Light scattering investigation of 2D and 3D opal template formation on hydrophilized surfaces for ordered porous nanostructured materials

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Templating techniques using colloidal spheres have become popular for the formation of multi-dimensional porous nanostructures with an interconnected architecture (1, 2). The accessible surfaces and scalable skeletal dimensions provided by the three-dimensional macroporous (3DOM) materials created by the infilling of these opal-like templates have proven useful for numerous applications within the fields of optics and electronics (3, 4).The unique optical properties derived from the periodic nature of these templates and subsequent inverted materials allow the use of spectroscopic analysis techniques for investigations into order and the structural integrity of the materials(5, 6). Many techniques exist for the assembly of these opal array templates and self-assembly by dip-coating is one of the more popular techniques (7) most frequently used at a slow-rate (several µm min^{-1}) for the assembly of 3DOM templates.

Here, we present methods for opal template growth using a fast-rate dip coating technique (several mm min^{-1}) to form mono (2D) and multi-layer (2 + 1)D opal templates of PMMA spheres on hydrophobic and hydrophilic surfaces. We present an investigation of monolayer 2D and multilayered (2 + 1)D opal template formation through controlled variations in evaporation temperature and substrate-solvent interactions for both fast-rate and for some slow-rate depositions. We find that the substrate choice and cleaning techniques that lead to varying degrees of hydrophobicity and hydrophilicity markedly affect the degree of order and opal template structure in 2D and 3D. We also demonstrate the use of angle resolved spectroscopic analysis for monitoring the structure select opal templates after fast rate dip-coating. The diffraction scattering ability of mono-layered templates is exploited in the case where the absence of three-dimensional order is evident in the lack of a wavelength-specific photonic band gap. The ability to form 2D or (2 + 1)D opal templates with varying degrees of crystallinity and 2D and 3D order at fast rates is also correlated through light scattering to the substrate hydrophilicity.

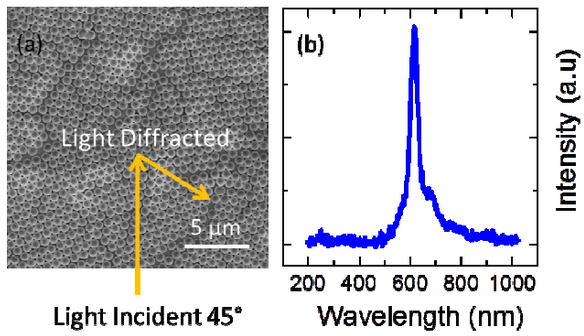

Fig. 1 (a) SEM image of the surface of a monolayer opal template formed by fast-rate dip coating and (b) scattering experiment showing first order planar diffraction at an angle β≈10° when light is incident at 45°

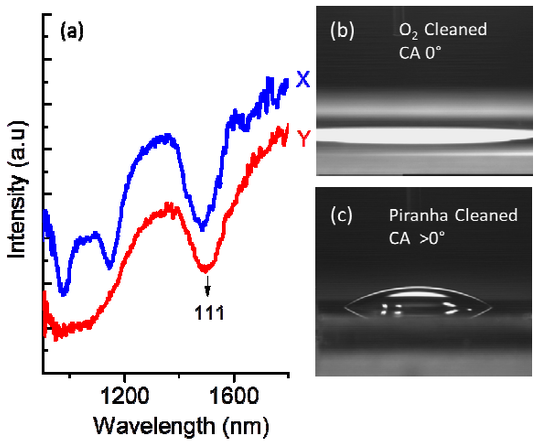

Fig. 2 (a) Transmission spectra for 3D templates grown using slow-rate dip coating on O_2 plasma cleaned glass X and piranha cleaned glass Y. There are a greater number of modes seen for X suggesting better long-range order for the more hydrophilic substrate, contact angle measurement images (b) and (c) confirm this.

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