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Supporting Information

Structural Color Materials with Color Mixing Effect Using Noble Metal-free Plasmonic Particles in SiO_2–ZrN System

*Shinji Noguchi, Milena Lama, Yuta Fujii, Akira Miura, Kiyoharu Tadanaga**

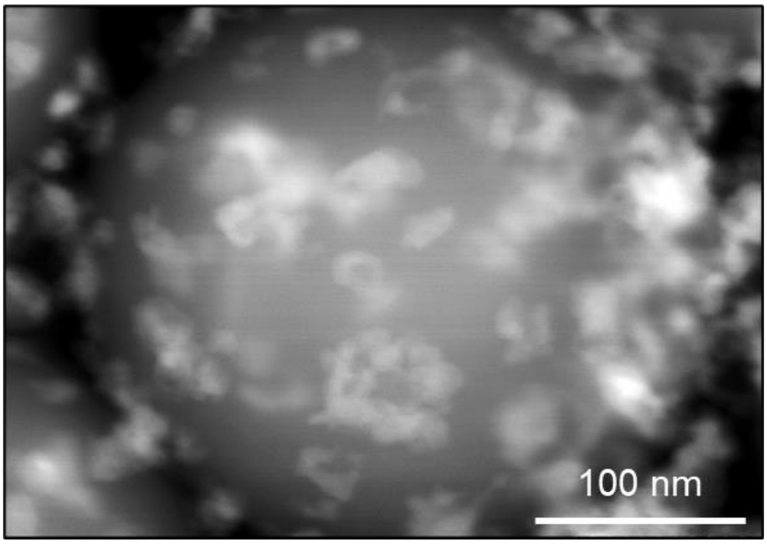

Figure S1. HAADF STEM micrograph of one SiO_2–ZrN core–shell particles.

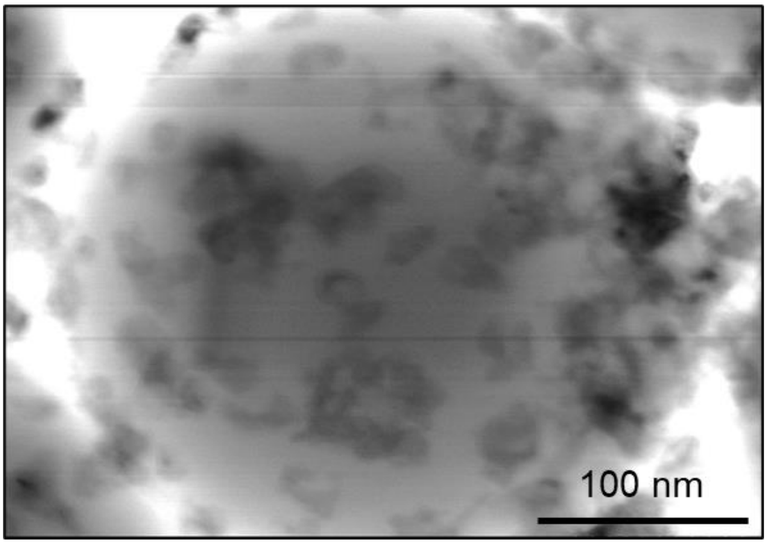

Figure S2. BF STEM micrograph of one SiO_2–ZrN core–shell particles.

