Silicon micro and nanofabrication in the context of quantum optics

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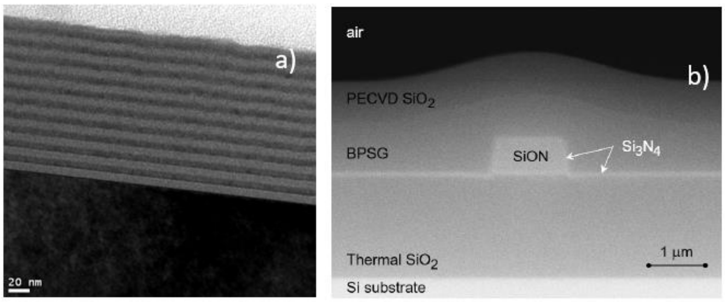
Development of dedicated fabrication processes and engineering of materials plays also an important role in the context of quantum technologies. These is illustrated by presenting two examples of our research, which start with material, process optimization, and end with characterization of quantum devices. The first example is the use of silicon nanocrystal based light emitting diodes in combination with silicon photomultiplier detectors used to realize a quantum random number generators. The second is the development of a platform for a photonic quantum simulator based on nonlinear optical waveguides in SiON for generation of entangled photons and the integration of SiPM single photon detectors in the very same chip. The technology was applied for the integration of both P-I-N and SiPM detectors.

All key components used where fabricated with silicon microfabrication technology in Bruno Kessler Foundation. The Silicon nanocrystal based diodes were realized with a dedicated multilayer CVD deposition process and the layer thickness was optimized in the nanometer range to allow for injection of both electrons and holes, which allows for long time stability, low switch on voltage. The LEDs where carefully characterized and behave as Poissonian light source (single-photon emitter). On the other hand a SiON waveguide was developed for operation from 780nm to 850nm. The waveguide was coupled efficiently to a P-I-N detector directly integrated in the same chip and the detection efficiency was estimated.

The Si-LEDS in combination with SiPM photodiodes were used to form a QRNG by observing the arrival time of photons continuously monitored by a FPGA. A post processing algorithm was used to correct imperfections in the electronic system and of the SiPM detectors. The QRNG passes all NIST tests for 2G random bits and achieves a maximum bitrate of 0.5 Mbps. On the other hand we developed a SiON nonlinear waveguide with a Kerr coefficient of 1.6 +/- 0.2 dB/cm at 800nm and a Kerr-coefficient of 1.3 10^-19 m2/W, which is in between the values reported for SiO_2 and Si_3N_4. For the integrated P-I-N detectors a record quantum efficiency of 44% at 850nm is achieved, while with a similar integrated SPAD detector we can observe single photon detection.



High resolution TEM cross section of a annealed Si/SiO_2 multilayer, b) SEM cross-section of a SiON waveguide

We show examples of the need for the optimization of materials and fabrication technologies to allow for realization of new quantum optical components.

References
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