Structural Study of Hyperbolic Surface Structures by Electron Microscopy

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The porous solids with hyperbolic surface structures have been discovered in a variety of biological and self-assembly systems. The gyroid, diamond and primitive surfaces are the most important most commonly observed hyperbolic surface structures. However, relatively little is known regarding their formation and the structural relationship, and the chemical fabrication of the controlled synthesis is still difficult. We developed a delicate method to fabricate the porous scaffolds with different structures, especially the hyperbolic surface structure, using the microphase-templating route through the self-assembly of an amphiphilic block polymer and silica source in a mixture of tetrahydrofuran and water. The unit cell parameter can be extended to several hundreds of nanometres with highly ordered structures.

To solve the obtained structures, the three-dimensional electrostatic potential map was obtained from the Fourier synthesis of the crystal structure factors extracted from the TEM images along various zone axes. The scaffold with shifted double diamond networks is the most common one is this synthesis system,[1] which shows a porous system separated by two sets of hollow double-diamond frameworks shifted along <001> and"adhered to each other crystallographically, forming a lower symmetry tetragonal lattice (space group $I4_1/amd$). This structure exhibits structural color in the visible wavelength range and a complete photonic bandgap can be achieved with high dielectric contrast materials.[2] The scaffold with the shifted double primitive structure was also obtained, which shows two hollow primitive networks shifted along 0.75*b* and 0.25*c* axes with the space group *Cmcm*. The interconversion of primitive to diamond structure was also revealed. The $[001]_P//[111]_D$ "side-by-side" relationship with the intermediate surface related to the rPD family have been directly observed.[3] Besides, the exceptional thermodynamically unstable single gyroid structure was also discovered in the system, which shows a unique structural relationship to the double diamond with half length scales.[4]

Our studies have demonstrated that electron"crystallography is the only way to solve these complex structures. We expect that our finding could outline a new concept and provide substantial opportunities in the study of these relevant biological structure and can be applied to further material synthesis.

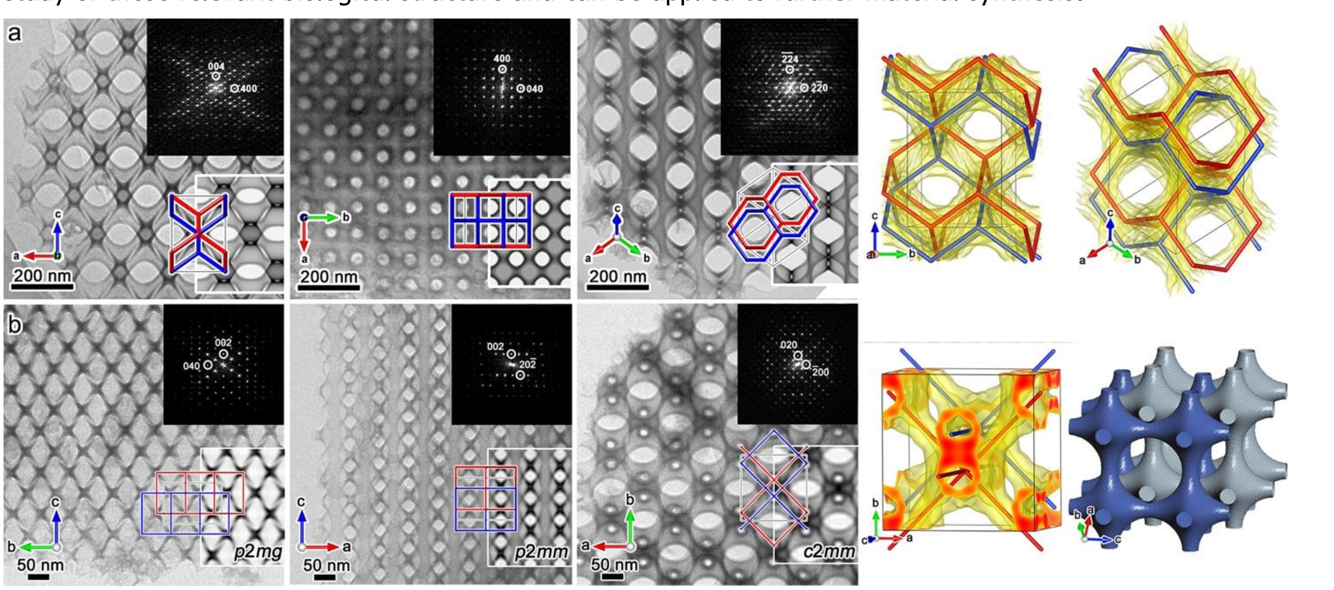

Figure 1. The TEM images and reconstructed volume of the (a) shifted double diamond and (b) shifted double primitive surface structures.

References

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