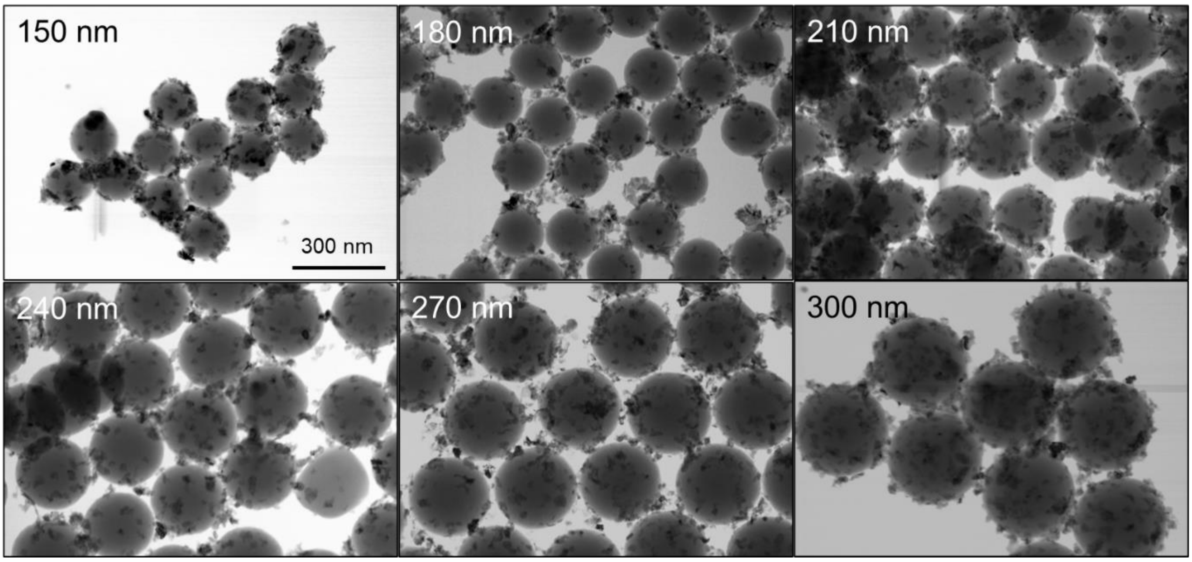

Figure S3. BF STEM images of the SiO_2–ZrN core-shell particles containing SiO_2 core particles of 150, 180, 210, 240, 270, and 300 nm.

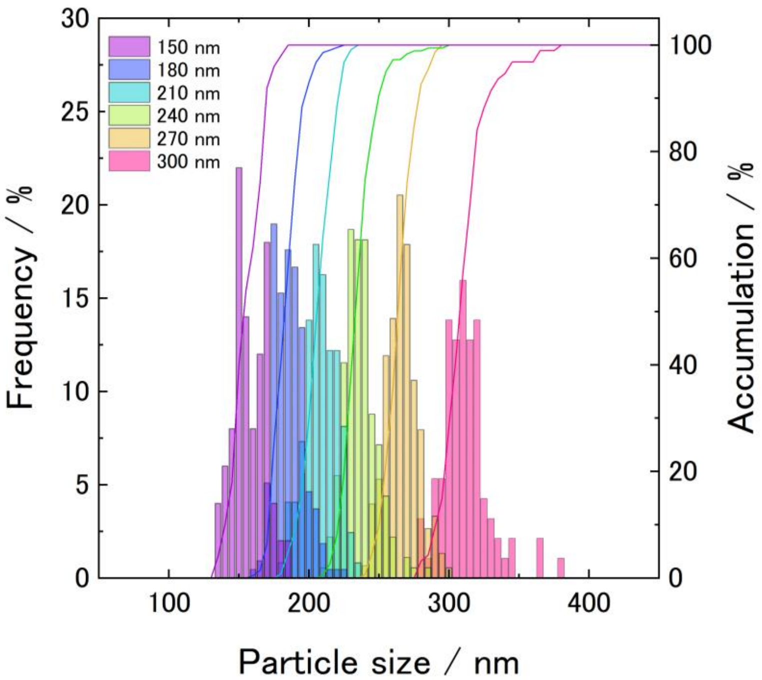

Figure S4. The particle size distribution diagram of produced SiO_2–ZrN core–shell particles containing 150–300 nm SiO_2 particle as the core. The particle size distribution is derived from STEM images of produced SiO_2–ZrN core–shell particles. The Coefficient of Variation (CV) values, which indicate the monodispersity of the particles, for core particles with sizes of 150, 180, 210, 240, 270, and 300 nm are respectively 7.2, 5.7, 5.3, 5.3, 4.1, 5.5 %. The Coefficient of Variation (CV) values are derived by dividing the standard deviation of the particle size by the mean value.

