

Supplementary Materials

Steam Reforming of Tar Impurities from Biomass Gasification with Ni-Co/Mg(Al)O Catalysts – Operating Parameter Effects

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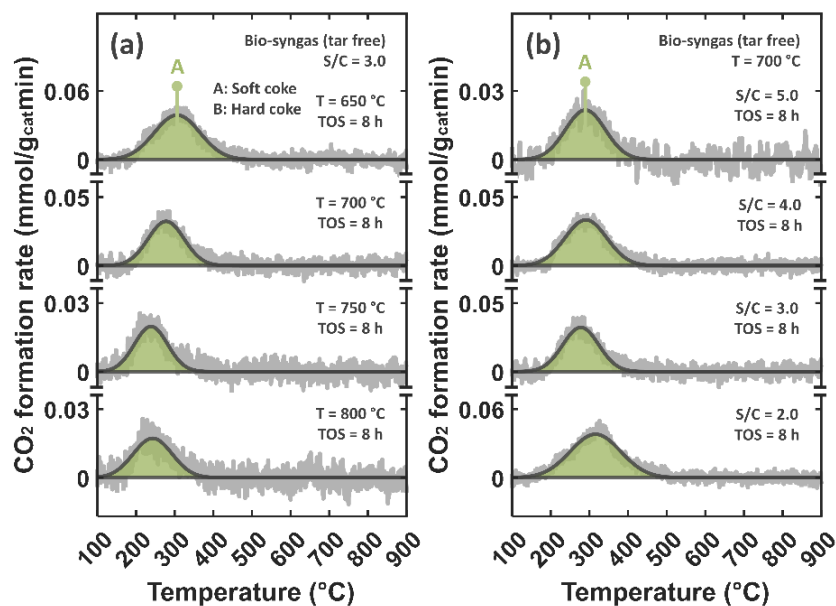


Figure S1. Post-run CO₂ formation in TPO-MS coke combustion experiments following steam reforming of CH₄ in tar free environment at different operating conditions (syngas = 10/35/25/25 mol% CH₄/H₂/CO/CO₂ with 5 mol% N₂ internal standard, Ar balance, syngas flow = 400 NmL/min, GHSV = 85000 NmL/g_{cat}min)

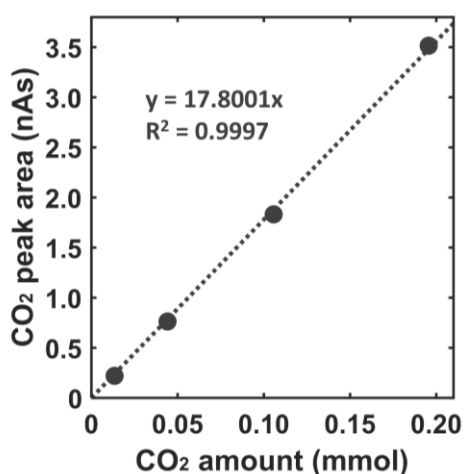


Figure S2. MS-detector calibration curve from TPO-MS based on CO₂ formation upon thermal decomposition of calcium oxalate monohydrate (third degradation step: $\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$).

