe based technology enables MEMS-IC integration at lower process temperatures.



Optical microscope picture of second generation free standing SiGe gyroscope processed above CMOS.



Assembled breadboards for stand-alone operation of integrated gyroscope with altimeter-like LED display (courtesy of project partner IMSE-CNM).

Benchmarking

The thick SiGe layers developed for the gyroscopes are deposited with a fast PECVD-based deposition process. This provides a much lower thermal budget for the CMOS wafers than competing CVD technologies, leading to less risk for reaction between the CMOS and the SiGe layers. Moreover the technology has been able to show very good and reproducible strain gradient control, not always possible with the competing CVD technique.

µc-SiGe:H micro-mirrors are a very promising alternative for Al-based micro-mirrors and might be the only candidate to meet all flatness, uniformity and reliability specifications for future integrated micro-mirror applications.

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