Supplementary Information

Hydrochar supported bimetallic Ni-Fe alloy nanocatalysts with tailored composition, size and shape for improved biomass steam reforming performance

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Figure S1. Fabrication strategy for preparation of the hydrochar-supported, iron-incorporated nickel-based catalysts and catalytic gasification test.

Figure S2. N_2 adsorption/desorption isotherms (a) and pore-size distributions (b) of $Ni_{0.5}$/HC-700, $Ni_{0.05}Fe_{0.05}$/HC-700, $Ni_{0.25}Fe_{0.25}$/HC-700 and $Ni_{0.25}Fe_{0.25}$/HC-900.

Figure S3. SEM images and the relative spatial distribution of elemental Ni and Fe in the fresh (A) and spent (B) catalyst of $Ni_{0.05}Ni_{0.05}$/HC-700.

Figure S4. Particle size distribution of the metal nanoparticles in the catalyst of $Ni_{0.05}Ni_{0.05}$/HC-700.

Figure S5. TEM images of the fresh (a, b) and spent (c, d) catalysts of $Ni_{0.05}Fe_{0.05}$/HC-900 and $Ni_{0.25}Fe_{0.25}$/HC-900, respectively.

Table S1. Surface areas, total pore volumes and average pore diameters of $Ni_{0.5}$/HC-700, $Ni_{0.05}Fe_{0.05}$/HC-700, $Ni_{0.25}Fe_{0.25}$/HC-700 and $Ni_{0.25}Fe_{0.25}$/HC-900.

Table S2. Effect of concentrations of precursory metal salts and calcination temperature on the crystallinity indexes of the fresh and reacted catalysts.

Table S3. Metal loading on the monometallic and bimetallic catalysts.

Table S4. Carbon deposition rates for the reacted monometallic and bimetallic catalysts.

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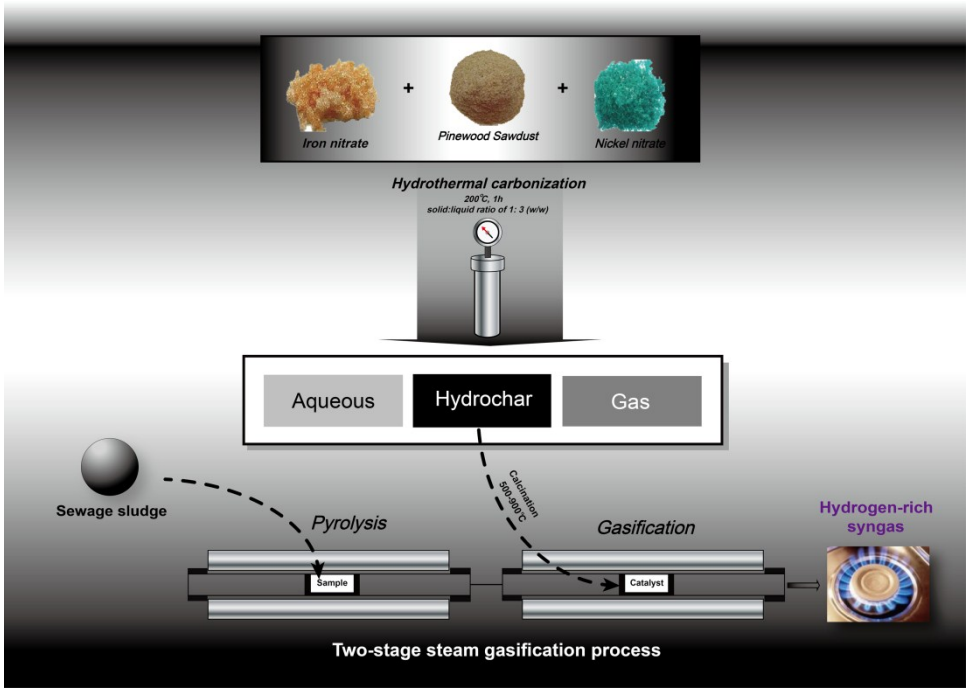