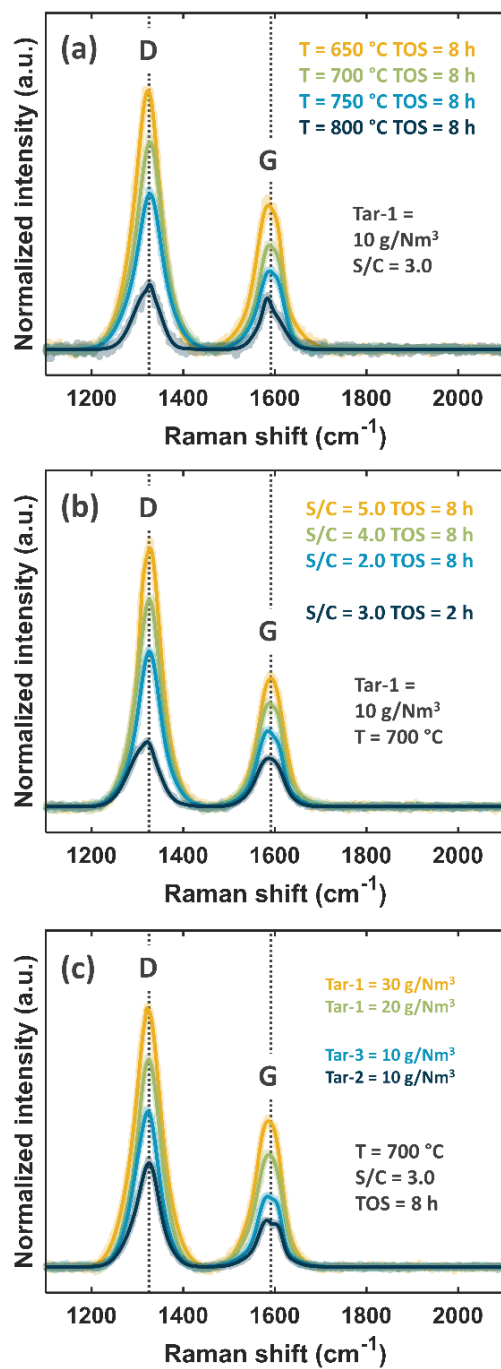


Figure S3. Raman spectra following model tar steam reforming at different operating conditions (syngas = 10/35/25/25 mol% $\text{CH}_4/\text{H}_2/\text{CO}/\text{CO}_2$ with 5 mol% N_2 internal standard, Ar balance, syngas flow = 400 NmL/min, GHSV = 85000 NmL/g_{cat}min, Tar-1 = 100/0/0, Tar-2 = 75/25/0 and Tar-3 = 70/25/5 wt% toluene/1-methylenaphthalene/phenol).

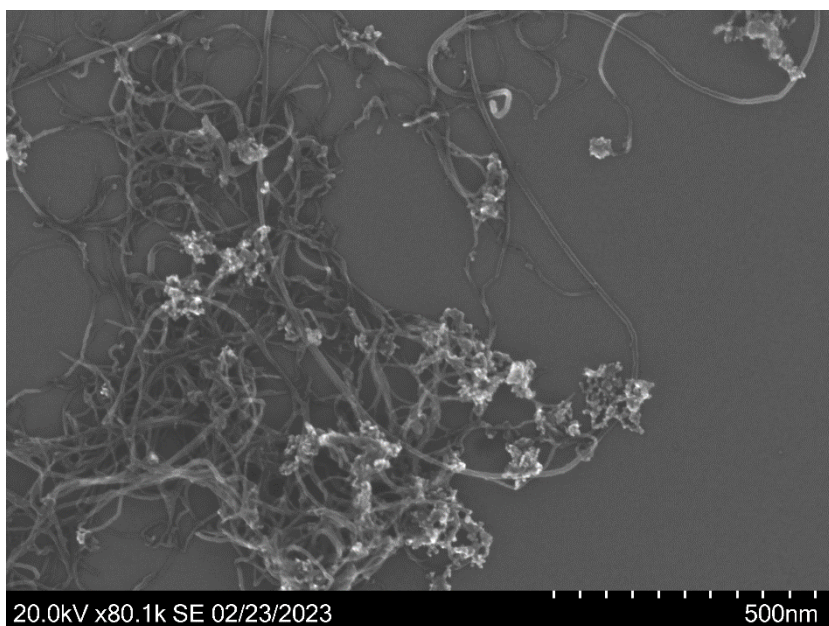


Figure S4. Unedited STEM image of filamentous carbon following tar steam reforming (temperature = 700 °C, S/C = 3.0, TOS = 2 hours, syngas = 10/35/25/25 mol% CH₄/H₂/CO/CO₂ with 5 mol% N₂ internal standard, Ar balance, syngas flow = 400 NmL/min, GHSV = 85000 NmL/g_{cat}min, tar model = 10 g/Nm³ toluene).

