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Supporting Information

Synthesis of $ZrN–SiO_2$ Core-shell Particles by a Sol-gel Process and Use as Particle-based Structured Coloring Material

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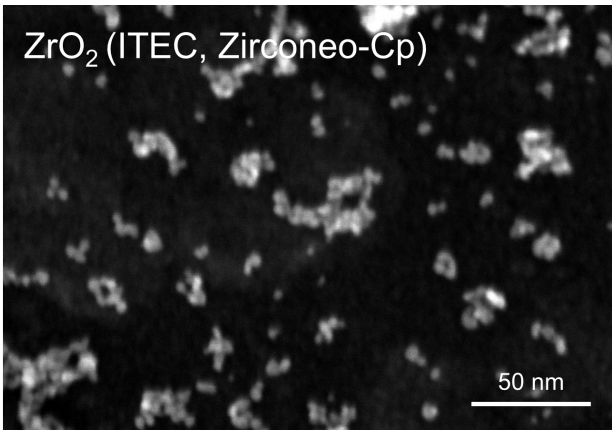


Figure S1. STEM image of the starting material ZrO_2 nanoparticles (ITEC, Zirconeo-Cp).

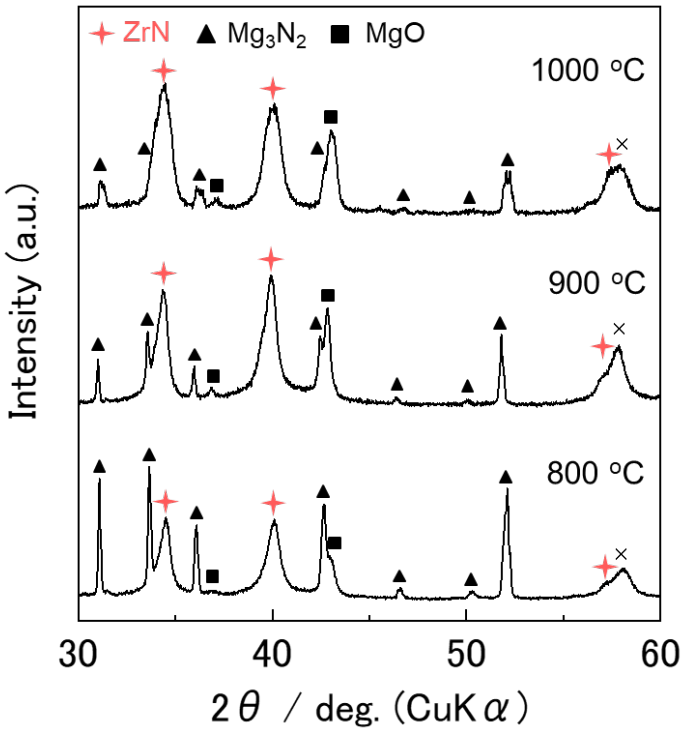


Figure S2. XRD profiles of the products before washing. The products were obtained by heating a mixture of ZrO_2 and Mg_3N_2 at 800 °C, 900 °C, and 1000 °C under a flow of N_2 gas.