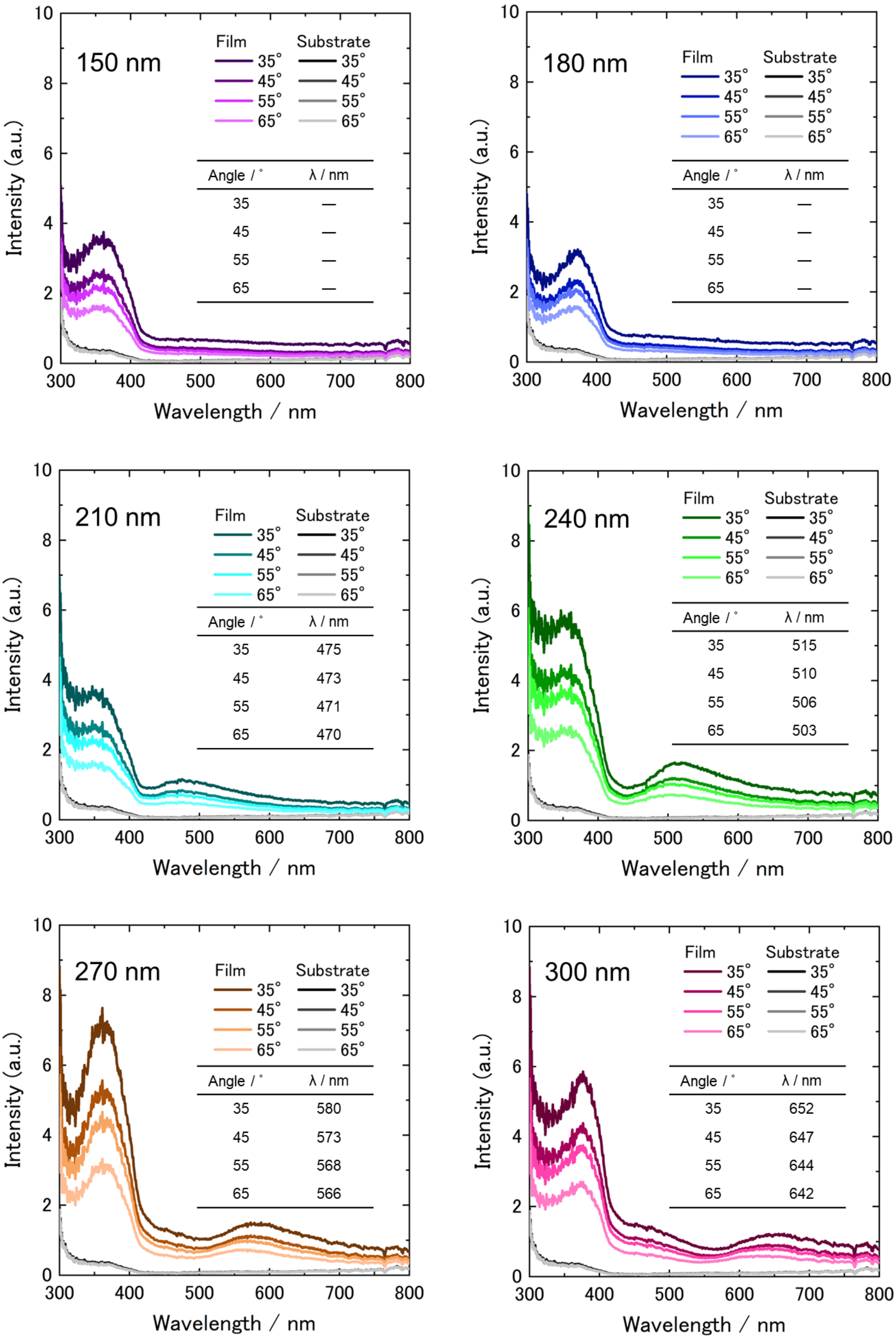

Figure S5. Angular dependence of reflection spectra of particle-stacked films comprising SiO_2–ZrN core–shell particles with core particles of 150, 180, 210, 240, 270, and 300 nm.