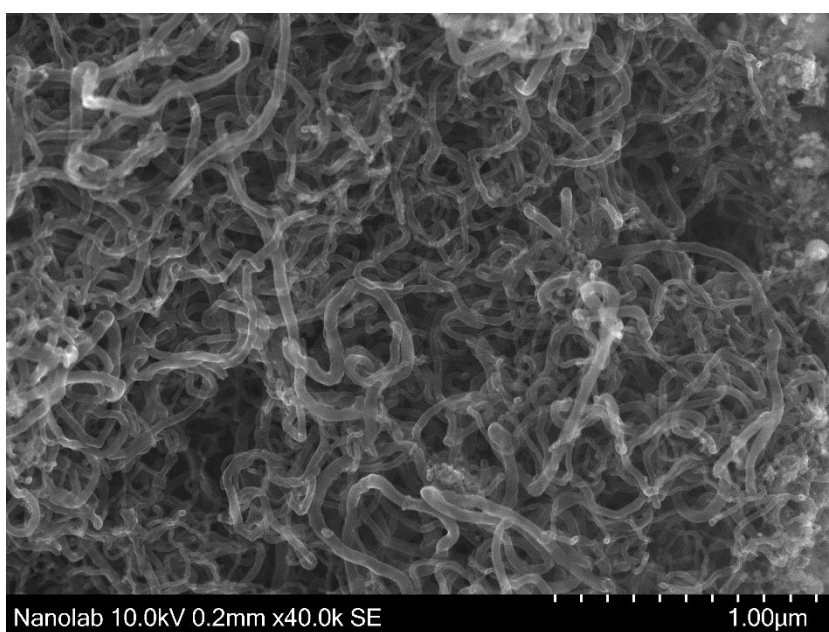


Figure S5. Unedited STEM image of filamentous carbon following tar steam reforming (temperature = 700 °C, S/C = 3.0, TOS = 8 hours, syngas = 10/35/25/25 mol% CH₄/H₂/CO/CO₂ with 5 mol% N₂ internal standard, Ar balance, syngas flow = 400 NmL/min, GHSV = 85000 NmL/g_{cat}min, tar model = 10 g/Nm³ toluene).

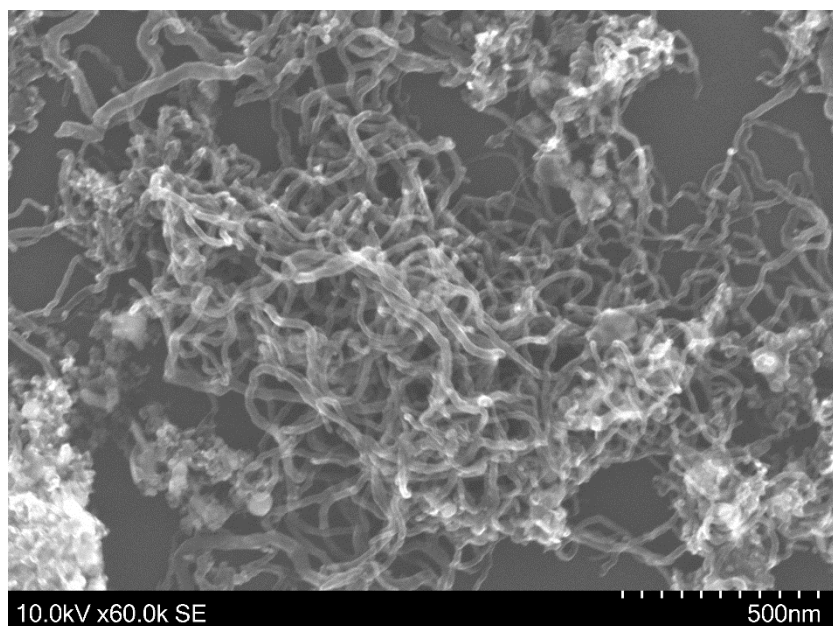


Figure S6. Unedited STEM image of filamentous carbon following tar steam reforming (temperature = 650 °C, S/C = 3.0, TOS = 8 hours, syngas = 10/35/25/25 mol% CH₄/H₂/CO/CO₂ with 5 mol% N₂ internal standard, Ar balance, syngas flow = 400 NmL/min, GHSV = 85000 NmL/g_{cat}min, tar model = 10 g/Nm³ toluene).