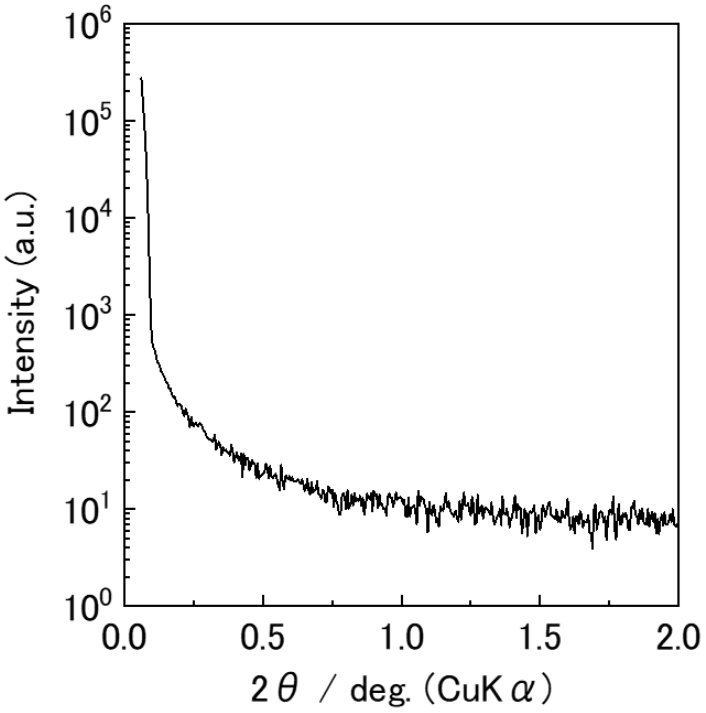


Figure S3. SAXS profile of the obtained ZrN particle dispersion.

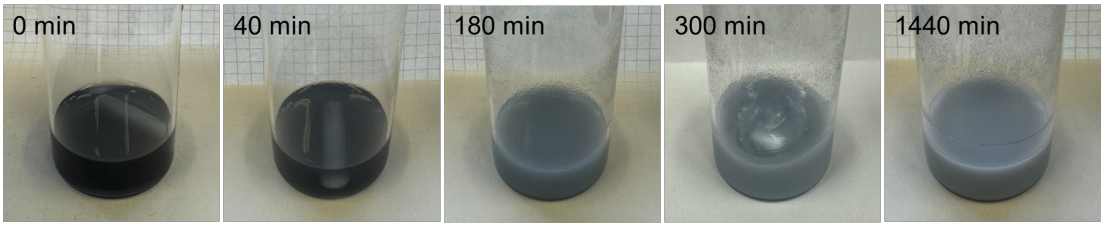


Figure S4. Photographs of the sol at the reaction times of 0 min, 40 min, 180 min, 300 min, and 1440 min.

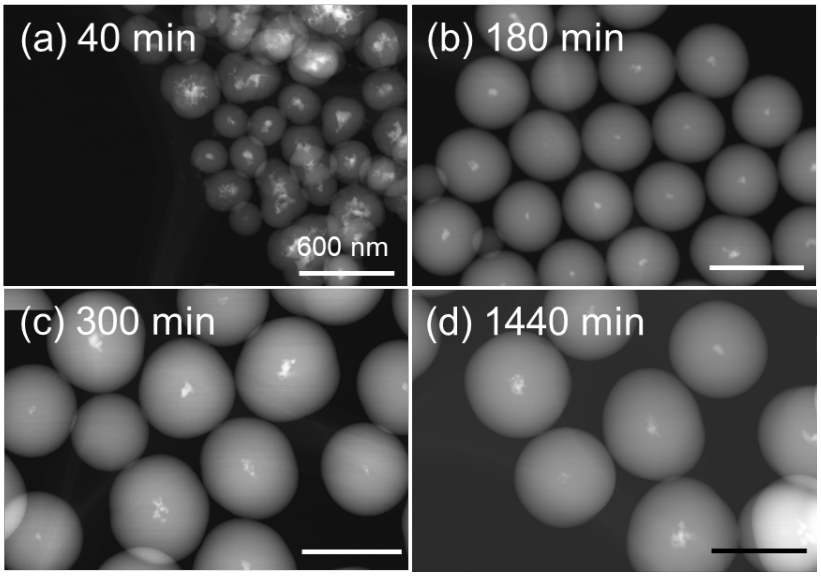


Figure S5. Low magnification HAADF STEM images of the ZrN–SiO_2 core–shell particles produced at the reaction times of (a) 40 min, (b) 180 min, (c) 300 min, and (d) 1440 min.