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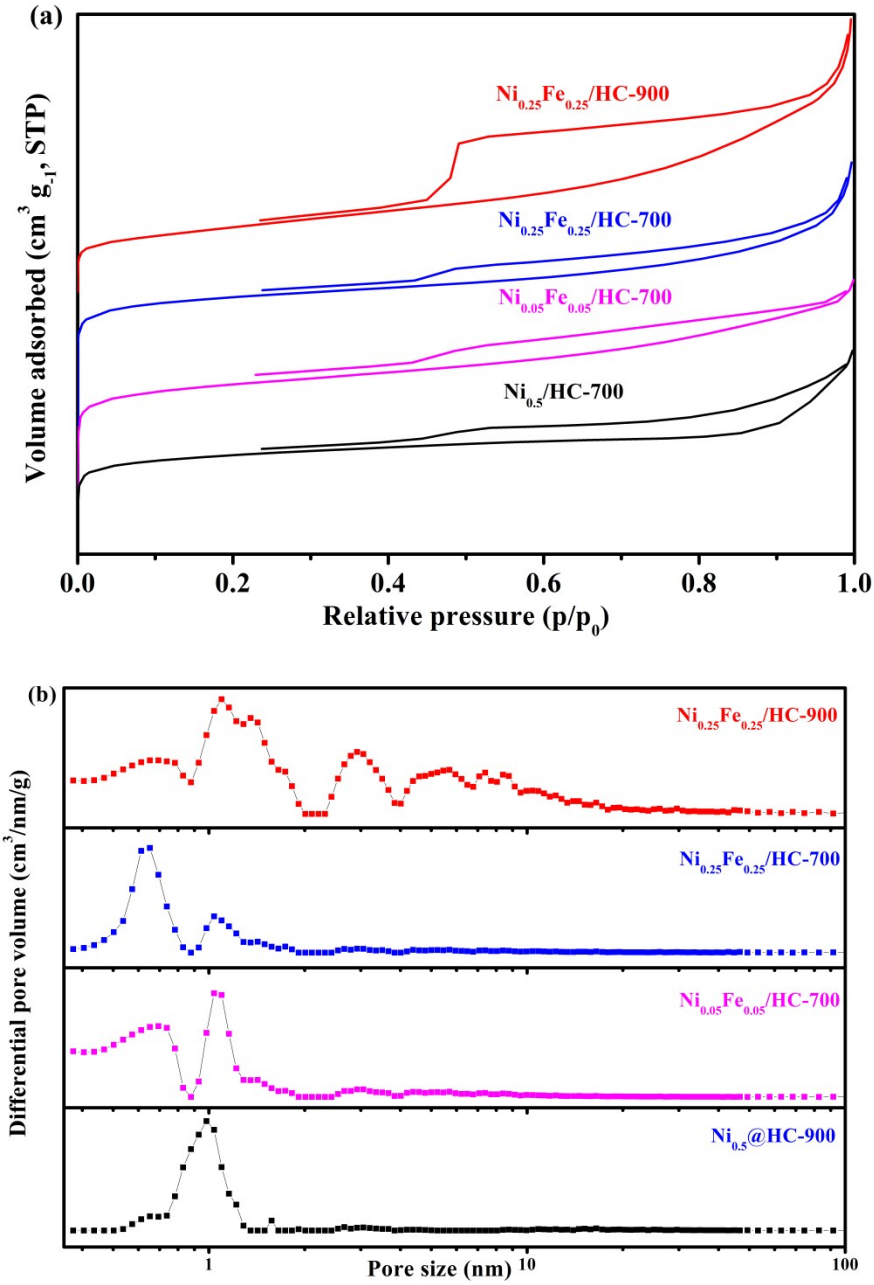