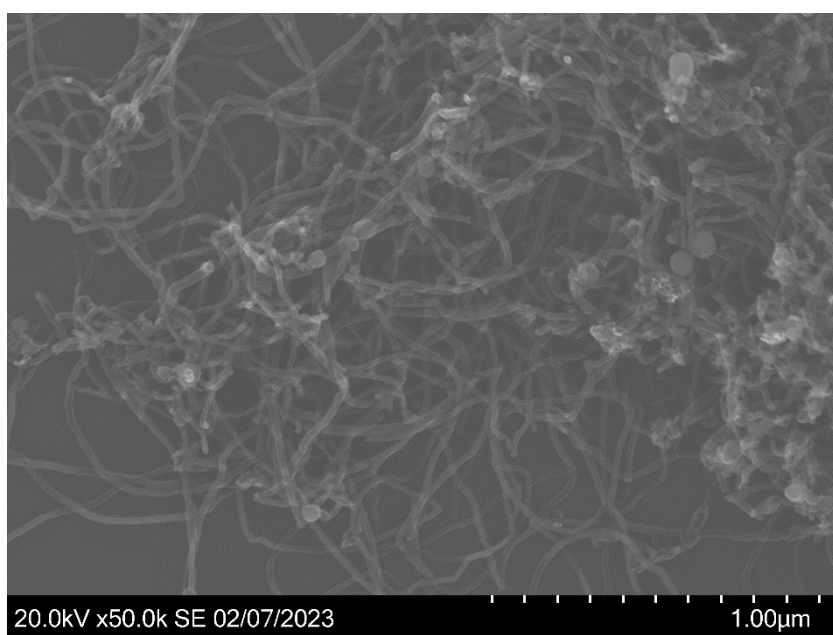


Figure S7. Unedited STEM image of filamentous carbon following tar steam reforming (temperature = 800 °C, S/C = 3.0, TOS = 8 hours, syngas = 10/35/25/25 mol% CH₄/H₂/CO/CO₂ with 5 mol% N₂ internal standard, Ar balance, syngas flow = 400 NmL/min, GHSV = 85000 NmL/g_{cat}min, tar model = 10 g/Nm³ toluene).

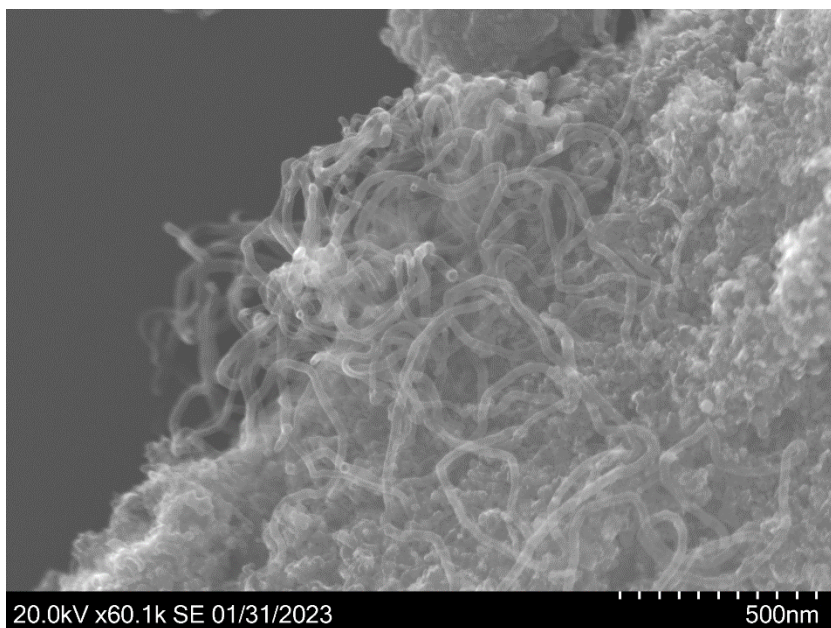


Figure S8. Unedited STEM image of filamentous carbon following tar steam reforming (temperature = 700 °C, S/C = 2.0, TOS = 8 hours, syngas = 10/35/25/25 mol% CH₄/H₂/CO/CO₂ with 5 mol% N₂ internal standard, Ar balance, syngas flow = 400 NmL/min, GHSV = 85000 NmL/g_{cat}min, tar model = 10 g/Nm³ toluene).

