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# Fabrication of Photonic Crystals with high refractive index

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Poster presented at *The Search for a Sustainable Energy Future: Challenges for Basic Research*, A Mini-Symposium sponsored by the Energy Working Group at Penn, March 9, 2007.

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# Fabrication of Photonic Crystals with high refractive index

## Abstract

• Complete photonic bandgap • High contrast of refractive index (RI) • Polymer material with a low RI • Inorganic material with a higher RI, such as silicon, titania. • Fabrication of diamond-like PCs by MBIL, • Fabrication of high RI inorganic PCs via double templating, • Core-shell morphology of replica • Pinch-off problem • Development of combined level-surface to address pinch-off problem • Electrodeposition of titania 3D structure • Electrophoretic deposition of surface charged nanoparticles

## Comments

Poster presented at *The Search for a Sustainable Energy Future: Challenges for Basic Research*, A Mini-Symposium sponsored by the Energy Working Group at Penn, March 9, 2007.

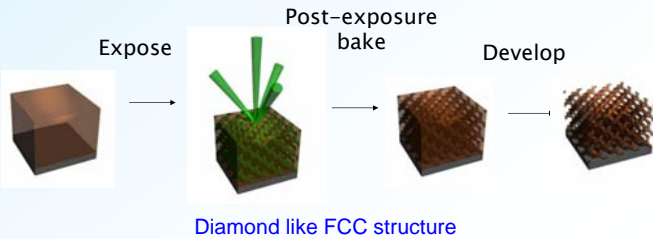
## Author(s)

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## Introduction

- ❖ Complete photonic bandgap
  - High contrast of refractive index (RI)
  - Polymer material with a low RI
  - Inorganic material with a higher RI, such as silicon, titania.
- ❖ Fabrication of diamond-like PCs by MBIL,
- ❖ Fabrication of high RI inorganic PCs via double templating,
  - Core-shell morphology of replica
  - Pinch-off problem
  - Development of combined level-surface to address pinch-off problem
- ❖ Electrodeposition of titania 3D structure
- ❖ Electrophoretic deposition of surface charged nanoparticles

## Holographic lithography



## Umbrella-like beam assembly

$$k_0 = \pi/a [3\ 3\ 3] \quad \text{Circular polarization}$$

$$k_1 = \pi/a [5\ 1\ 1] \quad e_1 = [0.680\ 0.680\ -0.272]$$

$$k_2 = \pi/a [1\ 5\ 1] \quad e_2 = [0.680\ -0.272\ 0.680]$$

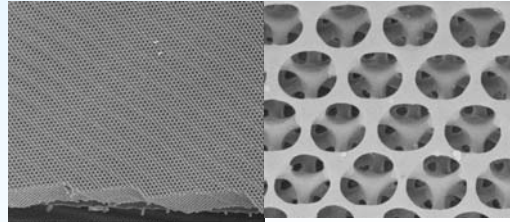
$$k_3 = \pi/a [1\ 1\ 5] \quad e_3 = [-0.272\ 0.680\ 0.680]$$

Superposed interference terms:  
 $I \sim \sin(x+y-z) + \sin(x-y+z) + \sin(-x+y+z)$

## Materials

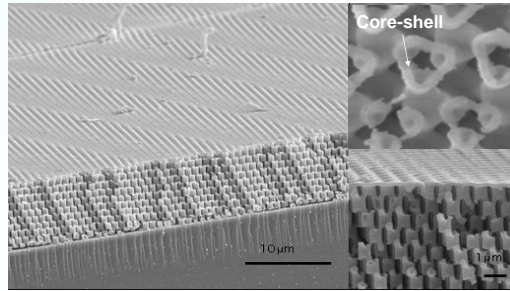
- SU-8 photoresist
- Photoacid generator: Irgacure 261

## 3D Polymer templates



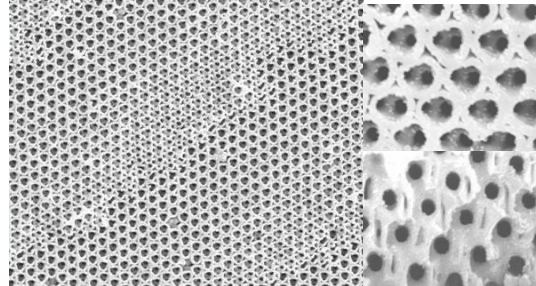
## Inversed silica replica

SiCl<sub>4</sub>, CVD  
Sintered at 500°C



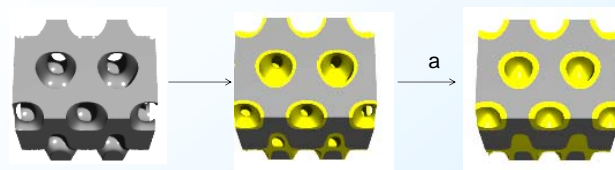
## Silicon photonic crystals

SiH<sub>4</sub>, LPCVD, 550°C,  
Remove silica



Core-shell morphology in replica due to incomplete filling

## Pinch-off problem in backfilling



a: The pores into the internal voids are closed during the deposition before filling the voids completely

## Simulation of the conformal coating layer on template using combined level surfaces

Simple cubic

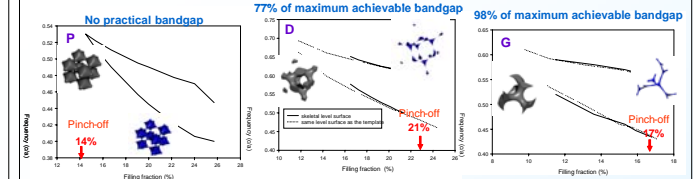
$$G_P(x, y, z) = \sin(x) + \sin(y) + \sin(z) - c(\sin(x)\sin(y) + \sin(y)\sin(z) + \sin(z)\sin(x))$$

•Diamond D

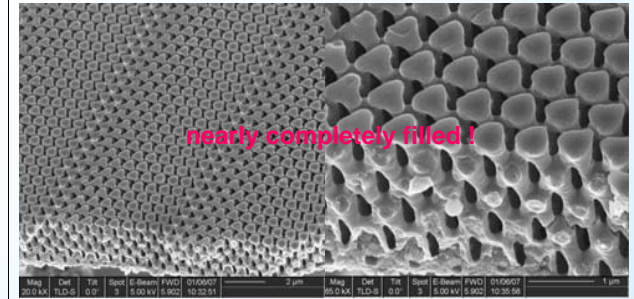
$$G_D = \sin(x+y+z) + \sin(-x+y+z) + \sin(x-y+z) + \sin(x+y-z) - c(\cos(2x) + \cos(2y) + \cos(2z))$$

•Gyroid G

$$G_G = \sin(x+y) + \sin(x-y) + \sin(y+z) + \sin(y-z) + \sin(z+x) + \sin(z-x) - c(\cos(2x)\cos(2y) + \cos(2y)\cos(2z) + \cos(2z)\cos(2x))$$



## Diamond-like titania by electrodeposition



## Infiltration of nanoparticles by electrophoretic Deposition

