HECTIC2—SiC-based MEMS Pressure Sensor Development

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Silicon carbide (SiC) is a highly corrosion and temperature resistant material, which makes it the material of choice for many harsh environments sensor applications. Its chemical inertness makes it also biocompatible [1]. The high temperature resistance makes it useful for developing MEMS suited for monitoring of gas turbines, jet engines, oil and gas wells, and space rockets [2]. CSEM is developing the key front-end and back-end fabrication processes of SiC-based MEMS sensors in order to fabricate fully functional pressure sensors with operating temperature in air up to +600°C [3].

Piezoresistive pressure sensors are formed of a cavity covered by a compliant membrane in which piezo-resistors have been defined. Silicon piezoresistive pressure sensors have been around since the 1960s. The use of SiC as a pressure sensor material has many advantages, due to its high temperature and chemical resistivity. However, the realization of such a pressure sensor requires the mastering of several technologies. An important one is the hermetic bonding of the SiC sensor to the back-plate to form a reference cavity.

The hermetic SiC to SiC bonding has been performed with a CSEM proprietary low-temperature laser bonding technology that has been developed in previous projects. The testing of the hermetic seal has been performed on sets of two back-plates bonded together with a laser (Fig. 1a). The seal is first tested for liquid-tightness by verifying the absence of dye penetration in the cavity (Figure 1a). A subsequent Helium leak test is carried out with an Inficon ULFab100 machine to verify the tightness of the seal.

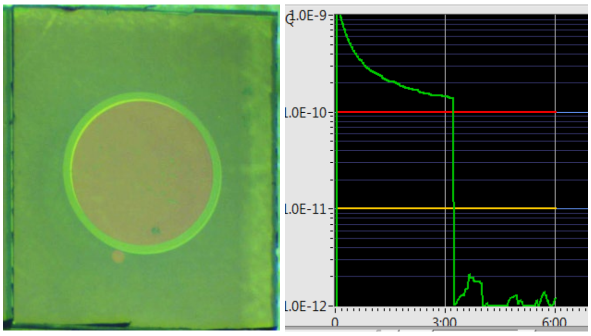

Figure 1: (a) Two lids sealed with laser and immersed in dye-penetrant liquid. In red, the wet (hermetic) area; (b) Helium leak-test profile after 10h in air at 600°C.

The yield of the hermetic laser bonding of the two lids together is very high, with a 100% pass for dye-penetration after 1 week testing. Samples of these chips were Helium leak-tested before and after 10 h at 600°C in air (Figure 1b). 100% of the sampled chips were still hermetically sealed. After testing 500 h at 600°C in air, 60% of the chips were still hermetic, indicating a degradation trend [4].

Though a few samples already have shown some potential, the technology still requires to be improved to show its full potential and reliability for operation up to 600°C in air. Investigations are now ongoing at CSEM to further optimize the technology and bring it to a high TRL to ensure fast and rapid time to market for CSEM customers and project partners.

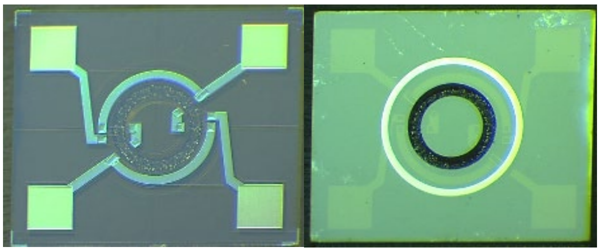

Figure 2: SiC-based MEMS pressure chip prototype realized.

The key processes are expected to become combined in one SiC-based MEMS fabrication technology aiming firstly at making a pressure sensor, starting from the current layout configuration (Figure 2) and secondly a temperature sensor out of the same bonding scheme, by exploiting the piezo-resistive temperature dependence.

It can be expected that a broad portfolio of harsh environments sensors can be addressed by CSEM with this technology, such as gas sensors, force sensors, and accelerometers.

These promising technology bricks and the related MEMS designs will be addressing a highly dynamic and emerging field and market of sensor components for harsh environments. Key enabling aspects are chemical resistance, intrinsic shock resistance due to doped piezo-resistance, and high-temperature stability due to process design choices.

In collaboration with customers, CSEM will be able to customize the above explored SiC-based MEMS technologies: developed products can therefore be tailored to various needs to match operation in harsh environments.

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[3] G. Spinola Durante, *et al.*, "HECTIC - Harsh Environment Ceramic Technology Involving Silicon Carbide", CSEM Scientific and Technical Report (2017) 17.

[4] G. Spinola Durante, P.-A. Clerc, M. Fretz, A. Hoogerwerf, R. Jose James, M. Despont, O. Dubochet, M.-A. Dubois, S. Mohrdiek, "Packaging technologies for harsh environments based on silicon-carbide (SiC) substrates", Proceedings of IMAPS MiNaPAD Event, Grenoble (France), May 2018.