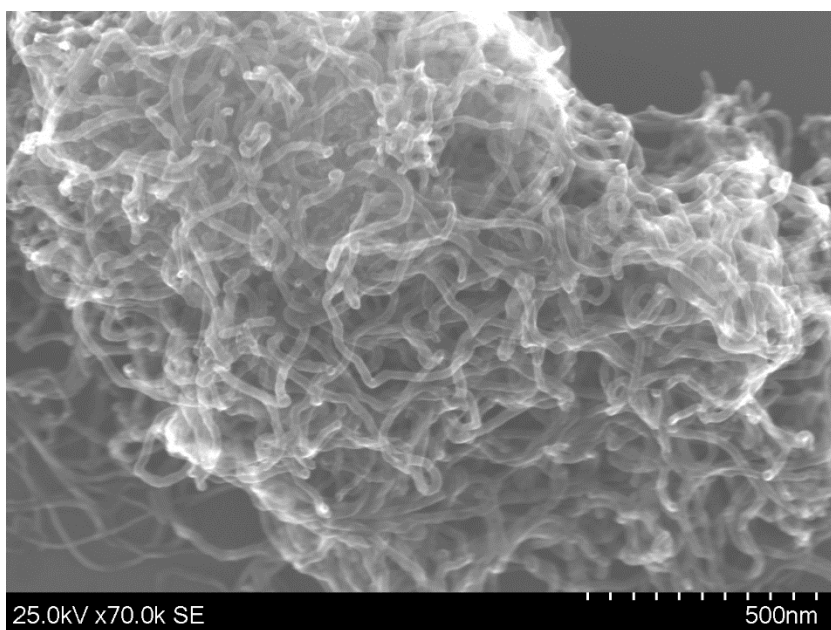


Figure S9. Unedited STEM image of filamentous carbon following tar steam reforming (temperature = 700 °C, S/C = 5.0, TOS = 8 hours, syngas = 10/35/25/25 mol% CH₄/H₂/CO/CO₂ with 5 mol% N₂ internal standard, Ar balance, syngas flow = 400 NmL/min, GHSV = 85000 NmL/g_{cat}min, tar model = 10 g/Nm³ toluene).

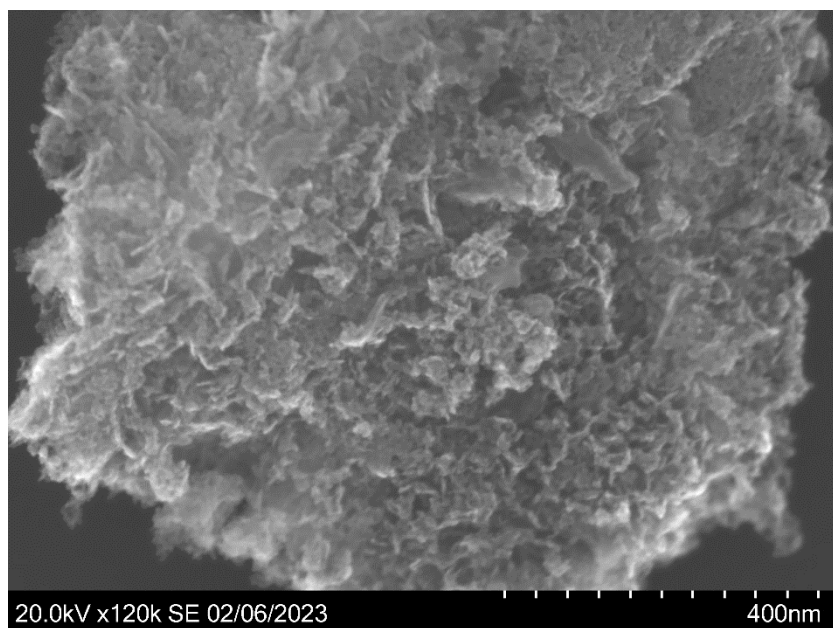


Figure S10. Unedited STEM image of fresh catalyst structures.

