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Light-emitting Silicon nanowires array as versatile optical biosensors.

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As one of the most earth-abundant materials, silicon nanowires (Si NWs) represent one of the most promising resources to be employed in modern nanodevices although their fabrication is still challenging. We demonstrated the fabrication of a dense array of vertically aligned Si NWs with a tunable aspect ratio by a low-cost, maskless approach compatible with the current Si technology. The synthesis of Si NWs was properly engineered for the realization of 2D random fractal systems by using a fractal gold layer above the percolation threshold. We demonstrated the control over the optical properties of the system through the optimization of different fractal geometries. Strong in-plane multiple scattering and efficient light trapping related to the fractal structure were observed with perspective for photonics and photovoltaics. NW achieved by this technique exhibited a very bright room temperature luminescence under both optical and electrical pumping, tunable with NW size in agreement with the occurrence of quantum confinement effects. These nanowires, characterized by a high-aspect ratio of about 10^3, have indeed proven highly effective in sensitive and selective label-free detection of biomolecules. An innovative label free optical Si NW biosensor was realized by exploiting the PL quenching upon the selective capture of target proteins or genome. A low cost selective sensor for the C-reactive protein, the major biomarker for heart failure pathology, was realized showing high sensitivity of a few fM across a broad concentration range for non-invasive analysis in saliva. By changing the functionalization protocol, we realized a label- and PCR-free NW optical sensor for the selective detection of a few copies of Hepatitis B virus without amplification, and exosomes detection with LOD of about 10^5 EVs/mL. A groundbreaking application of Si NWs is the development of a sensor for SARS-CoV-2 responsible for COVID-19 with outstanding sensitivity of only a few copies. Remarkably, it maintains its functionality even with different virus variants, such as Omicron. This capability suggests a significant advancement in diagnostic technology, offering a pathway to developing new, cost-effective optical label-free devices for primary healthcare.