Supplementary Information (SI) for Journal of Materials Chemistry A.

Non-thermal plasma enabled catalytic dry reforming of methane over ceria nanorods supported NiO catalyst: the role of Ru as coke resistant active sites

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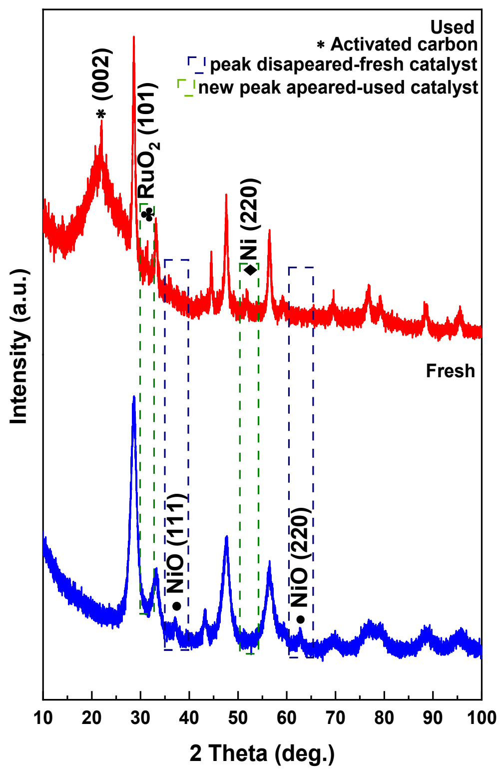

Fig. S1 XRD patterns of the fresh and spent 14 wt% Ni -1 wt% Ru/CeO_2 NR catalysts.

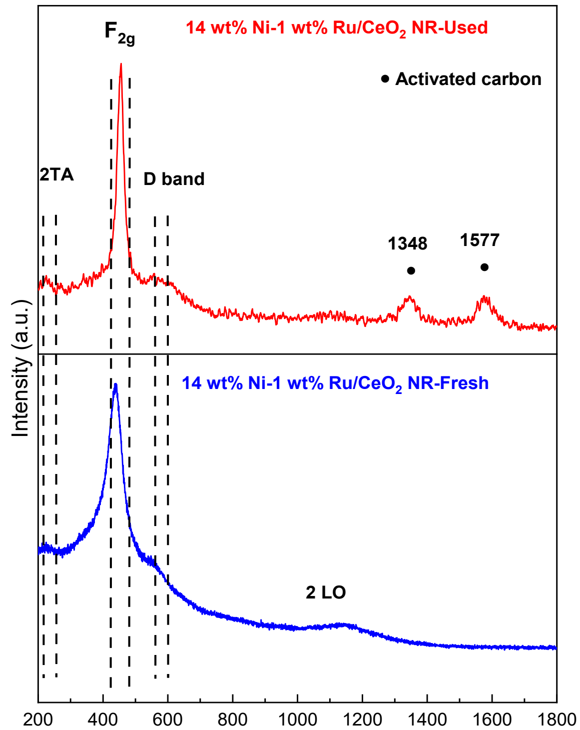

Fig. S2 Raman spectra of the fresh and spent 14 wt% Ni -1 wt% Ru/CeO_2 NR catalysts.

