Enhanced thermally carbonized porous silicon for extreme harsh conditions

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Thermal carbonization has been one of the most effective methods for stabilizing porous silicon (PSi) for over 20 years, despite the fact that it completely quenches the intrinsic photoluminescence (PL). However, most current applications of PSi do not rely on PL [1]. Instead, desirable properties include good electrical conductivity, chemical stability in harsh environments, and the potential for versatile further surface chemistry modifications.

Thermal carbonization provides most of these properties. The so-called low-temperature hydrocarbonization process (500–600 °C) results in a hydrophobic hydrocarbon-terminated surface (THCPSi), enabling versatile further functionalization through methods similar to thermal hydrosilylation of as-anodized PSi. This treatment also enhances electrical conductivity [2] and can be applied to optical multilayer structures, such as Bragg reflectors and rugate filters, without compromising their functionality.

By adding an immediate subsequent carbonization cycle at a higher temperature (800–900 °C), the surface chemistry changes significantly. At these temperatures, all hydrogen atoms desorb, and together with the reintroduction of acetylene into the process, the surface changes from hydrocarbon terminated to a non-stoichiometric SiC surface (TCPSi). This surface is hydrophilic, and its electrical conductivity is typically orders of magnitude higher than in THCPSi. But, due to the absence of hydrogen, the surface termination needs to be finalized by thin layer of oxide.

In the talk, we will explore what will happens if we repeat these thermal carbonization cycles to a treated PSi sample. Specifically, instead of allowing TCPSi to be terminated with thin oxide layer, we repeat the low temperature carbonization cycle (THC-cycle) again. How the additional cycles affect the properties of these thermally carbonized samples, which we are calling as enhanced thermally carbonized PSi (EnTCPSi)? How the specific surface area or pore diameter decrease, and what happens to the electrical conductivity? Although EnTCPSi will be hydrolytically far too stable to be considered in drug delivery or in other applications where some kind of biodegradability is needed, it may meet needs of some more challenging applications e.g., electrochemical sensing in a harsh environment.

References

[1] J. Salonen and E. Mäkilä, Adv. Mat. 30, 170381, (2018).

[2] J. Salonen, M. Björkqvist and J. Paski, Sensors and Act. A. 116, 438 (2004).

Figures

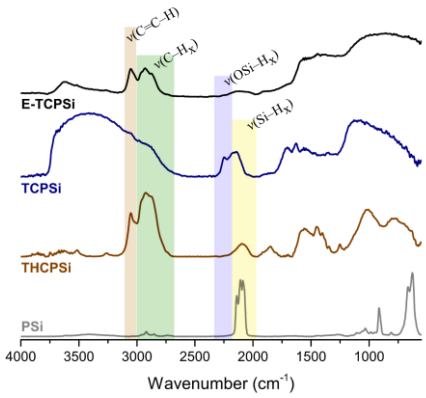

Figure 1: FTIR spectra of as-anodized PSi, THCPSi, TCPSi, and EnTCPSi. C-H_x peaks around 3000 1/cm clearly reappear after the additional THC-cycle together with a peak of vinyl groups above 3000 1/cm.