

Development of new sustainable materials from an industrial perspective: requirements and effort to reduce the critical gap between a validated prototype and a fully operational system

The development of compact, autonomous and field-deployable analytical systems is becoming increasingly important for continuous environmental and industrial gas monitoring¹. Within this context, the present industrial PhD research, carried out in collaboration with **Pollution Analytical Equipment**, focused on the development of technological solutions aimed at improving the miniaturization and selectivity of gas analysis. The company portfolio includes compact platforms such as **PyxisGC BTEX**, based on MEMS microfluidics and microfabricated chromatographic separation, **PicoGC** for continuous monitoring applications in gas networks, and **OneFID**, a portable FID-based analyser for the determination of methanic and non-methanic hydrocarbons.

Two complementary research lines were investigated. The first concerned the development and functionalization of **MEMS chromatographic columns**, with particular attention to the transfer of conventional PDMS stationary-phase coating procedures to silicon microchannels fabricated by photolithography, deep reactive ion etching and anodic bonding^{2,3}. The second focused on **selective catalytic pretreatment** for methane analysis in the OneFID system, where non-methane hydrocarbons must be oxidized while preserving methane. Commercial and zeolite-supported catalysts were evaluated, with particular attention to cobalt-containing MFI materials as promising alternatives to conventional Cu/Mn-based formulations⁴.

Although based on different physicochemical principles, both approaches share the same technological objective: the development of compact, low-consumption and highly selective analytical systems. The integration of microfabrication, chromatographic separation, heterogeneous catalysis and industrial instrumentation represents a promising route towards the next generation of portable devices for continuous gas monitoring.

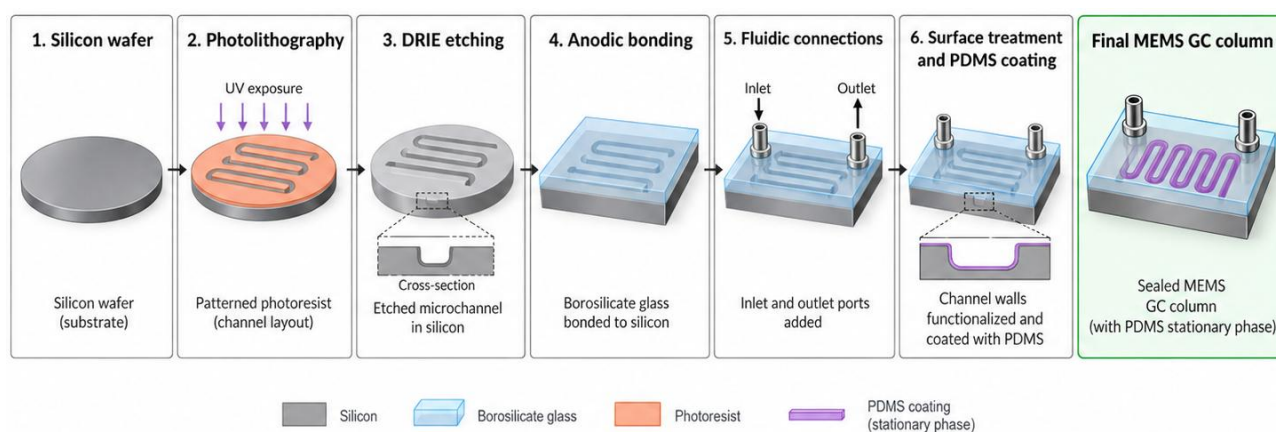


Figure 1. Simplified workflow for the fabrication and functionalization of a MEMS gas chromatographic column, including silicon wafer patterning, photolithography, DRIE microchannel etching, anodic bonding with borosilicate glass, integration of inlet/outlet fluidic connections, and final surface treatment and PDMS stationary-phase coating.

¹ Lee et al., «Review on Micro-Gas Chromatography System for Analysis of Multiple Low-Concentration Volatile Organic Compounds».

² Zhang et al., «An all-silicon microfabricated gas chromatographic column with a high aspect ratio»; Azzouz et al., «Review of Stationary Phases for Microelectromechanical Systems in Gas Chromatography».

³ Azzouz et al., «Review of Stationary Phases for Microelectromechanical Systems in Gas Chromatography».

⁴ Negri et al., «Tailoring Zeolite-Based Catalysts for Mild, Methane-Selective VOC Combustion in Stack Emission Monitoring Systems».