Electronic Supplementary Material (ESI) for Journal of Materials Chemistry A.

Ni-based bimetallic nano-catalysts anchored on $BaZr_{0.4}Ce_{0.4}Y_{0.1}Yb_{0.1}O_3$ for internal steam reforming of methane in a low-temperature proton-conducting ceramic fuel cell

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Key Words: bimetallic alloy catalyst; steam reforming of methane; proton-conducting ceramic fuel cell; hydrogen yield; carbon resistance.

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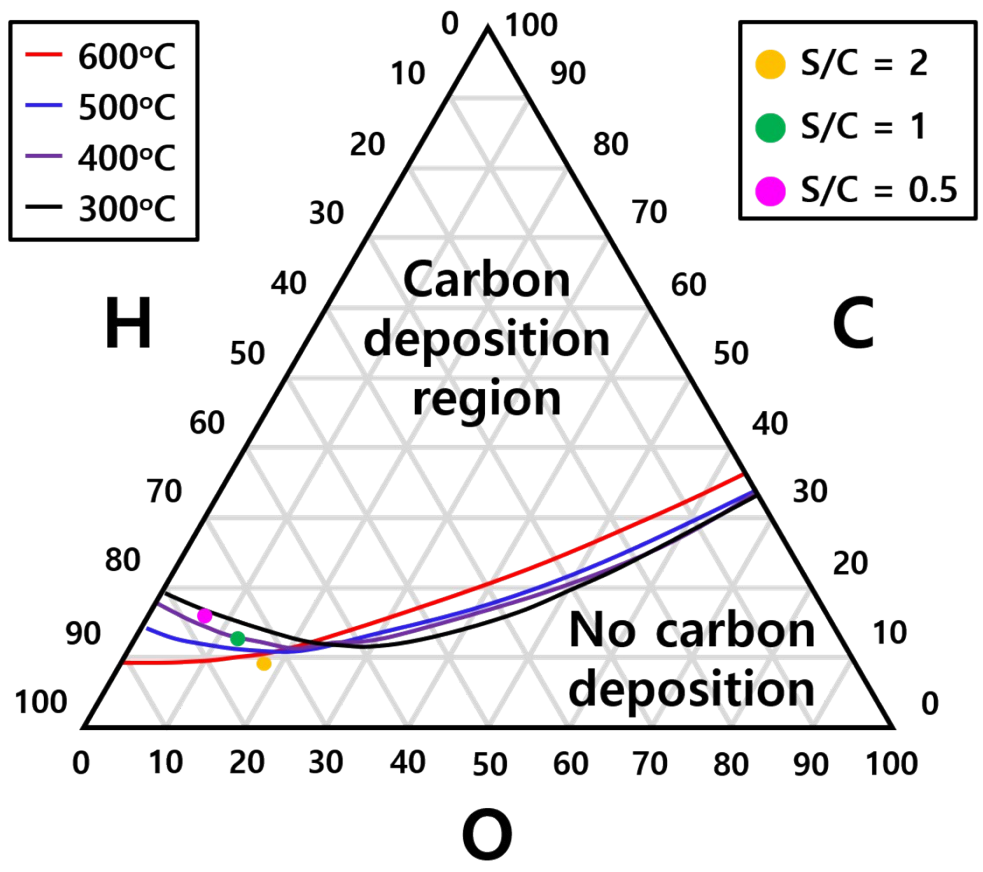
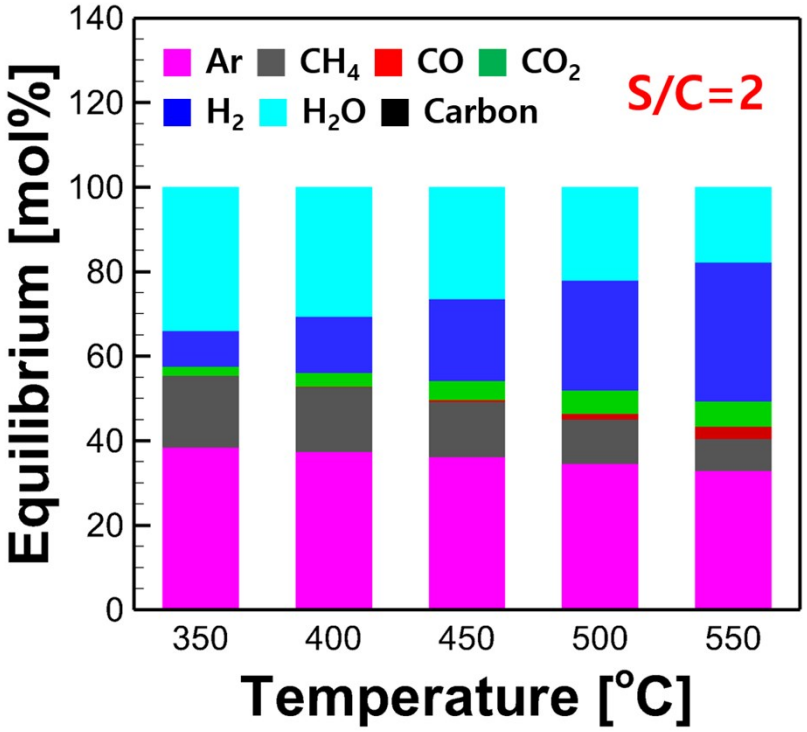


Fig. S1 Carbon formation ternary diagram with S/C ratio points.