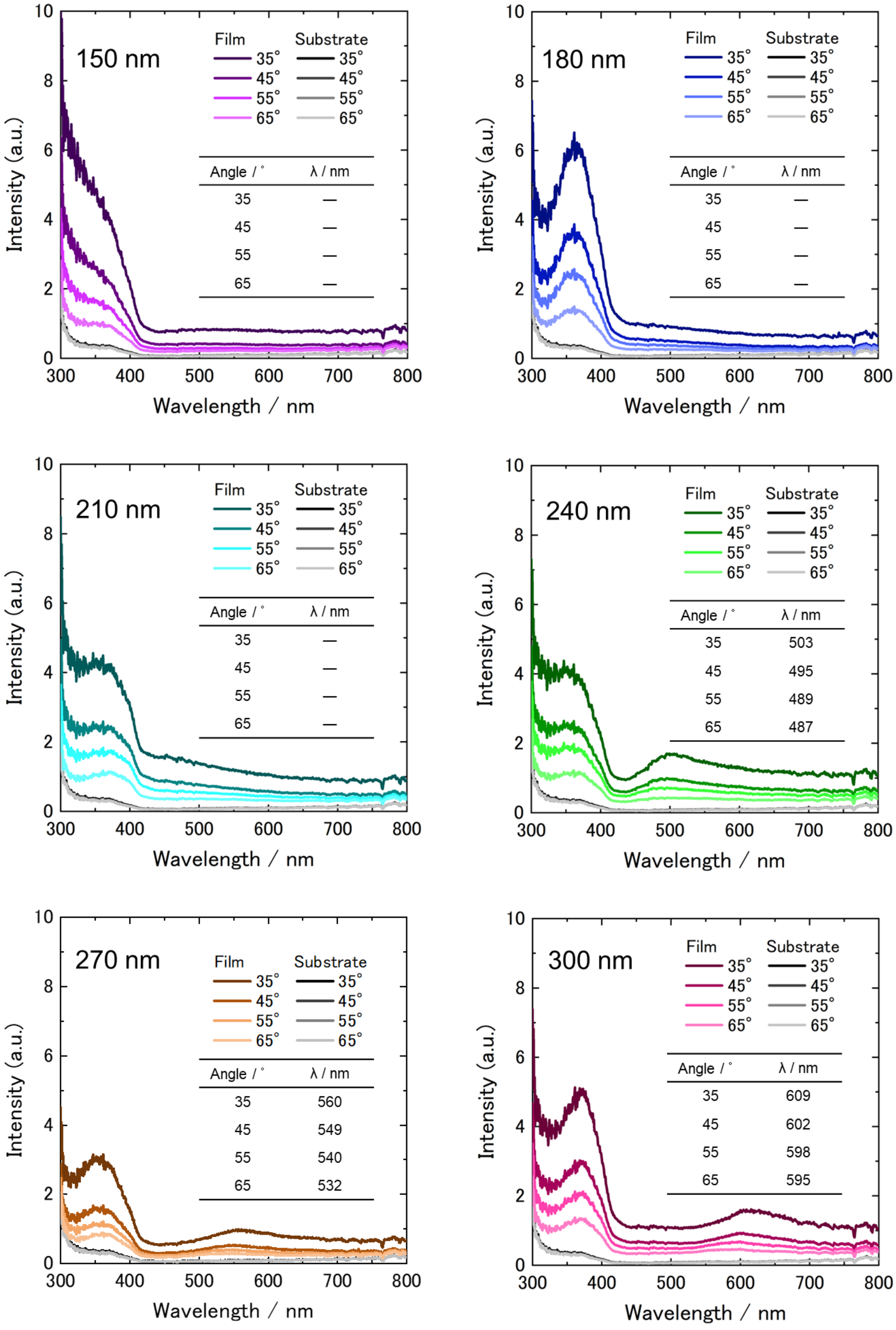

Figure S6. Angular dependence of reflection spectra of particle-stacked films comprising SiO_2 particles with particle size o 150, 180, 210, 240, 270, and 300 nm.