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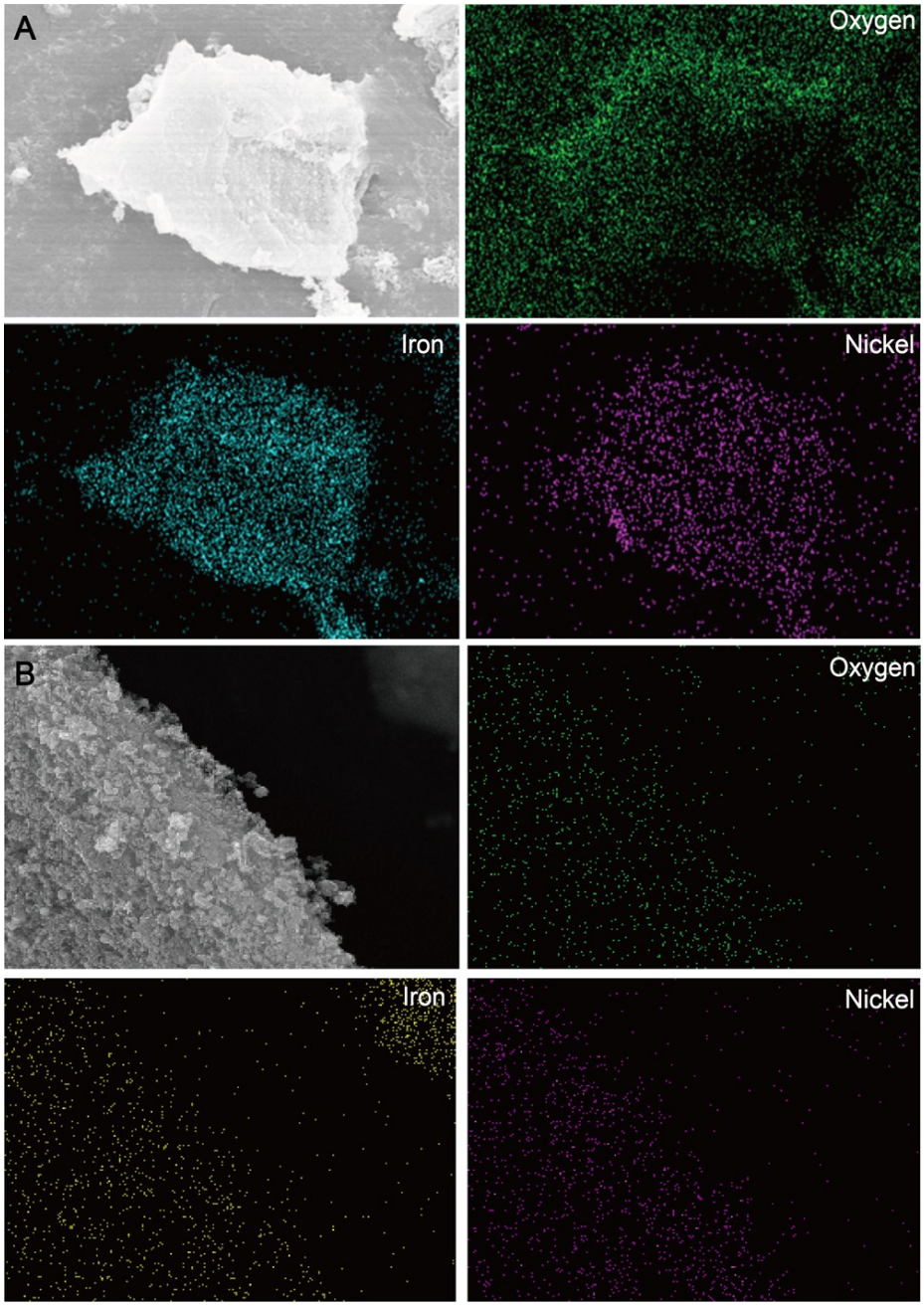

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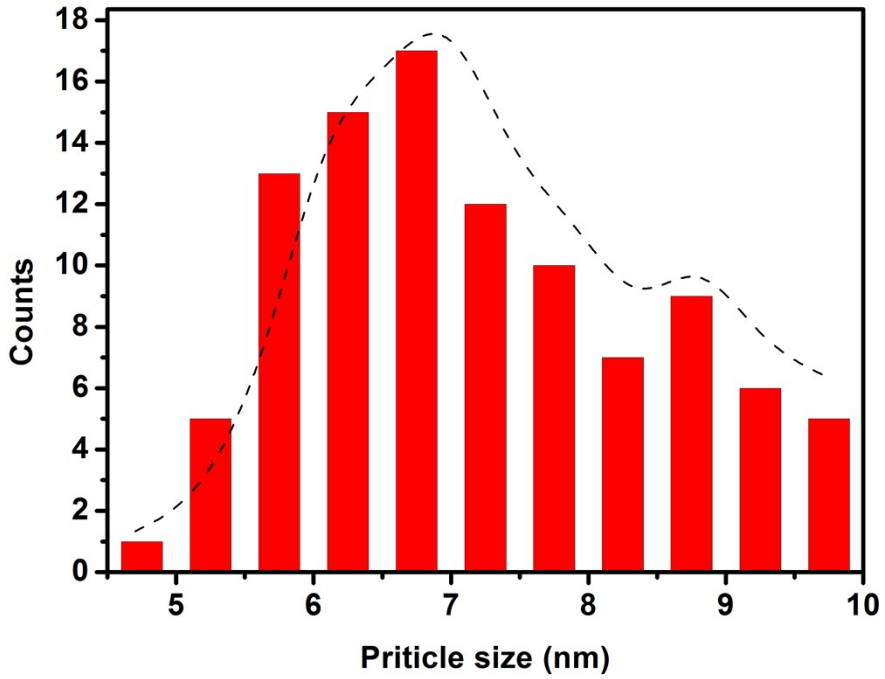

Figure S5. TEM images of the fresh (a, b) and spent (c, d) catalysts of $Ni_{0.05}Fe_{0.05}$/HC-900 and $Ni_{0.25}Fe_{0.25}$/HC-900, respectively