(a)



(b)

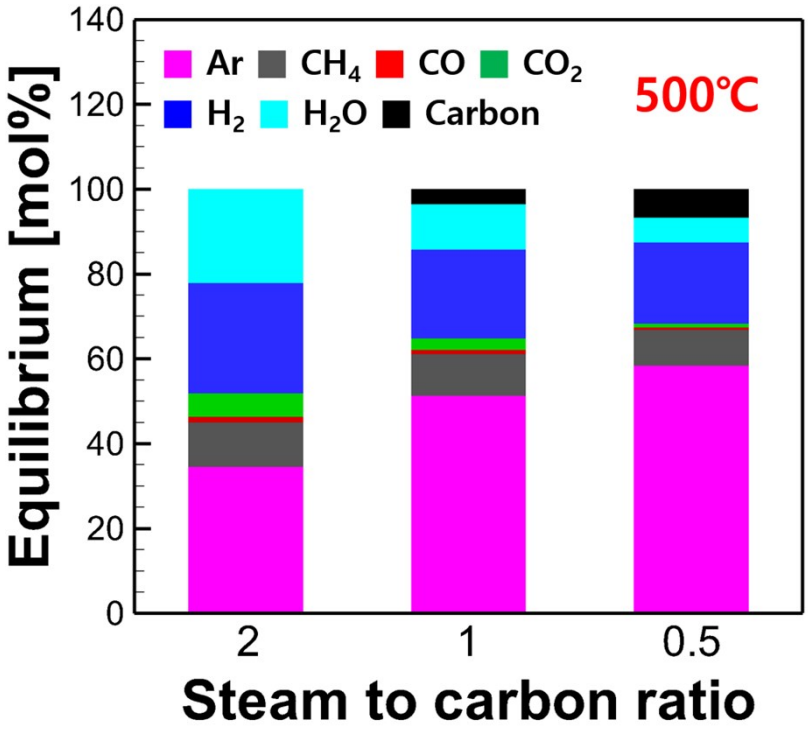
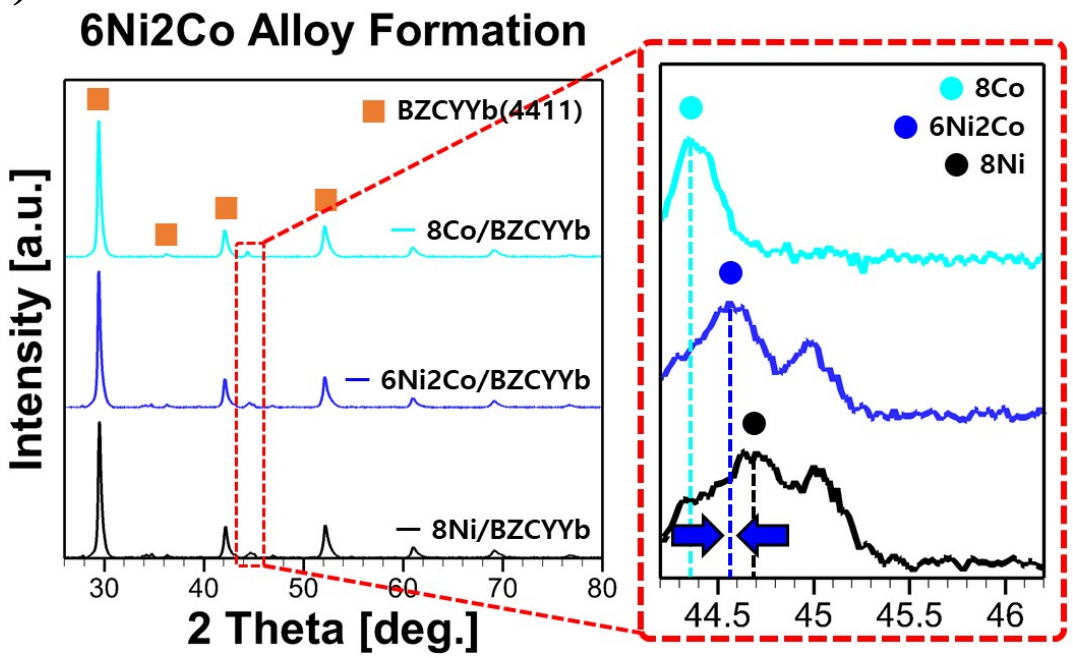
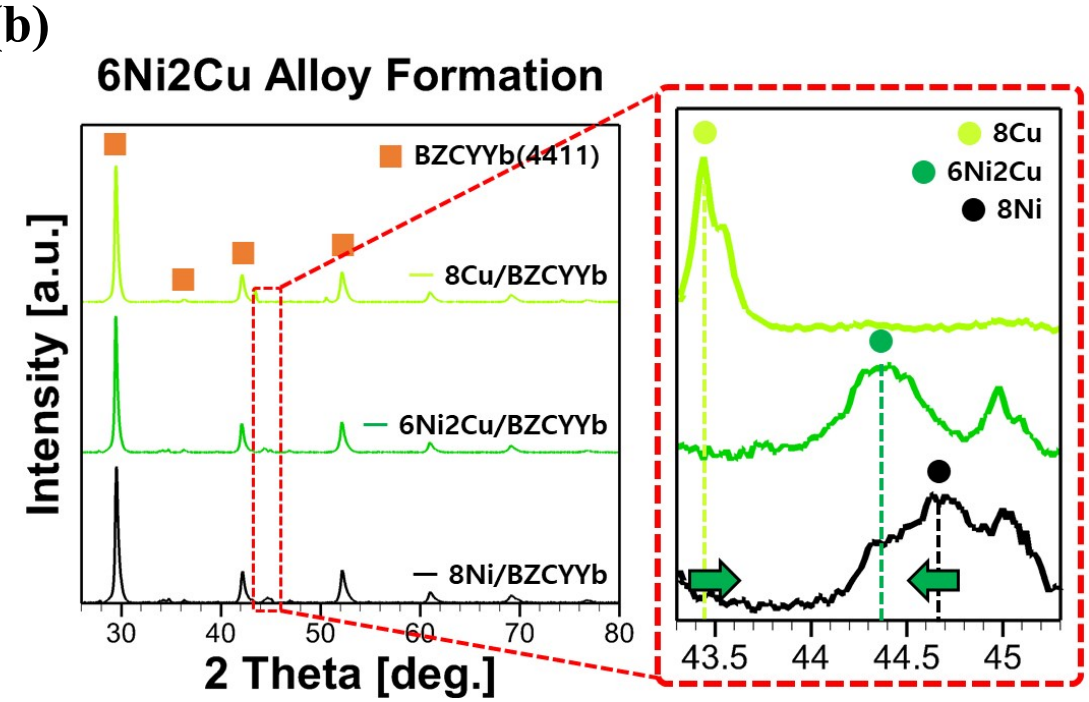