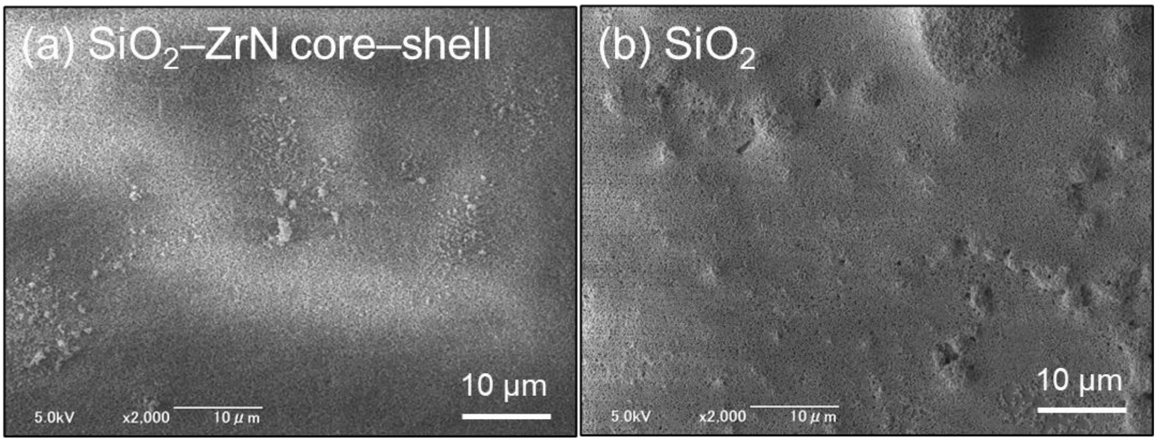

Figure S7. The low magnification FE-SEM images of particle-stacked film surface. (a) The particle-stacked films are composed of SiO_2–ZrN core–shell particles with core particles of 270 nm, and (b) 270 nm SiO_2 particles.

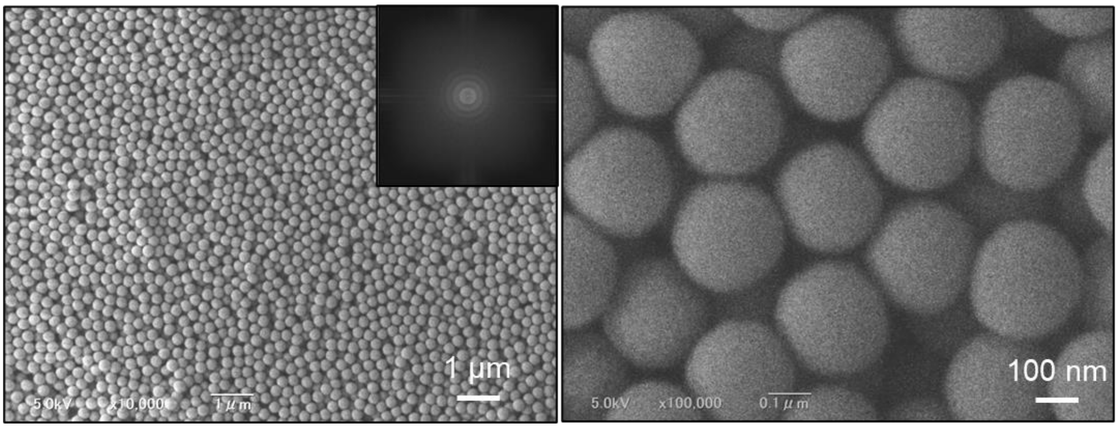

Figure S8. The surface FE-SEM images of particle-stacked films composed of 270 nm SiO_2 particles and Fourier transform image.

