Light-Emitting Silicon Nanowires: A Versatile Photonic Platform for Biological and Environmental Sensing

Antonio Alessio Leonardi[1,2], Maria José Lo Faro[3,4], Maurilio Galletta[2], Barbara Fazio[2], Rosaria Anna Picca[5], Francesco Nastasi[1,2], Fausto Puntoriero[1,2], Francesco Priolo[3,4], Alessia Irrera[2]

Author(s) information:

[1] Dipartimento di Scienze Chimiche, Biologiche, Farmaceutiche, ed Ambientali (ChiBioFarAm), Università degli studi di Messina, V.le F. Stagno D'Alcontres 31, 98158 Messina, Italy;

[2] CNR-IMM Messina, V.le F. Stagno D'Alcontres 31, 98158 Messina, Italy;

[3] Dipartimento di Fisica ed Astronomia, Università di Catania, Via Santa Sofia 64, 95123 Catania, Italy;

[4] CNR-IMM Catania Università, Via Santa Sofia 64, 95123 Catania, Italy;

[5] Dipartimento di Chimica, Università degli Studi di Bari "Aldo Moro", Via Orabona 4, 70126, Bari;

Abstract

Silicon nanowire (Si NW)-based biosensors combine the unique properties of nanostructured materials with the scalability of silicon technology. We have demonstrated the fabrication of quantum-confined light-emitting Si NWs by a low-cost CMOS-compatible process, enabling highly sensitive optical sensing architectures.

In these years we have demonstrated two main functionalization strategies that transformed light-emitting silicon nanowires into a versatile label-free sensing platform for a wide variety of targets. This approach has enabled femtomolar detection limits for clinically relevant protein biomarkers, including C-reactive protein, supporting non-invasive diagnostic applications. Beyond protein sensing, these platforms have demonstrated outstanding capabilities for the detection and characterization of small extracellular vesicles. Functionalized Si NW biosensors enabled the direct detection of pathogen DNA and RNA as demonstrated with SARS-CoV-2 down to few target copies in hundreds of microliters of sample. The platform versatility has been further demonstrated through the ppb detection in water of pyrene, a hazardous environmental pollutant, as well as toxic gases down to ppm with both optical and electrical detection. More recently, our efforts have been directed toward the prototyping and development of portable Si NW sensing devices. By exploiting both optical and electrical transduction mechanisms, we aim to translate laboratory-scale demonstrations into compact, low-cost, and user-friendly platforms suitable for point-of-care diagnostics, environmental monitoring, and real-time field measurements.

These results highlight the potential of Si NW sensors as versatile, low-cost, and highly scalable platforms. By combining ultra-high sensitivity, label-free operation, rapid response, and industrial compatibility, silicon nanowire platforms represent a promising route toward point-of-care devices, and future nanophotonic sensing technologies