Fig. S2 Reactant gas composition in equilibrium by test types (a) temperature; (b) S/C ratio;

(a)


6Ni2Co Alloy Formation
BZCYYb(4411)
8Co/BZCYYb
6Ni2Co/BZCYYb
8Ni/BZCYYb
Intensity [a.u.]
2 Theta [deg.]
30
40
50
60
70
80
8Co
6Ni2Co
8Ni
44.5
45
45.5
46

(b)


6Ni2Cu Alloy Formation
BZCYYb(4411)
8Cu/BZCYYb
6Ni2Cu/BZCYYb
8Ni/BZCYYb
Intensity [a.u.]
2 Theta [deg.]
30
40
50
60
70
80
8Cu
6Ni2Cu
8Ni
43.5
44
44.5
45

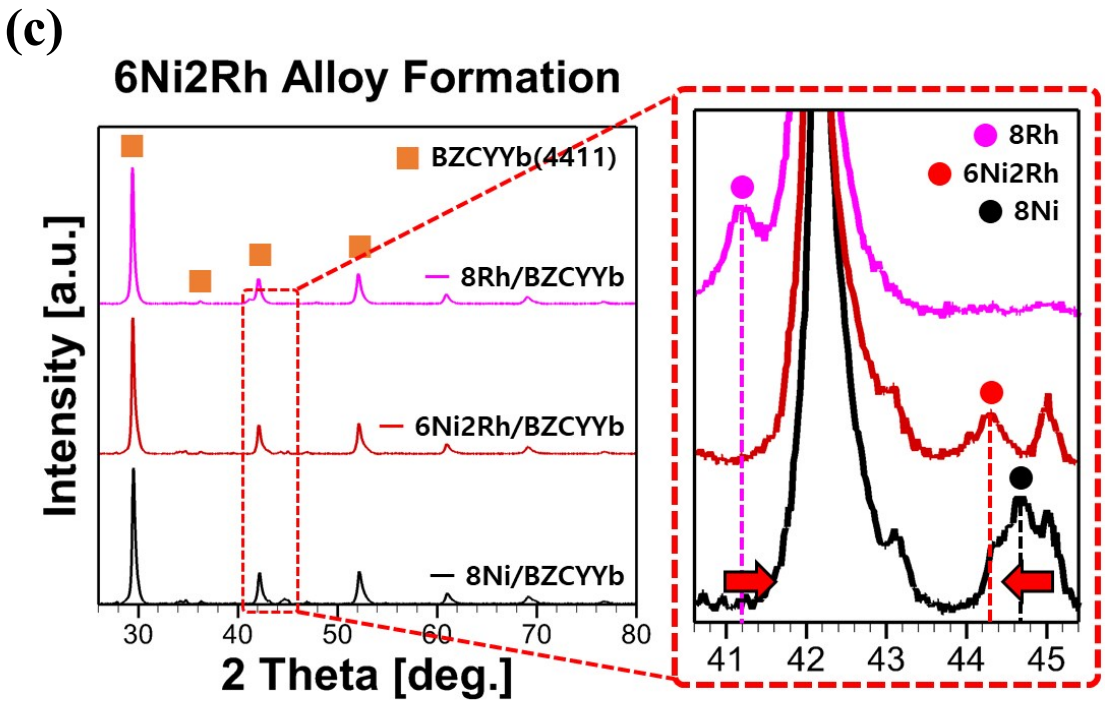
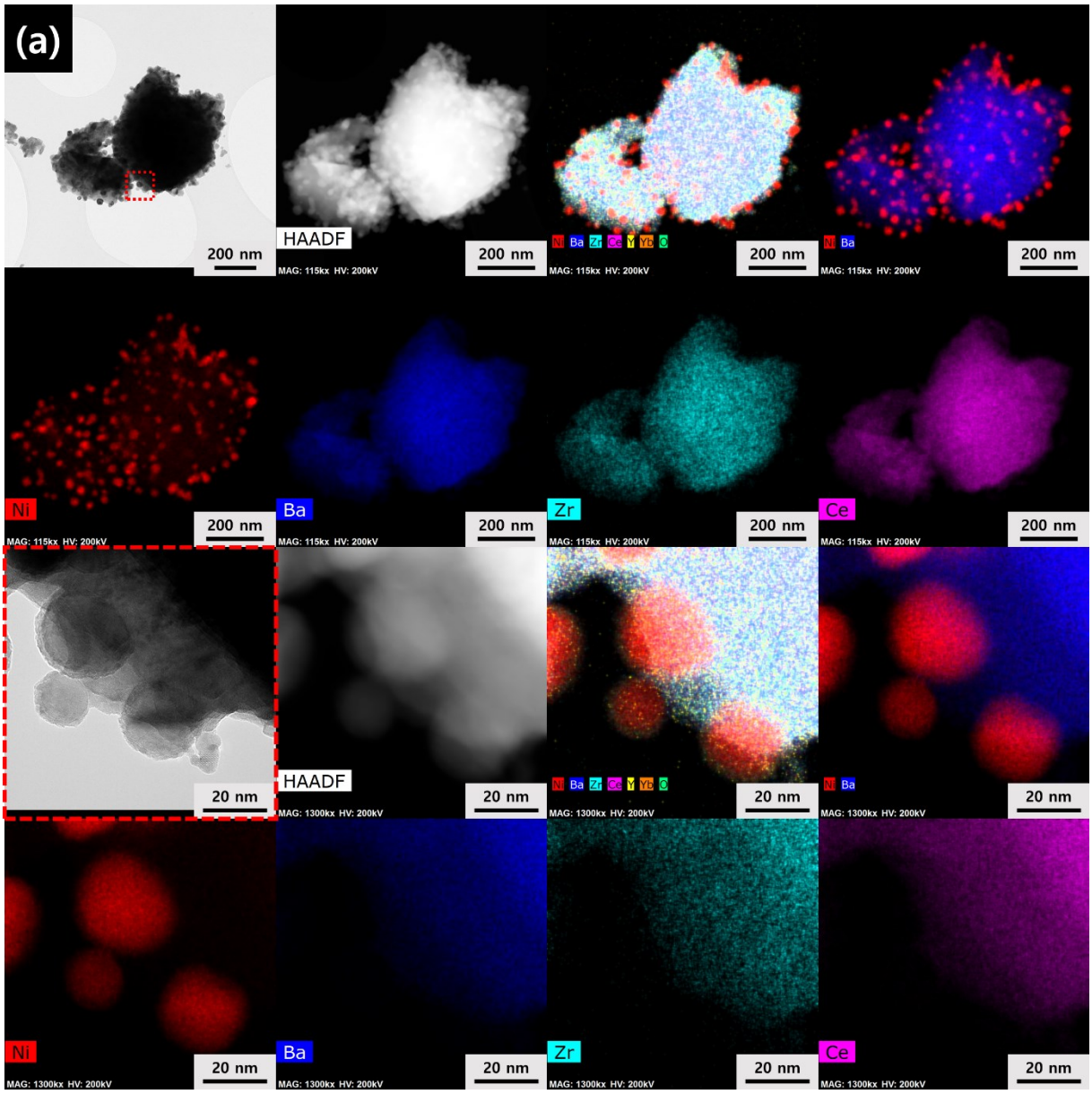
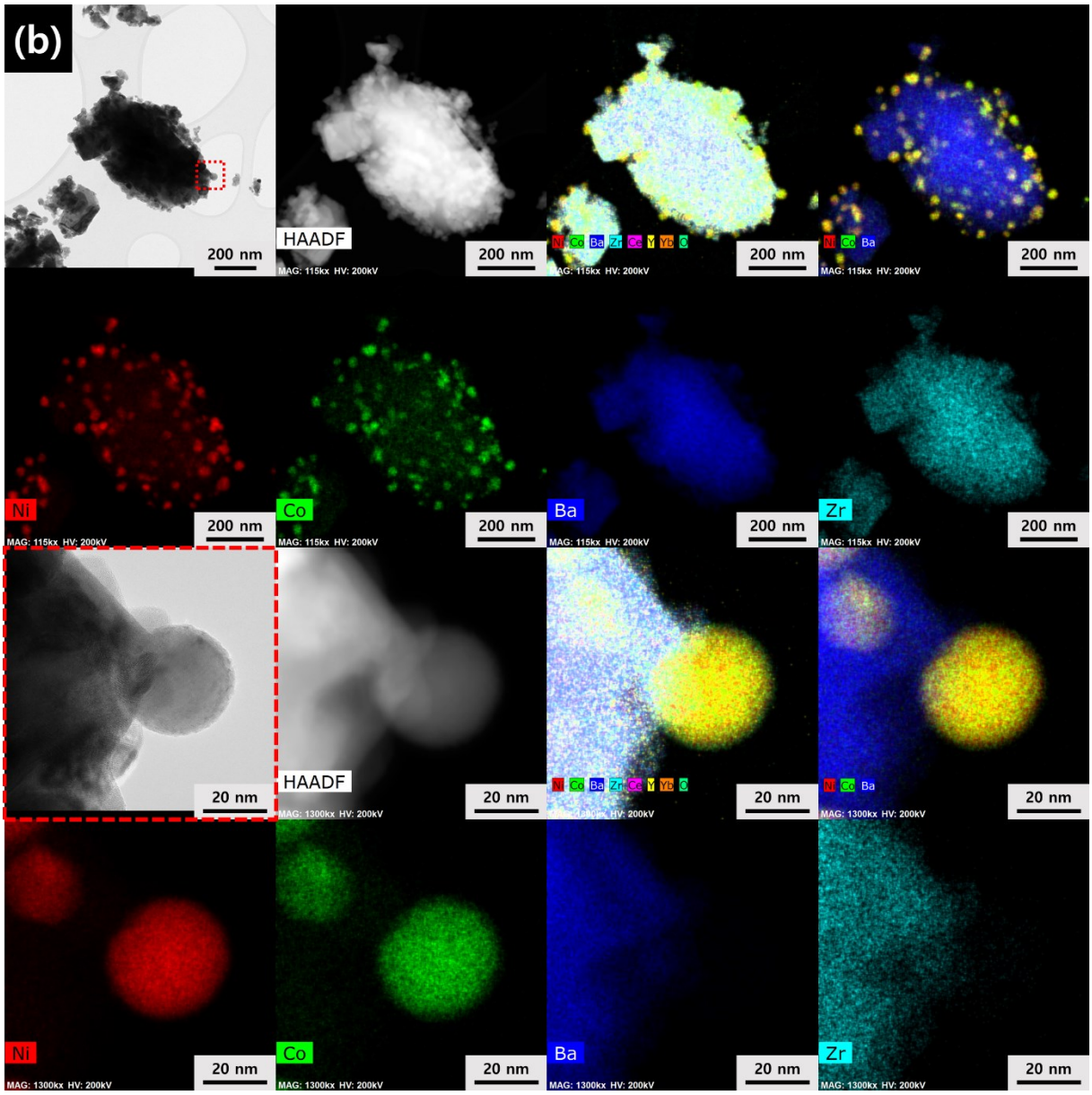
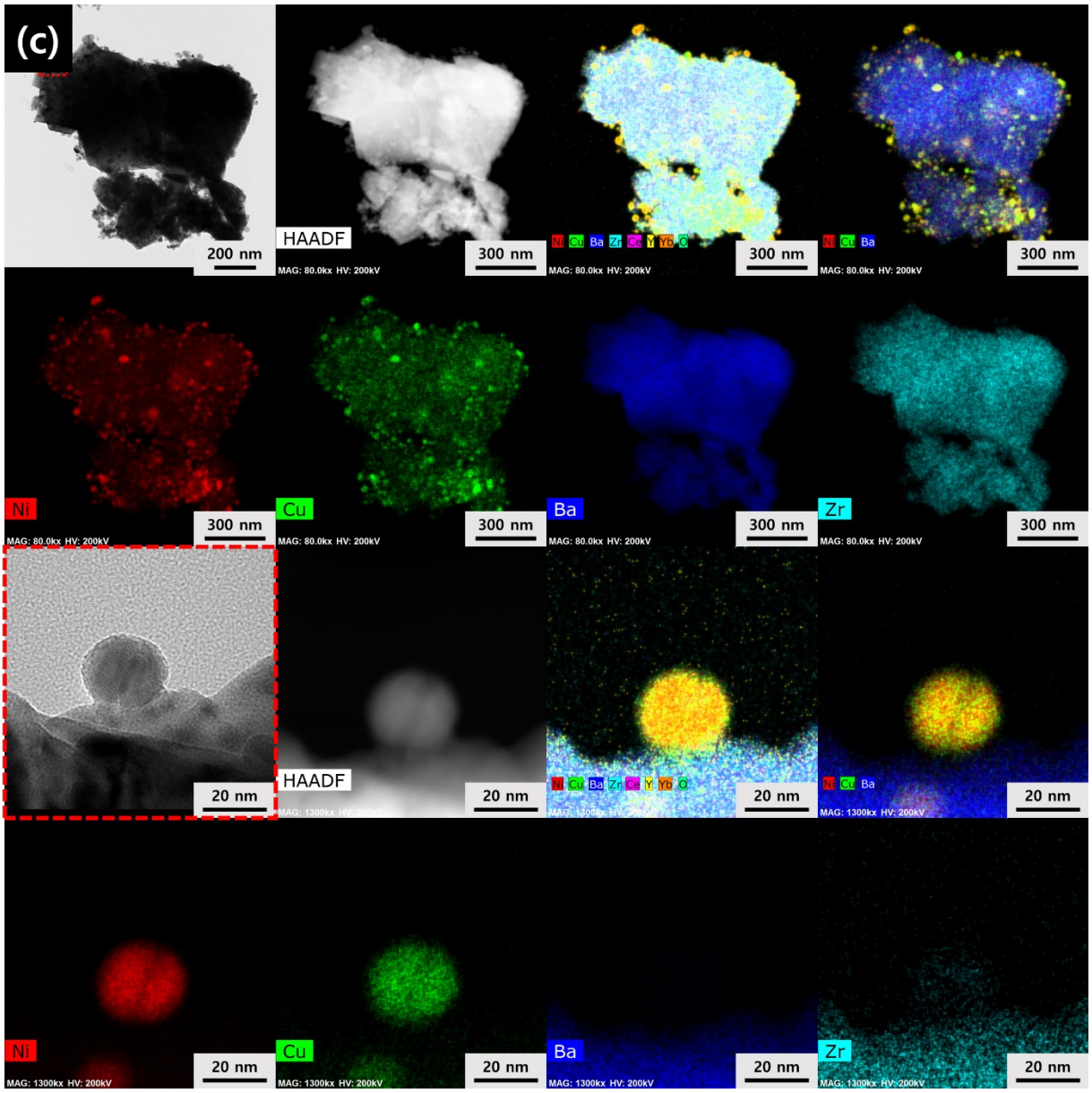


