TCSPC Setup with SiPM Readout for Volatile Organic Compound Identification

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Abstract: The setup aims to identify volatile organic compounds in gas mixtures by performing TCSPC spectra with a setup employing NUV sensitive SiPM developed with FBK technology

Volatile organic compounds (VOC) detection in gas mixtures is crucial for air pollution monitoring as well as gaseous contaminants identification. A compact system able to quickly analyze the presence of such compounds could be deployed in a wide variety of environments with different applications ranging from gas fluorescence lifetime measurements to sub-ppb gas quality monitoring [1].

An effective and innovative approach for gas analysis involves Time Correlated Single Photon Counting (TCSPC) technique [2], where the fluorescence time spectrum from the gas is acquired after being exposed to excitation light. A successful TCSPC setup needs to be fast with a high detection efficiency to the emitted photons. Typical VOC fluorescence peaks in the near-UV (NUV) spectrum, where traditional photosensors have low quantum efficiency. This quantity is fundamental when single-photon detection is required in processes such as TCSPC.

At Fondazione Bruno Kessler, we developed a silicon photomultiplier (SiPM) technology with enhanced sensitivity in the NUV range with compact footprint [3], a picture of an uncut wafer is shown below (left) . This device will be deployed in a setup shown in the figure below (center), where a fast pulsed LED will illuminate the gas sample and its fluorescence will be detected by the SiPM after passing through a band-pass filter to limit the stray light from the primary source.

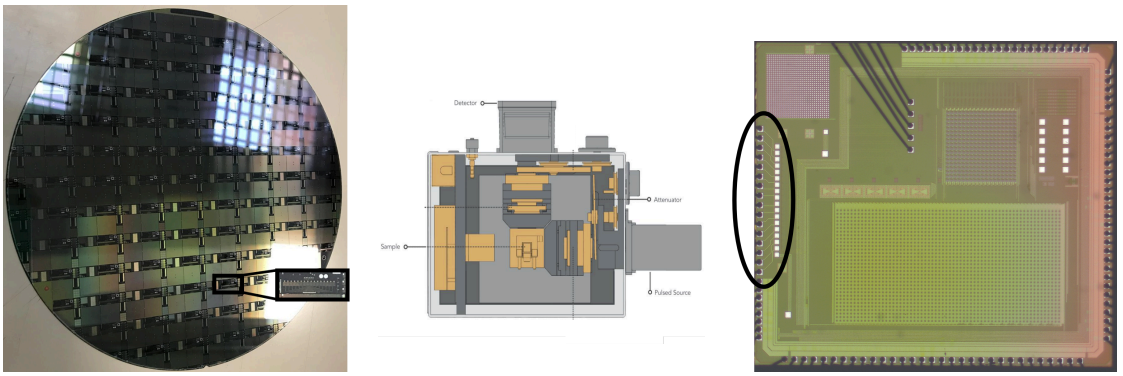

Fig. Left: Schematic cross-section of a commercial TCSPC setup (adapted from Edinburgh instruments Mini-tau spectrometer). **Center:** Picture of the production wafer. The inset shows the structure containing the SiPM and the SiPM array. **Right:** Detail of the ASIC containing the 16 TDCs. In the black circle the contact pads with the sensor array are highlighted.

Thanks to the modularity of the system, in a second phase, the filter/SiPM stack can be substituted by a dispersive grating coupled to an array of 16 SiPMs (pixels) read out by a in-house custom designed ASIC designed in LFoundry 110nm CIS technology and equipped with 16 time-to-digital-converters (TDC) reprogrammable as photon counters (right). The fully digital readout chain allows for a fast data stream to enable higher exitaction rates. With this upgrade, the setup will spectroscopically separate the different peaks present in the VOCs, acquiring in parallel their fluorescence time spectra, hence enabling the detection of multiple molecules using the same gas sample with a reduced measurement time.

A production run of NUV-sensitive SiPM has been successfully completed, the characterization of the device with its electrical and optical functional measurements will be reported, along with preliminary tests on the custom ASIC present in the upgrade.

References

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