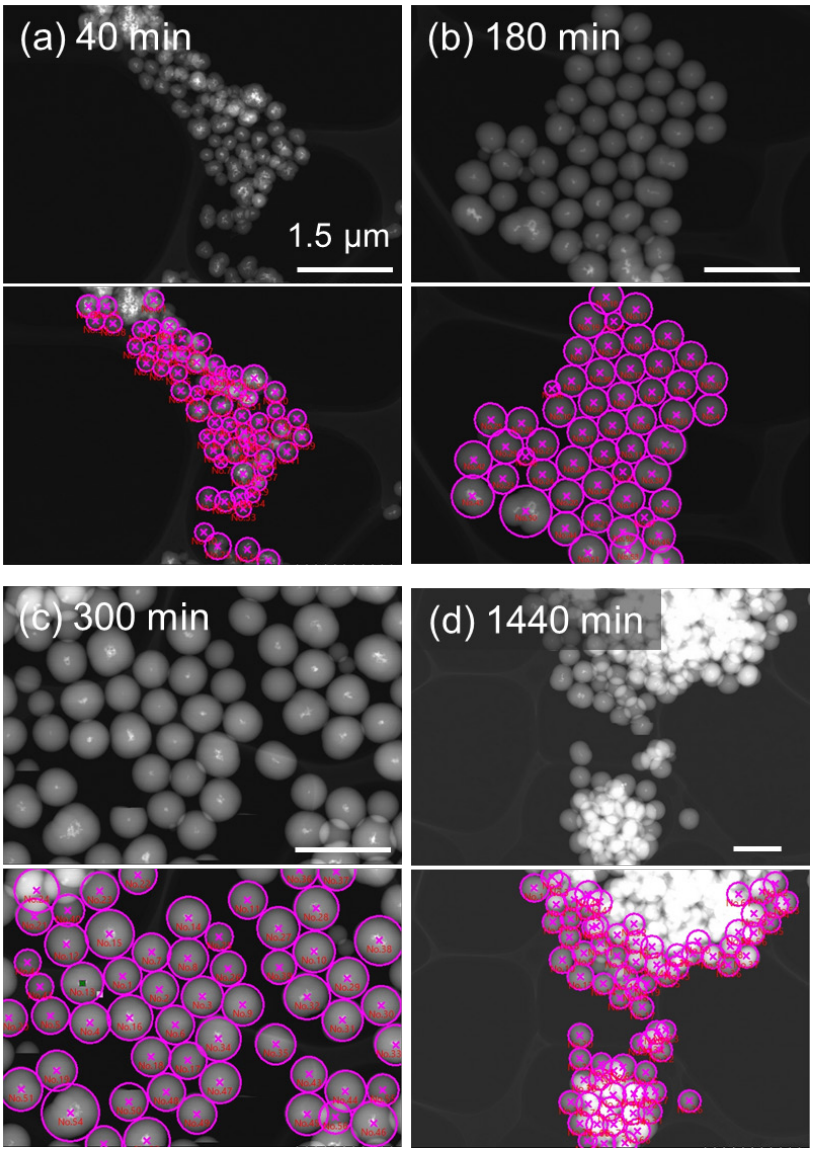


Figure S6. HAADF STEM images and target areas for analysis of the particles produced at the reaction times of (a) 40 min, (b) 180 min, (c) 300 min, and (d) 1440 min.

