SILICON-BASED PHOTONIC CRYSTALS:
TECHNOLOGY, OPTICAL PROPERTIES AND THEORY

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PROJECT ABSTRACT

The present project focuses on fabrication, optical studies and theory of silicon-based photonic crystals of different dimensionalities. The aims of the project are: to develop the fabrication technologies of photonic crystals and of their infiltration with active media; to perform a detailed study of optical properties and, for active systems, of radiation-matter interaction; to develop the theory of photonic bands and of the optical response for the investigated photonic crystals.

By combining deposition techniques, lithography (electron-beam, X-ray and nanoimprint), wet and dry etching, sedimentation and infiltration the following kinds of photonic crystals with a gap in the near-infrared or in the visible will be produced:

(i) two-dimensional systems: macroporous silicon, films based on amorphous silicon (a-Si:H) and amorphous silicon nitride (a-Si(1-x)Nx:H) with high photoluminescence intensity;

(ii) two-dimensional systems embedded in planar waveguides: SOI-Silicon on Insulator structures (a-Si:H on SiO2);

(iii) three-dimensional systems: macroporous silicon with vertical modulation of the pore diameter, periodic multilayers (a-Si:H/a-Si3N4:H) patterned with a lattice of holes, opals and inverse opals (Si and TiO2), Yablonovite and inverse Yablonovite.

In all kinds of structures obtained by lithography, linear defects (channel waveguides also with sharp bends) and point defects (photonic cavities) will be defined, also in order to realize demonstrators for devices.

The structures will be infiltrated with Erbium, dyes, liquid crystals and colloidal quantum dots in order to obtain active media with an emission frequency at the band gap. In order to have active media in controlled positions, local infiltration techniques will be developed.

Optical studies will mainly consist in:

** characterization of the optical response and of the position of the gap by reflectance and transmittance;*

** measurements of the photonic band dispersion by variable-angle reflectance from the sample surface and by phase-sensitive Mach-Zehnder interferometry;*

** measurements of transmission in channel waveguides and in microcavities with butt-coupling and near-field optical microscopy techniques;*

** studies of the effects of disorder by time-resolved spectroscopy and coherent backscattering;*

** measurements of spontaneous emission modifications in photonic crystals infiltrated with active media.*

The theory of photonic crystals and of their optical properties will consist of the following developments:

- calculations of photonic bands and density of states for 2D, waveguide-embedded 2D and 3D systems;

- calculations of reflection and transmission spectra, and of diffraction phenomena, for finite and semi-infinite photonic crystals;

- simulation of electromagnetic wave propagation in photonic crystals and in channel waveguides, also with disorder effects, and study of time-resolved propagation of wavepackets;

- calculation of modified spontaneous emission for an emitter placed in periodic photonic crystals of different dimensionalities and in photonic cavities;

- modelling of near-field optical microscopy.