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Morphological engineering of two-dimensional inverse opal TiO_2 structures via modification of polymeric masks using Argon plasma jet irradiation

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Abstract

In this study, the effect of argon plasma jet irradiation on two-dimensional polymeric opals and its role in engineering inverse opal TiO_2 structures was investigated. Two-dimensional opals were fabricated from poly(methyl methacrylate) (PMMA) microspheres via a self-assembly method at the air-liquid interface and subsequently exposed to atmospheric-pressure argon plasma. The influence of the plasma–sample distance and irradiation time on the morphological evolution of the structures was systematically examined. The TiO_2 precursor was infiltrated into the opal templates before and after plasma treatment, and after removal of the polymer mask, inverse opal TiO_2 structures were obtained. Field-emission scanning electron microscopy (FESEM) revealed that at a 4 mm distance, increasing irradiation time from 3 to 8 minutes caused a continuous reduction in microsphere diameter and gradual deterioration of hexagonal order, whereas at a distance of 6 mm, changes were less pronounced, with only a slight reduction in particle size. Analysis of the final TiO_2 structures showed that plasma-treated templates produced smaller pores and thicker walls, leading to a higher TiO_2 filling fraction. However, excessive irradiation induced lattice disorder and wall damage. These results demonstrate that careful adjustment of plasma parameters—distance and exposure time—provides an effective tool for controlling the morphology and structure of inverse opals. The resulting nanostructures, with tunable optical and surface properties, are promising for photonic devices, biosensors, chemical sensors, chromatography, biomedical systems, solar cells, and photocatalytic applications.

Keywords: Two-dimensional inverse opal colloidal crystals, Deposition at the air–water interface, Monodisperse polymer microspheres, Cold plasma, Surface modification

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