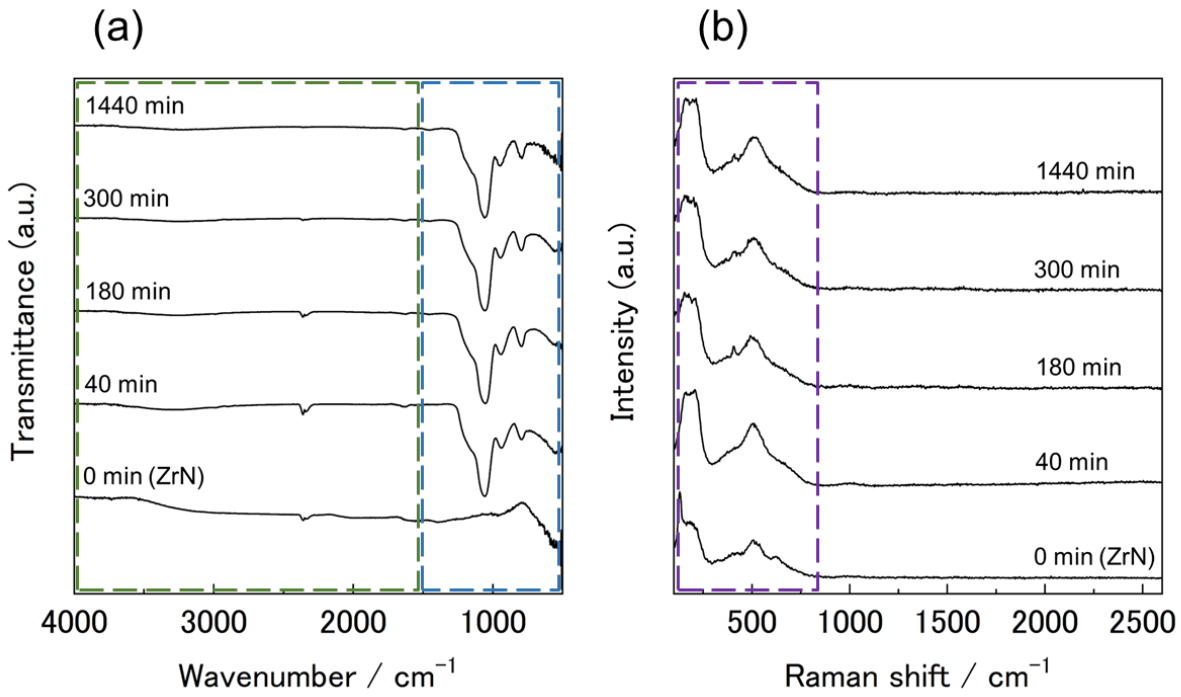


Figure S7. (a) FTIR spectra and (b) Raman spectra of the particles produced at the reaction times of 0 min, 40 min, 180 min, 300 min, and 1440 min. FTIR bands: 3500 to 3200 cm^{-1} for O-H stretching, 2950 cm^{-1} for C-H stretching of the methyl group ($-CH_3$), 2850 cm^{-1} for C-H stretching of the methylene group ($-CH_2-$), and 1600 cm^{-1} for H-O-H bending of water. FTIR bands at 1200 cm^{-1}, 1070 cm^{-1}, 930 cm^{-1}, and 800 cm^{-1} correspond to the Si-O or Si-OH bonds. Raman bands at 160 cm^{-1}, 220 cm^{-1}, and 520 cm^{-1} corresponding to the Zr-N[1] are observed in all products. The band at 140 cm^{-1} corresponds to the acoustic modes of ZrN.[2] The 420 cm^{-1} band observed in products with reaction times of 180 min, 300 min, and 1440 min is assigned to the Si-O bond.[3] The formation of SiO_2 around the ZrN particles leads to a decrease in the scattering intensity of the acoustic modes of ZrN.

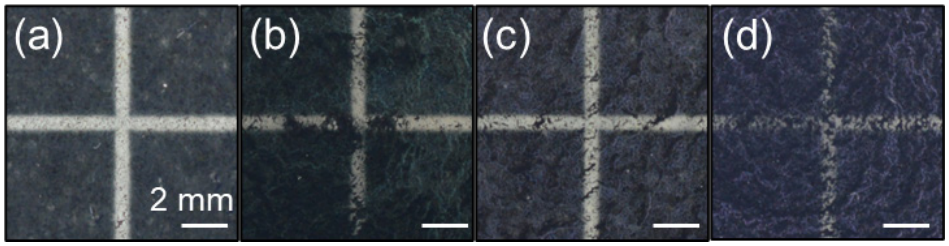


Figure S8. Photographs of the particle-stacked film consisting of ZrN–SiO_2 core–shell particles synthesized at reaction times of (a) 40 min, (b) 180 min, (c) 300 min, and (d) 1440 min.