Fig. S3 Detailed X-ray diffraction patterns for alloy formation of (a) 6Ni2Co; (b) 6Ni2Cu; (c) 6Ni2Rh in comparison with the monometallic (8Ni and 8M, M: Co, Cu, Rh) catalysts.


(a)
200 nm
HAADF
MAG: 115kx HV: 200kV
Ni Ba Zr Ce Y Yb C
Ni Ba
Ni
Ba
Zr
Ce
20 nm
MAG: 1300kx HV: 200kV


(b)
200 nm
HAADF
MAG: 115kx HV: 200kV
Ni
Co
Ba
Zr
20 nm
MAG: 1300kx HV: 200kV


(c)
200 nm
HAADF
300 nm
MAG: 80.0kx HV: 200kV
Ni Cu Ba Zr Ce Y Yb O
Ni Cu Ba
Ni
Cu
Ba
Zr
20 nm
MAG: 1300kx HV: 200kV

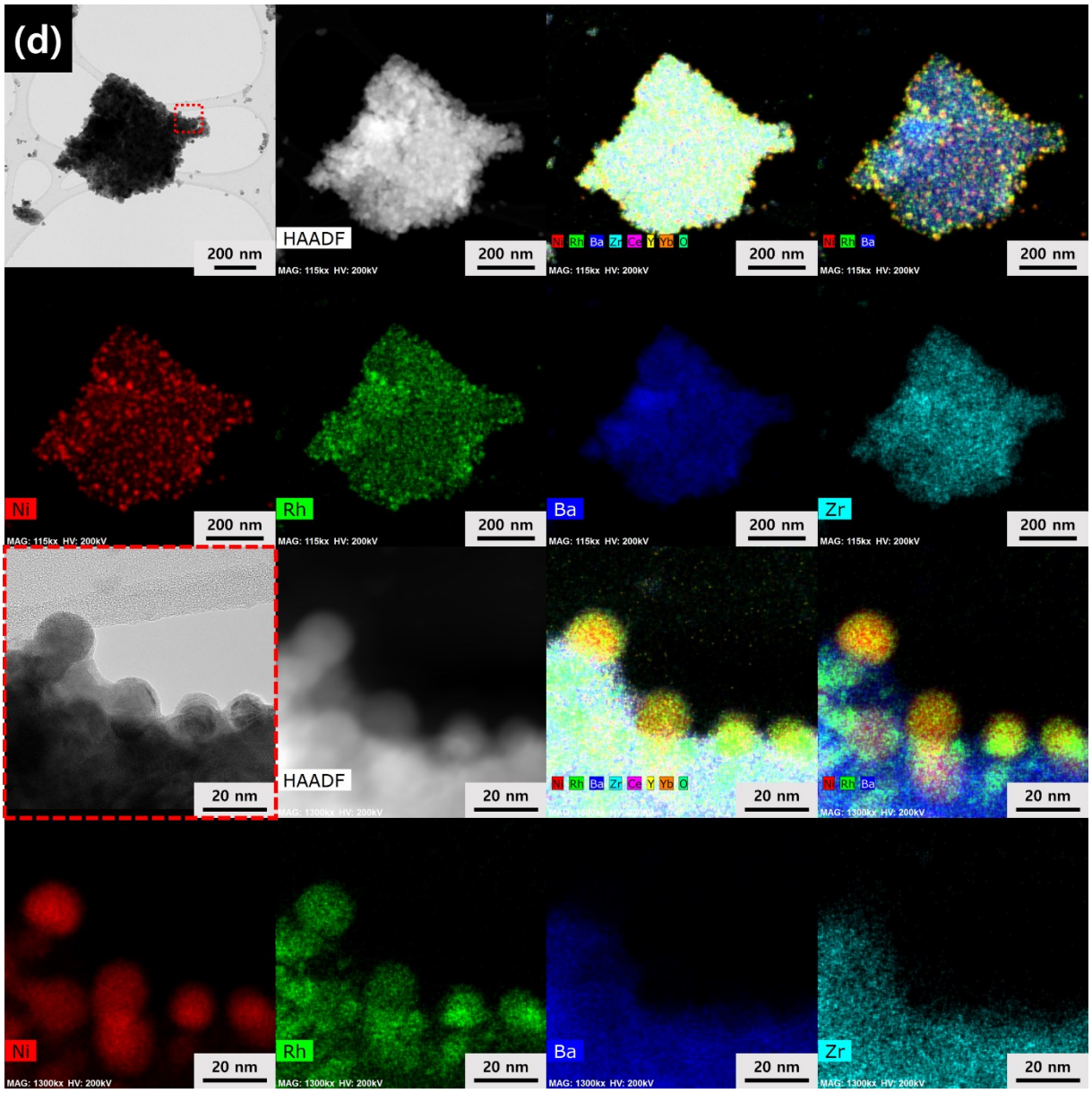
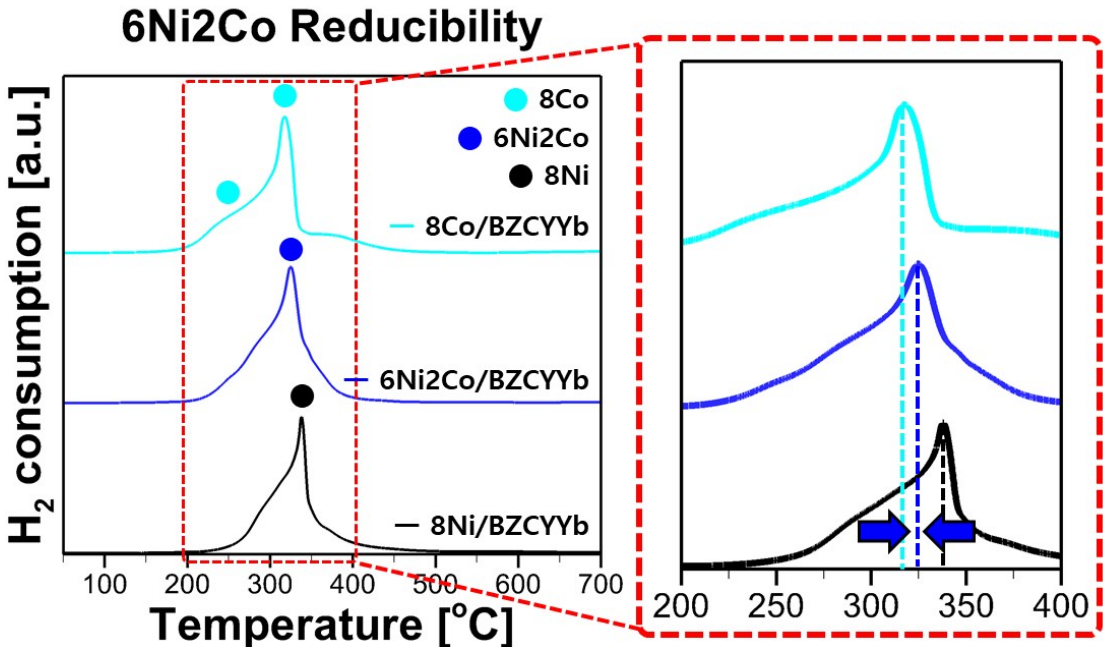
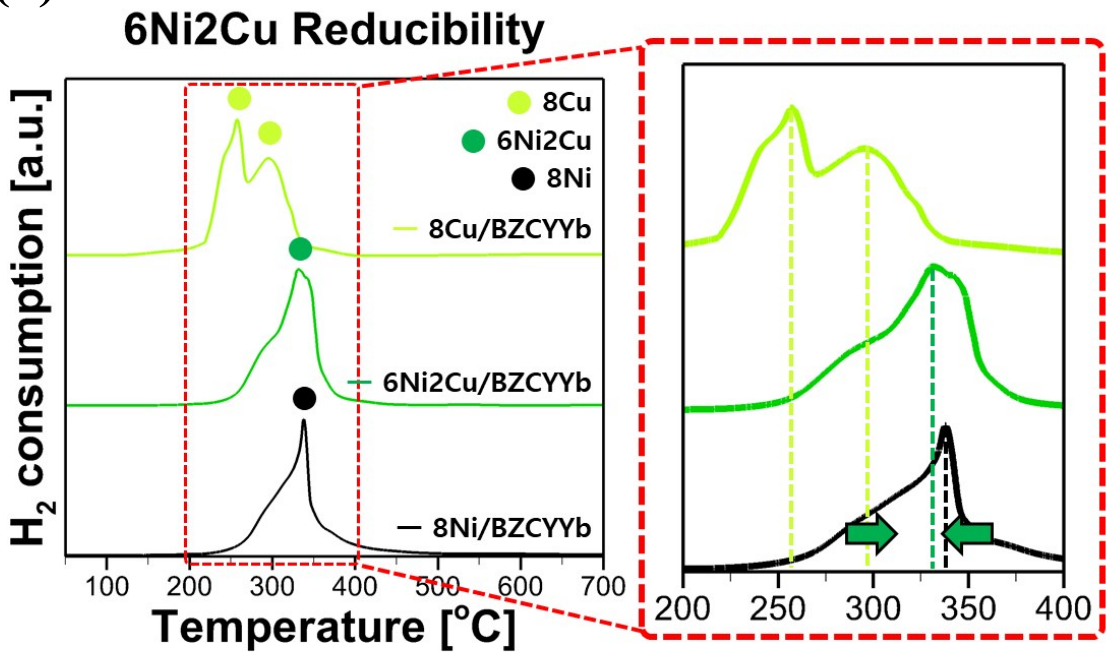