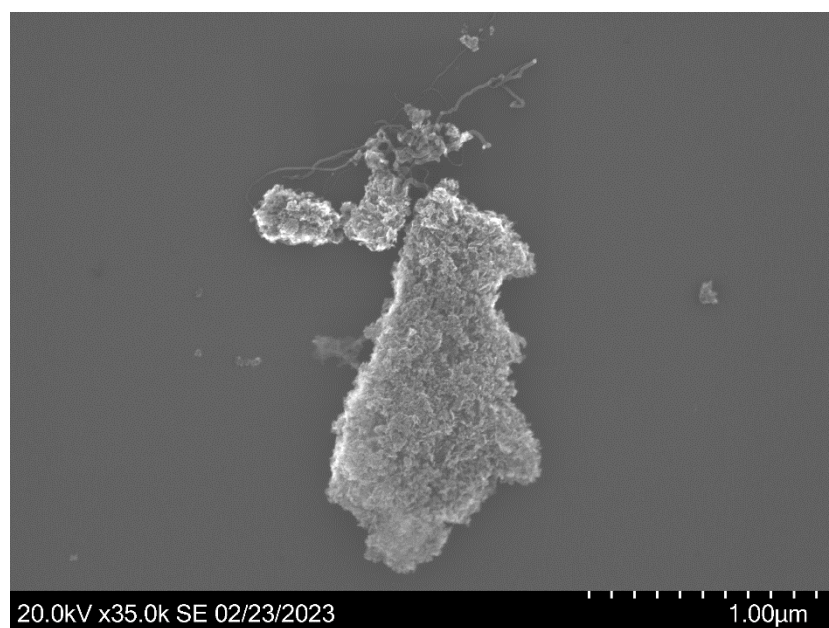


Figure S11. Unedited STEM image of fresh catalyst structures following tar steam reforming (temperature = 700 °C, S/C = 3.0, TOS = 2 hours, syngas = 10/35/25/25 mol% CH₄/H₂/CO/CO₂ with 5 mol% N₂ internal standard, Ar balance, syngas flow = 400 NmL/min, GHSV = 85000 NmL/g_{cat}min, tar model = 10 g/Nm³ toluene).

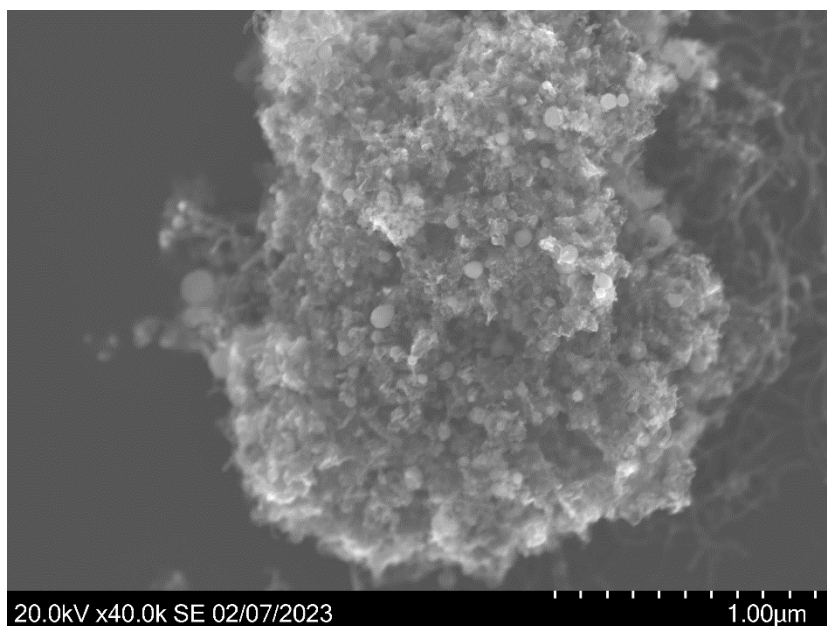


Figure S12. Unedited STEM image of sintered metal particles following tar steam reforming (temperature = 800 °C, S/C = 3.0, TOS = 8 hours, syngas = 10/35/25/25 mol% CH₄/H₂/CO/CO₂ with 5 mol% N₂ internal standard, Ar balance, syngas flow = 400 NmL/min, GHSV = 85000 NmL/g_{cat}min, tar model = 10 g/Nm³ toluene).

