Porous Silicon: when void enables new Si application fields

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Porous silicon (PoSi) was accidentally discovered by the Uhlir in the mid '50s while trying to develop an electrochemical method to polish Si wafers. Following this, the material did not attract any attention until the '70s and '80s and especially '90s when interest in PoSi exploded with the discovery of its photoluminescence [1].

PoSi is a sponge-like structure presenting a variety of morphologies depending on its fabrication process. Several parameters are used to characterize it: porosity (10% to 95%), pore diameter (few nm to tens µm), the thickness of the porous layer (few nm to hundreds µm), pore tortuosity (straight or in "spaghetti bunch"), surface to volume ratio (up to 500 m^2/cm^3), the pore surface condition, pore filling, etc.

The Si porosification generates substantially different electrical, optical, chemical, mechanical, biological, thermal, fluidic … properties than bulk Si. This leads to interest in many fields of application: Si micromachining, heat insulation, photonic, photoluminescence, solar, gas sensing, lab-on-chip, bio-sensing, micro-fuel cell, filtering, energy storage, etc.

First considered as a "material to explore", PoSi has become a research axis in our research laboratories in recent years. It holds the center place in several master and PhD thesis at UCL, where the characterization platforms offers a suitable research environment for PoSi. The fabrication is performed in the WINFAB platform. Characterization of porous layer morphology is made mainly by using electron microscopy technique of LACAMI platform. Topics of research around the PoSi at UCL are:

1. Gas sensing application: With its high surface-to-volume ratio, PoSi concentrate a large number of surface reactions (e.g. physico-chemical adsorption of gas) in a small volume. The variation in its electrical resistivity in the presence of the gas enables the use of PoSi as gas-sensitive layer. Electrical characterization under gas-, temperature- and humidity-controlled environment is made with equipment of the WELCOME platform. PoSi functionalization (in collaboration with UMons) improves its selectivity to a specific gas. The X-Ray photoelectron spectrometry (XPS) equipment of SURF platform helped the physicochemical characterization of the functionalization.

2. Biomimicry application: The high tunability of PoSi as well as its optical properties allowed us to replicate the microstructure of the wings of butterfly *Papilio blumei* responsible for the observed physical color. The surfaces were fabricated in WINFAB and were used for the optical detection of gas in collaboration with UNamur.

3. Bio-sensing application: Due to its high porosity and numerous interactions, PoSi is a material of choice for biosensing applications. Two sensing approaches are developed. PoSi is functionalized in order to bind and detect biomolecules of vitamin B12. The characterization and detection were performed by FTIR (MICA platform) and impedance spectroscopy. PoSi also aims at developing a bacteria biosensor exploiting its highly sensitive optical properties to selectively detect bacteria in collaboration with the MIAE laboratory.

4. RF isolation application: A high frequency (>1GHz), electric conduction phenomena appear in the substrate (normally electrical insulator) on which are made the radio-frequency circuits. These parasitic phenomena strongly deteriorate the circuit performance. PoSi with its high electrical resistivity and low electrical permittivity is an ideal candidate to overcome these phenomena. High frequencies characterization equipment of WELCOME platform are used to measure the RF performance of the PoSi. The surface roughness of the PoSi impact the RF performances. Atomic force microscopy (AFM) techniques present in MICA platform allow characterization of this parameter.

[1] M.J. Sailor, Wiley, 9 janv. (2012)