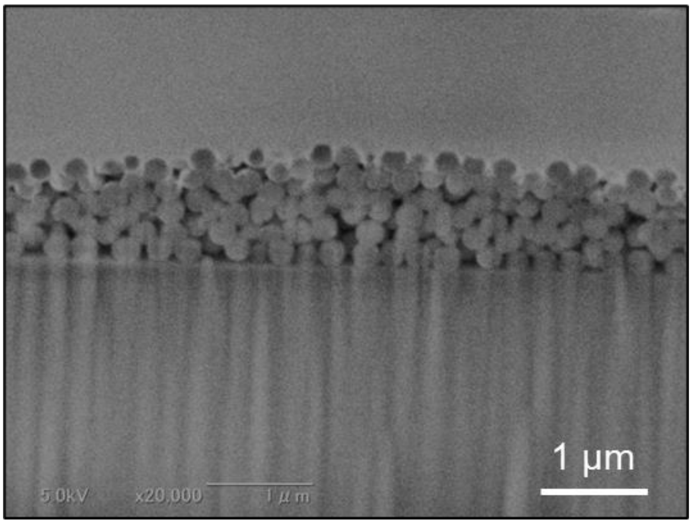

Figure S9. Cross-sectional FE-SEM images of particle-stacked films composed of 270 nm SiO_2 particles.

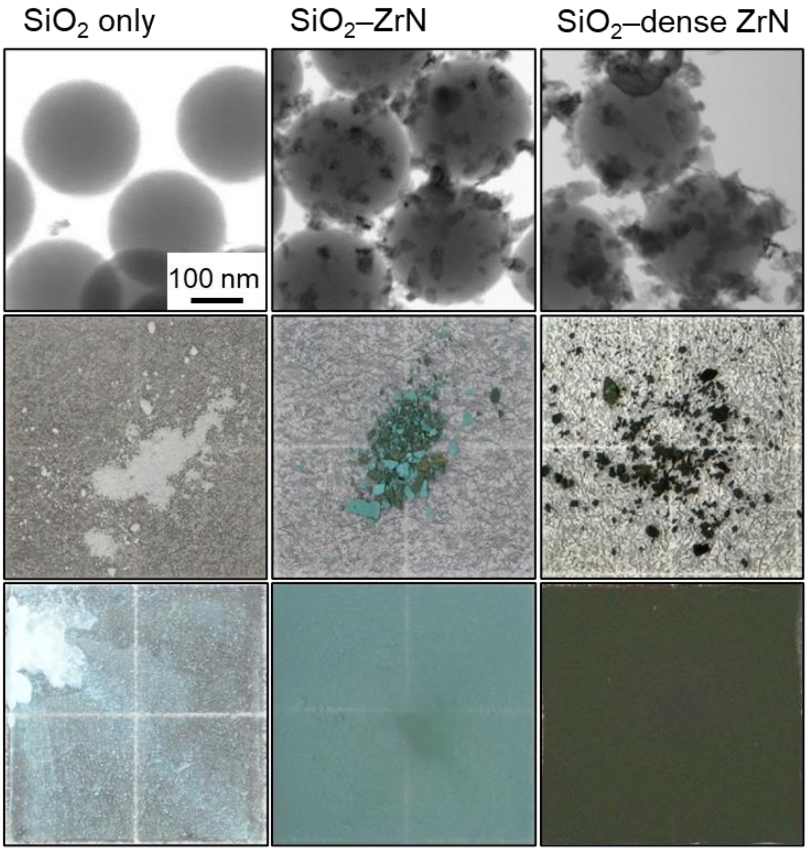

Figure S10. BF-STEM images, photographs of the obtained powder, and photographs of the particle-stacked films are presented for the following samples: 240 nm SiO_2 particles, SiO_2–ZrN core–shell particles containing 240 nm SiO_2 particles as the core, and SiO_2–ZrN core–shell particles with a dense ZrN as shell and 240 nm SiO_2 particles as the core.