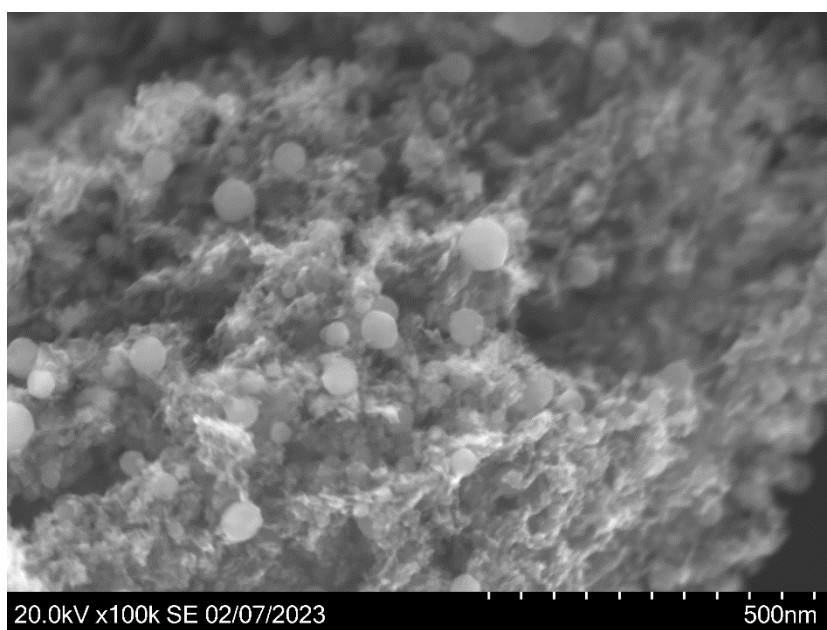


Figure S13. Unedited STEM image of sintered metal particles following tar steam reforming (temperature = 800 °C, S/C = 3.0, TOS = 8 hours, syngas = 10/35/25/25 mol% CH₄/H₂/CO/CO₂ with 5 mol% N₂ internal standard, Ar balance, syngas flow = 400 NmL/min, GHSV = 85000 NmL/g_{cat}min, tar model = 10 g/Nm³ toluene).

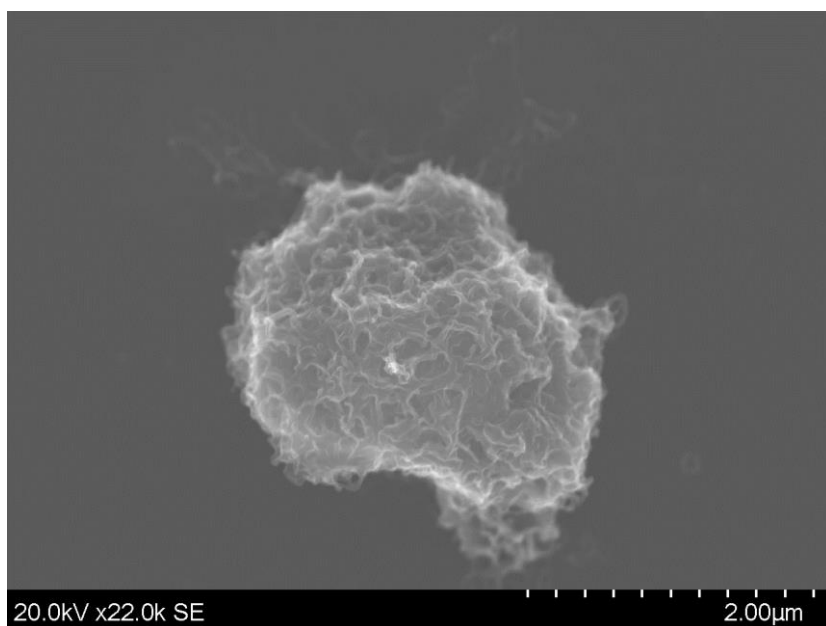


Figure S14. Unedited STEM image of partly fused/graphitized carbon filaments following tar steam reforming (temperature = 650 °C, S/C = 3.0, TOS = 8 hours, syngas = 10/35/25/25 mol% CH₄/H₂/CO/CO₂ with 5 mol% N₂ internal standard, Ar balance, syngas flow = 400 NmL/min, GHSV = 85000 NmL/g_{cat}min, tar model = 10 g/Nm³ toluene).