Fig. S4 Detailed TEM and EDS mapping images for (a) 8Ni; (b) 6Ni2Co; (c) 6Ni2Cu; (d) 6Ni2Rh.

(a)


6Ni2Co Reducibility
8Co
6Ni2Co
8Ni
8Co/BZCYYb
6Ni2Co/BZCYYb
8Ni/BZCYYb
H2 consumption [a.u.]
100 200 300 400 500 600 700
Temperature [°C]
200 250 300 350 400

(b)


6Ni2Cu Reducibility
8Cu
6Ni2Cu
8Ni
8Cu/BZCYYb
6Ni2Cu/BZCYYb
8Ni/BZCYYb
H2 consumption [a.u.]
100 200 300 400 500 600 700
Temperature [°C]
200 250 300 350 400

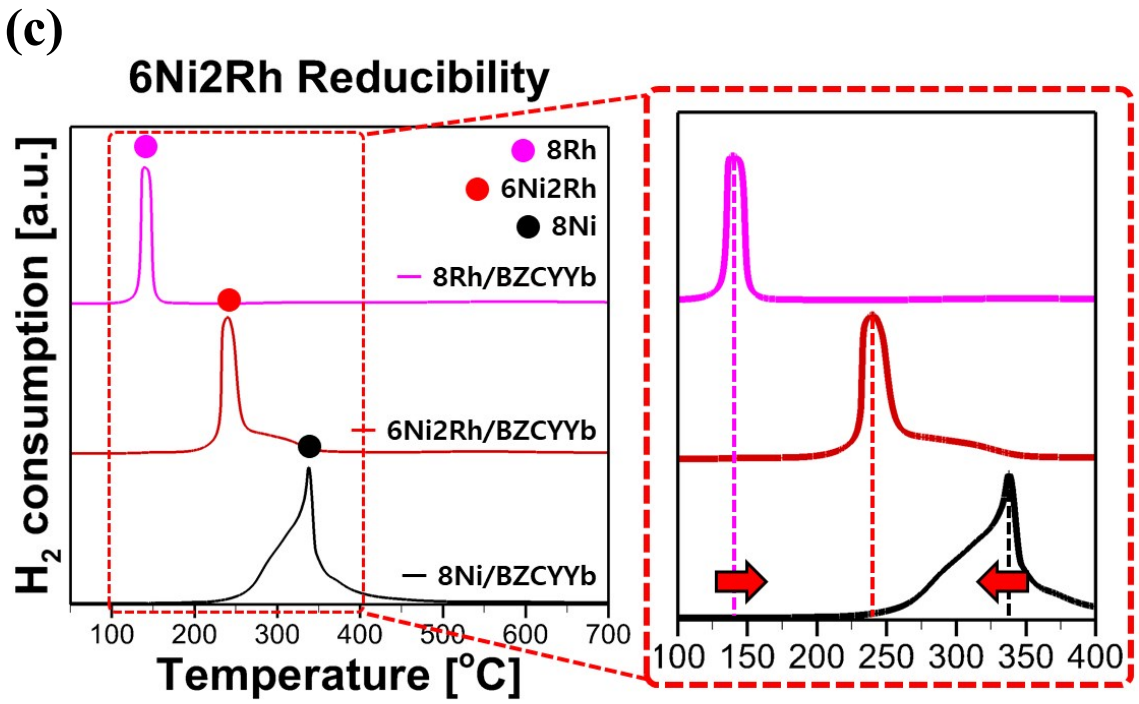


Fig. S5 Detailed temperature-programmed reduction peaks of (a) 6Ni2Co; (b) 6Ni2Cu; (c) 6Ni2Rh in comparison with the monometallic (8Ni and 8M, M: Co, Cu, Rh) catalysts.

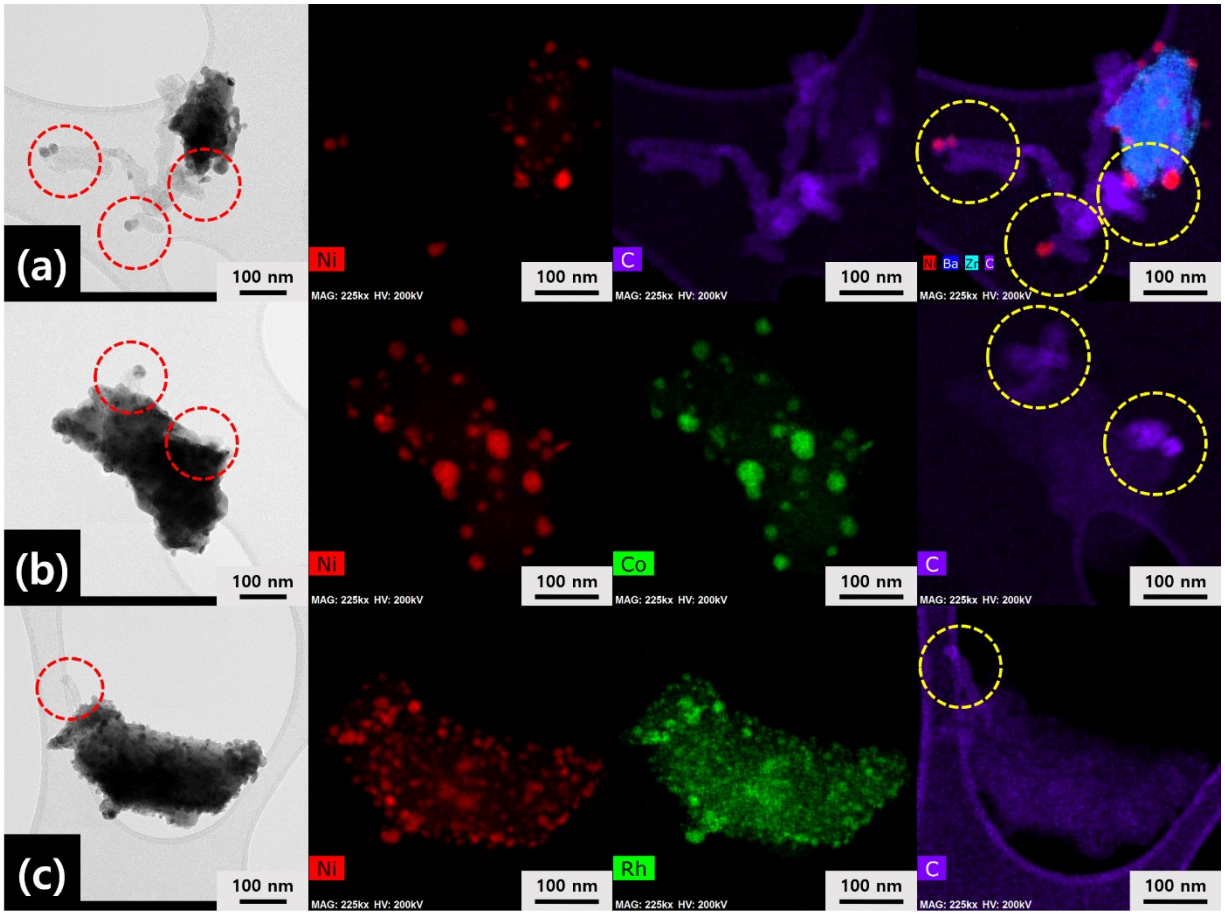


Fig. S6 TEM and EDS mapping images for (a) 8Ni; (b) 6Ni2Co; (c) 6Ni2Rh after long-term stability tests.