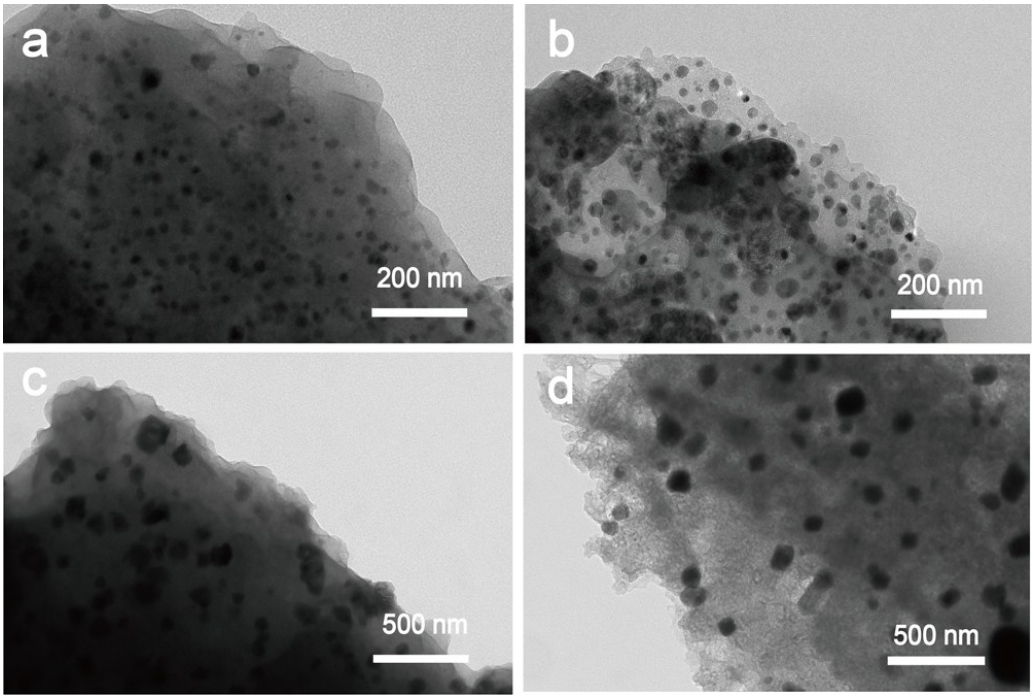

Table S1. Surface areas, total pore volumes and average pore diameters of $Ni_{0.5}$/HC-700, $Ni_{0.05}Fe_{0.05}$/HC-700, $Ni_{0.25}Fe_{0.25}$/HC-700 and $Ni_{0.25}Fe_{0.25}$/HC-900.

Catalyst	S_{BET} ($m_2 \cdot g^{-1}$)	V_{pore} ($cm^3 \cdot g^{-1}$)	AD_{pore}, nm
$Ni_{0.5}$/HC-700	320.91	0.2201	2.7432
$Ni_{0.05}Fe_{0.05}$/HC-700	373.31	0.2465	2.6411
$Ni_{0.25}Fe_{0.25}$/HC -700	323.99	0.2453	3.0289
$Ni_{0.25}Fe_{0.25}$/HC -900	147.68	0.2395	6.4874

Table S2. Effect of concentrations of precursory metal salts and calcination temperature on the crystallinity indexes of the fresh and reacted catalysts.

Catalyst	Temp. (°C)	$CI_{xrd\text{-}f}$ (%)	$CI_{xrd\text{-}r}$ (%)
$Ni_{0.05}Fe_{0.05}$/HC	500	6.5	8.9
	700	8.3	12.7
	900	11.9	10.6
$Ni_{0.1}$/HC	500	11.2	13.5
	700	9.7	17.6
	900	12.9	9.9
$Ni_{0.25}Fe_{0.25}$/HC	500	18.2	23.5
	700	17.9	19.8
	900	16.7	10.9
$Ni_{0.5}$/HC	500	12.4	14.3
	700	13.9	15.8
	900	25.2	14.7

Table S3. Metal loading on the monometallic and bimetallic catalysts.

Catalyst	Temp. (°C)	Ni (wt.%)	Fe (wt.%)
$Ni_{0.05}Fe_{0.05}$/HC	500	0.71	0.82
	700	0.93	1.06
	900	1.07	1.15
$Ni_{0.1}$/HC	500	1.38	-
	700	1.76	-
	900	1.95	-
$Ni_{0.25}Fe_{0.25}$/HC	500	2.73	3.12
	700	3.35	3.93
	900	3.89	4.68
$Ni_{0.5}$/HC	500	4.88	-
	700	6.25	-
	900	7.13	-

Table S4. Carbon deposition rates for the reacted monometallic and bimetallic catalysts.

Catalyst	Temp. (°C)	Rate of coke deposition (wt.%)
$Ni_{0.05}Fe_{0.05}$/HC	500	16.3
	700	13.7
	900	14.4
$Ni_{0.1}$/HC	500	17.9
	700	14.2
	900	16.7
$Ni_{0.25}Fe_{0.25}$/HC	500	3.9
	700	2.8
	900	3.1
$Ni_{0.5}$/HC	500	5.3
	700	3.2
	900	4.7

[a]Reaction conditions: reaction temperature: 500-900 °C; steam flow rate: 0.05 g min^{-1}; reaction time: 0.5 h; mass of catalyst: 300 mg.