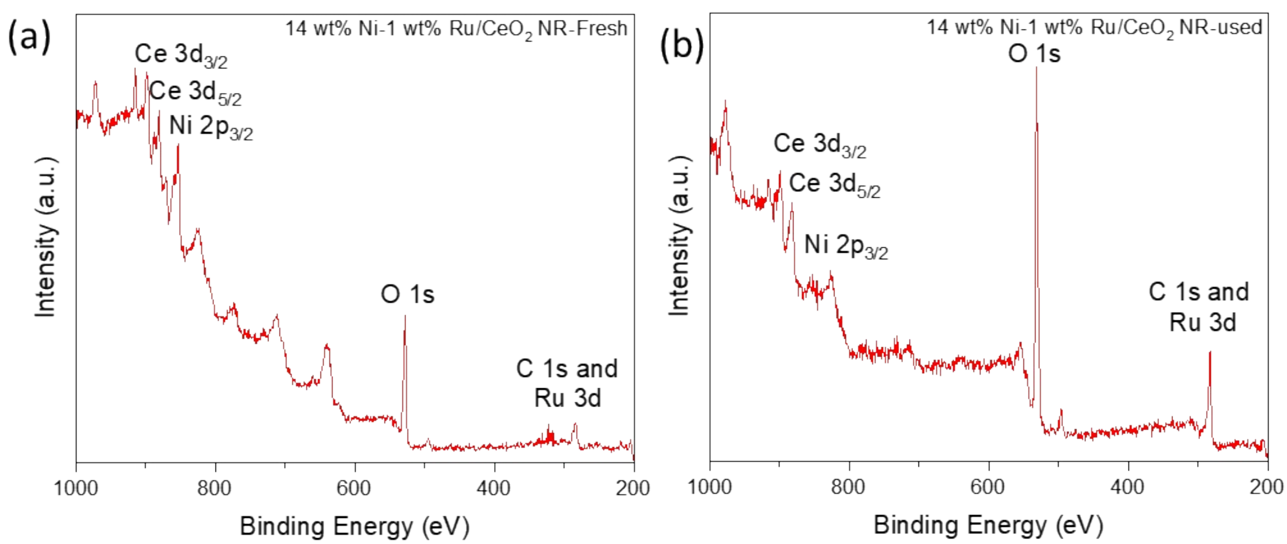

Fig. S3 XPS survey of the fresh and spent 14 wt% Ni -1 wt% Ru/CeO_2 NR catalysts.

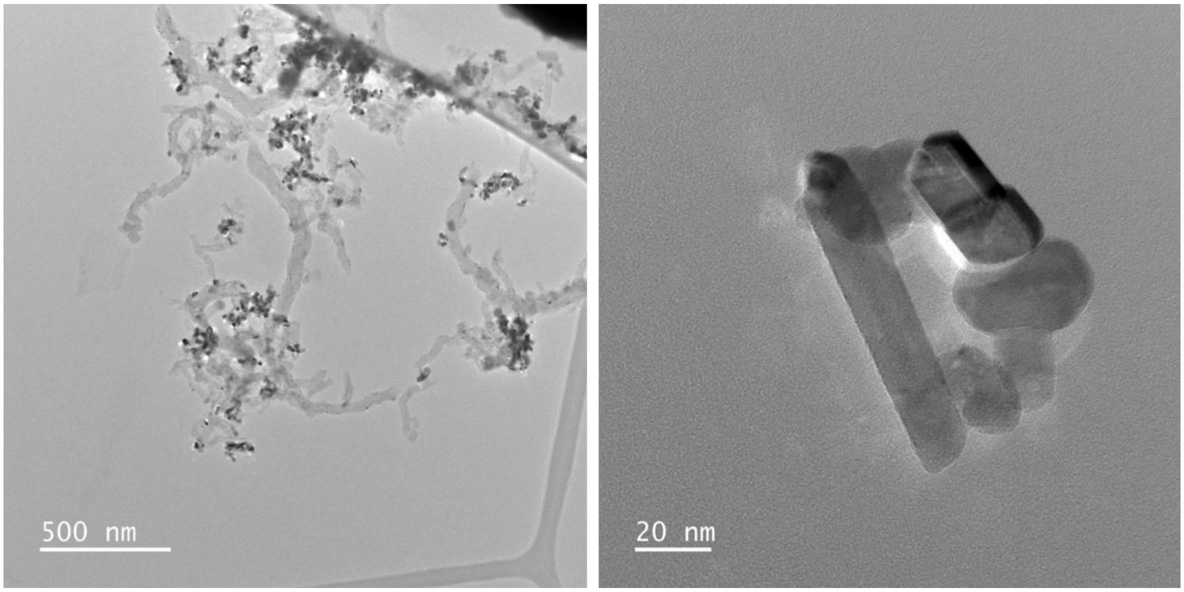

Fig. S4 TEM images of the spent 14 wt% Ni -1 wt% Ru/CeO_2 NR catalyst.