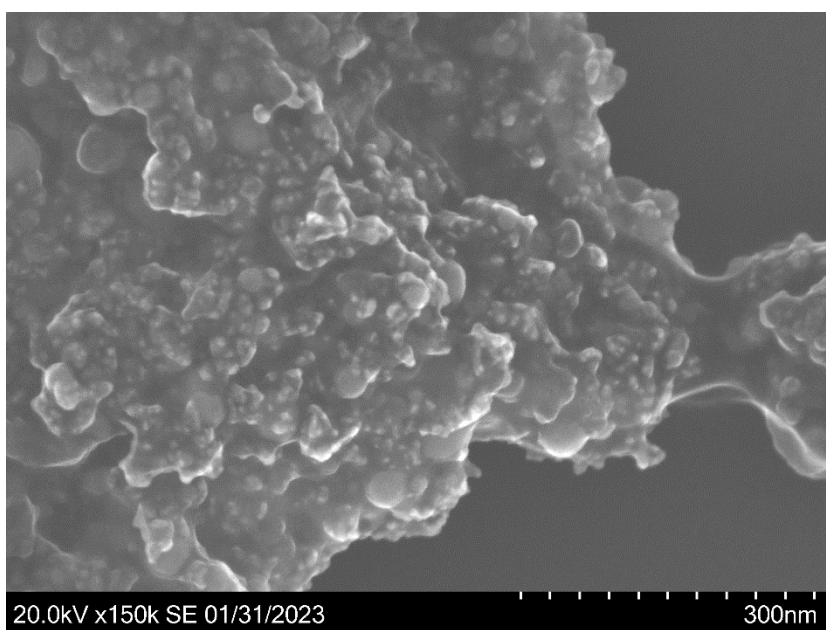


Figure S15. Unedited STEM image of bulk encapsulating coke following tar steam reforming (temperature = 700 °C, S/C = 2.0, TOS = 8 hours, syngas = 10/35/25/25 mol% CH₄/H₂/CO/CO₂ with 5 mol% N₂ internal standard, Ar balance, syngas flow = 400 NmL/min, GHSV = 85000 NmL/g_{cat}min, tar model = 10 g/Nm³ toluene).

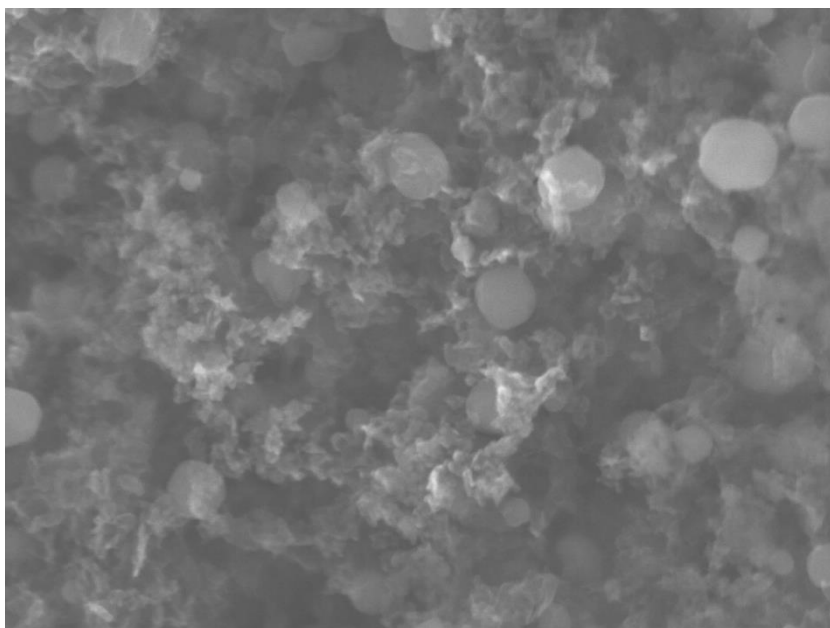


Figure S16. Unedited STEM image of sintered metal particles following tar steam reforming (temperature = 800 °C, S/C = 3.0, TOS = 8 hours, syngas = 10/35/25/25 mol% CH₄/H₂/CO/CO₂ with 5 mol% N₂ internal standard, Ar balance, syngas flow = 400 NmL/min, GHSV = 85000 NmL/g_{cat}min, tar model = 10 g/Nm³ toluene).