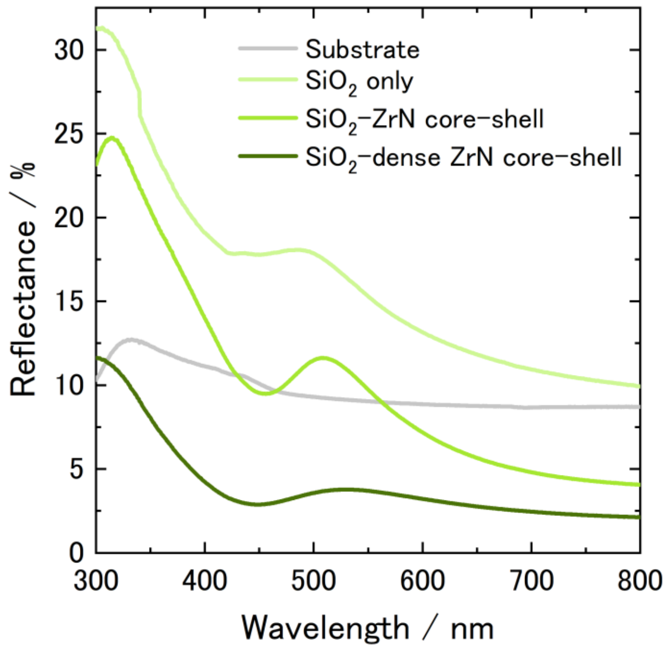

Figure S11. Reflection spectra of the particle-stacked films composed of 240 nm SiO_2 particles, SiO_2–ZrN core–shell particles with core particles of 240 nm, and SiO_2–ZrN core–shell particles with a dense ZrN as shell and 240 nm SiO_2 particles as the core. The light was incident at 5° from the vertical plane of the particle laminated film, with the reflected light detected with an integrating sphere unit.

Table S1. Wavelength of maximum peaks of the short wavelength side (λ_s), wavelength of maximum peaks of the long wavelength side (λ_l), reflectance of the short wavelength side (R_s), reflectance of the short wavelength side (R_l),and reflection intensity ratio ($R_l\ R_s^{-1}$) of the long wavelength side (R_l) to the reflection intensity on the short wavelength (R_s) side in the reflection spectrum of the particle-stacked films using 240 nm SiO_2 particles, SiO_2–ZrN core–shell particles with core particles of 240 nm, and SiO_2–ZrN core–shell particles with a dense ZrN as shell and 240 nm SiO_2 particles as the core.

Type	λ_s / nm	λ_l / nm	R_s / %	R_l / %	$R_l\ R_s^{-1}$ / –
SiO_2 only	306	485	31.31	18.07	0.58
SiO_2–ZrN core–shell	314	509	24.77	11.63	0.47
SiO_2– dense ZrN	301	530	12.92	4.20	0.33

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Author Contributions

- Shinji Noguchi led the study, including conceiving the study idea, developing the experimental plan, conducting the experiments, drafting the original manuscript, and securing some research funding.
- Milena Lama assisted in developing the experimental plan and conducted some of the experiments.
- Yuta Fujii discussed the results.
- Akira Miura discussed the results.
- Kiyoharu Tadanaga played a multifaceted role, including conceiving the study idea, developing the experimental plan, securing a portion of the research funding, and overseeing the entire study's execution.

All authors reviewed the manuscript draft and revised it critically on intellectual content. All authors approved the final version of the manuscript to be published.

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Notes

The authors declare no competing financial interests.