Functionalization of Thermally Carbonized Porous Silicon Optical Multilayer Structures for Sensing Applications

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Porous silicon is a versatile material for sensing applications. Its large surface together with easily adjustable morphology offer an excellent platform for different applications. In addition to the conventional resistive and capacitive sensors, PSi has been used in optical gas sensing and very promising results of it have been reported.

The refractive index of PSi is depending on the porosity and the porosity can be controlled by a current density in electrochemical etching. This enables relatively precise control of refractive index of PSi and allows a fabrication of complex refractive index profile, e.g., multistopband rugate filters with apodization and refractive index matching.

However, for decades, the biggest stumbling block for PSi sensor applications has been the chemical instability of PSi. As-anodized PSi is hydrogen terminated and it slowly oxidizes even at room temperature. This changes also the electrical and optical properties of PSi, which is unacceptable in sensor applications. On the other hand, intentional oxidation of PSi, in order to improve the stability, usually leads to too high resistivity in electrical sensors and destroys the stopband in optical sensors.

In 2000, thermal carbonization by acetylene to stabilize PSi was introduced [1]. It produces a very stable non-stoichiometric silicon carbide layer on PSi, which is stable in harsh environments, like in NaOH, HF, KOH, etc. It also increases the conductivity of PSi, which is beneficial for electrical sensor application.

In 2008, thermal carbonization was used first time to stabilize optical multilayer structures [2]. The stopband was found to be intact after the carbonization, but the stability was significantly enhanced. Depending on the treatment temperature, two different surface chemistries can be achieved with thermal carbonization. Using treatment temperatures below 650^{o}C, the surface become hydrocarbon terminated which is hydrophobic, while with temperature above 650^{o}C, the surface is hydrophilic, hydrogen free silicon carbide covered by thin oxide layer.

Although, the thermally carbonized PSi is stable in HF solution, it is possible to fabricate a new PSi layer beneath the initial stabilized PSi layer. This enables to fabrication of multifunctional optical stack structures, in which topmost reflector structure has different surface chemistries than the one beneath it. These kind of structures has been used already to improve the selectivity of the PSi optical sensors and used to produce electrically isolated sensing layer (EISL) on the Si substrate [3].

Although the thermally carbonized PSi is stable, it is still possible to functionalize it further. During the last few years, we have developed several methods to functionalize both, hydrocarbon and silicon carbide terminated surfaces [4, 5]. In my talk, I will introduce these functionalization methods and show how these can be used to improve the sensitivity and selectivity of the PSi optical sensors. I would also discuss how straightforward it is to apply these kind of functionalized sensors also in biosensing application.

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