Electronic Supplementary Information (ESI)

Nickel Nanoparticles Individually Encapsulated in Densified Ceramic Shells for Thermally Stable Solar Energy Absorption

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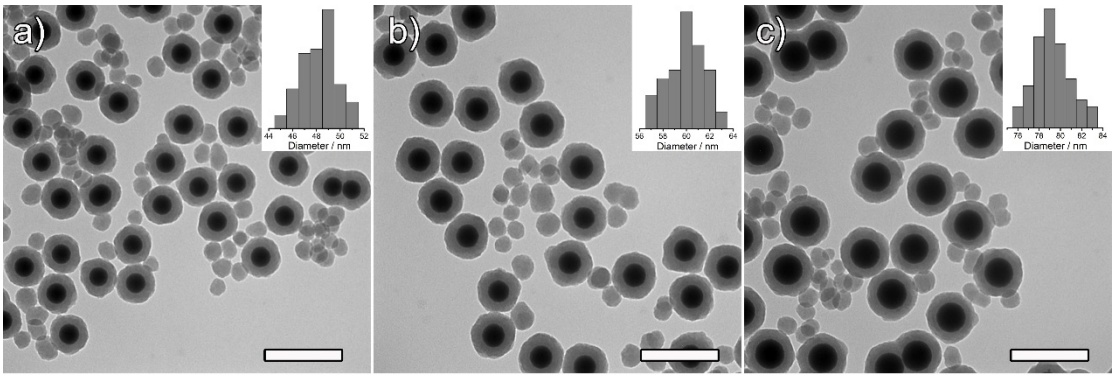

Fig. S1. (a–c) TEM images of the as-prepared Ni-B NPs of 50, 60, and 80 nm, respectively, coated with a SiO_2 shell of 22 ± 2 nm thickness. Scale bars: 200 nm. Ni-B NPs of 60 and 80 nm were prepared in a similar way to the typical synthesis of 50 nm Ni-B NPs, except that the reaction temperatures were set to 20 °C and 15 °C and the amount of $NaBH_4$ were 0.66 and 0.53 mmol, respectively. It is worth noting that free silica NPs are observable in these images, which could be attributed to the self-nucleation of silica in the coating process. However, the number of the free silica NPs is quite limited, and the utilization rate of silica for the coating of the Ni-B NPs could be estimated to be ~75% from Fig. S1a.

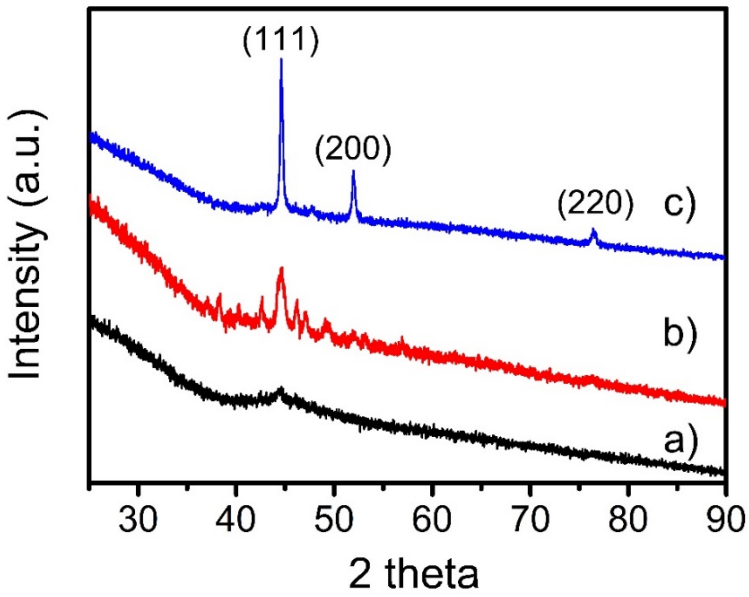

Fig. S2. XRD patterns of the Ni-B@SiO_2 NPs after annealing at 300 ℃ (a), 450 ℃ (b), and 600 ℃ (c) in N_2.

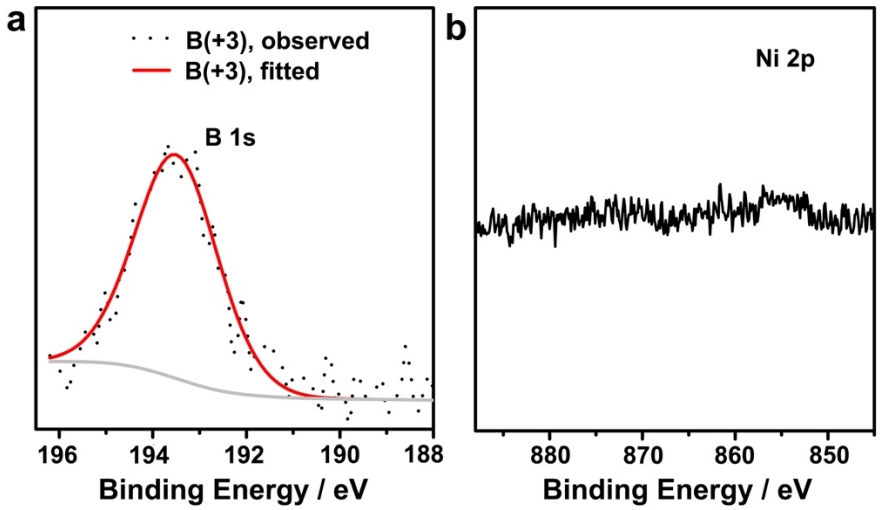

Fig. S3. XPS of the Ni@SiO_2 NPs obtained after annealing of the Ni-B@SiO_2 NPs at 700 °C for 5 h. a) Core-level B 1s spectrum. b) Core-level Ni 2p spectrum. The results confirm that the boron species were oxidized into B_2O_3. The XPS shows negligible signals from Ni while substantial signals from B. Because XPS is a surface-sensitive technique, this observation clearly indicates the diffusion of B_2O_3 into the silica shells.