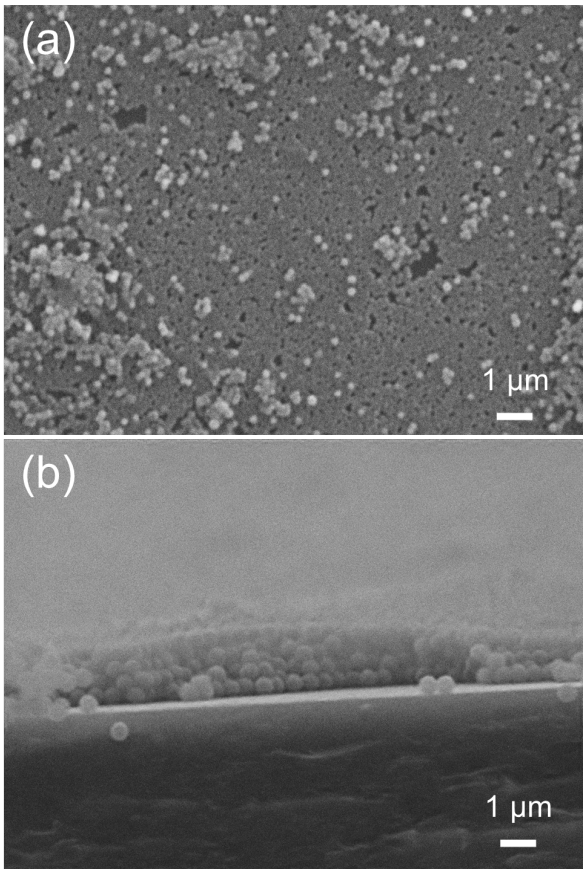


Figure S9. (a) Surface SEM image and (b) cross-sectional SEM image of the prepared particle-stacked film.

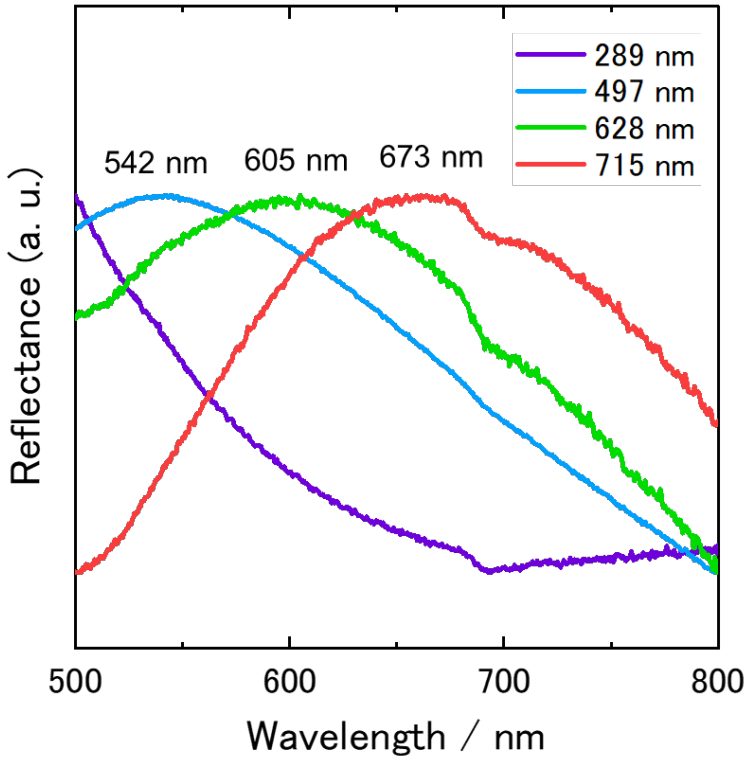


Figure S10. Reflection spectra normalized at the wavelength range 500–800 nm of the particle-stacked films composed of ZrN–SiO_2 core–shell particles with diameters of 289, 497, 628, and 715 nm.

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