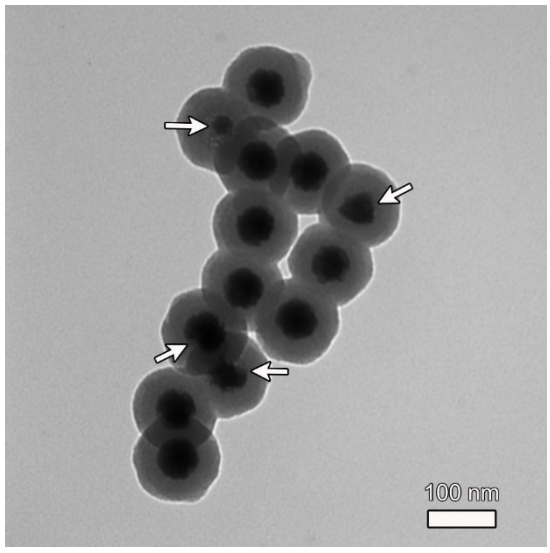

Fig. S4. TEM image of the Ni-B NPs (60 nm) coated with SiO_2 using ammonia as a catalyst, resulting in an etching of the Ni-B NPs as indicated by the arrows.

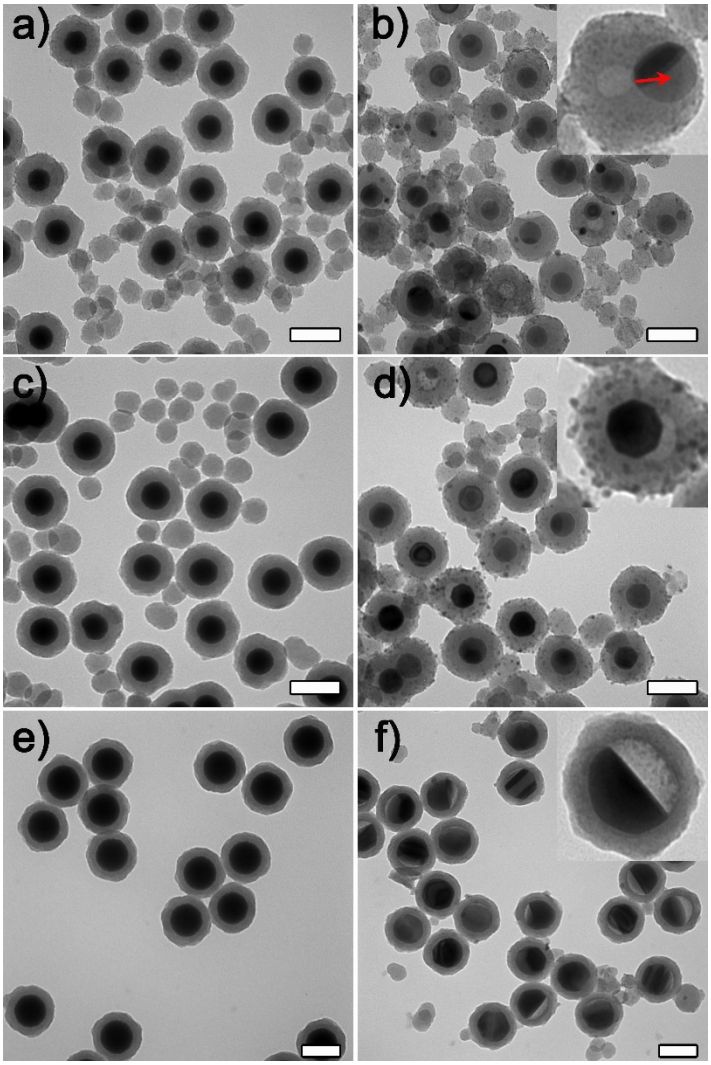

Fig. S5. TEM images of the Ni-B@SiO_2 NPs synthesized in an ethanolic solution of a high DEA concentration (3mL of DEA in 80 mL of ethanol), which results in the formation of porous SiO_2 shells and severe diffusion of the Ni NPs during a subsequent annealing process at 600 ℃ in N_2 for 3 h. (a) As-prepared Ni-B (50 nm) @SiO_2 (22 nm) NPs; (b) Ni-B (50 nm) @SiO_2 (22 nm) NPs after annealing, showing that the whole Ni cores migrated toward the outside of SiO_2 shells, leaving a void; (c) As-prepared Ni-B (60 nm) @SiO_2 (25 nm) NPs; (d) Ni-B (60 nm) @SiO_2 (25 nm) NPs after annealing, showing that small Ni NPs separated from the Ni core migrated outward through the silica shell. (e) As-prepared Ni-B (80 nm) @SiO_2 (22 nm) NPs; (d) Ni-B (80 nm) @SiO_2 (22 nm) NPs after annealing, showing complete outward diffusion of partial Ni NPs, leaving a hemispheric Ni NPs in the silica cavities. Scale bars: 100 nm.