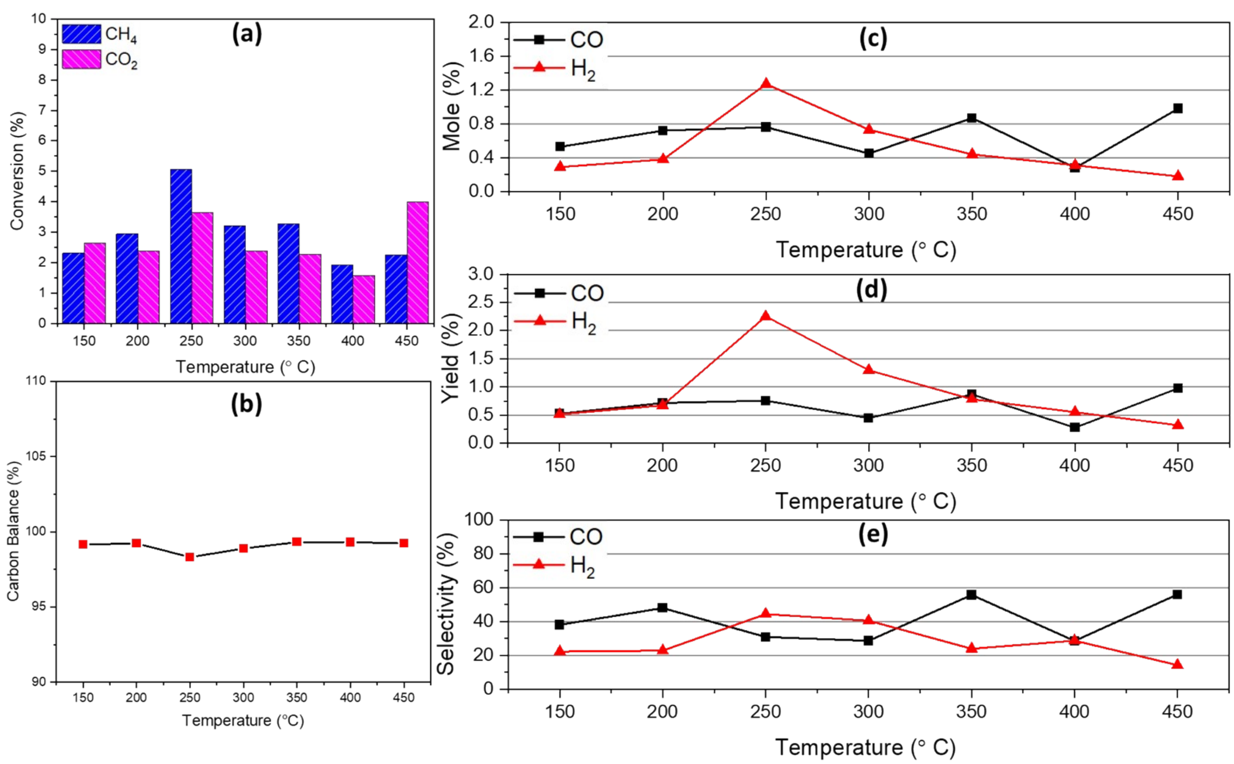

Fig. S5 DRM reaction performance under plasma only (without catalyst) condition: (a) CH_4 and CO_2 conversion, (b) Carbon balance, (c) CO and H_2 mole concentration, (d) yield and selectivity, from 150 °C to 450 °C. (Catalyst weight: ~200 mg, Power: 17.66 to 22.73 W, Flow rate: CO_2: 250 sccm and CH_4: 100 sccm, and Frequency: 20 kHz).

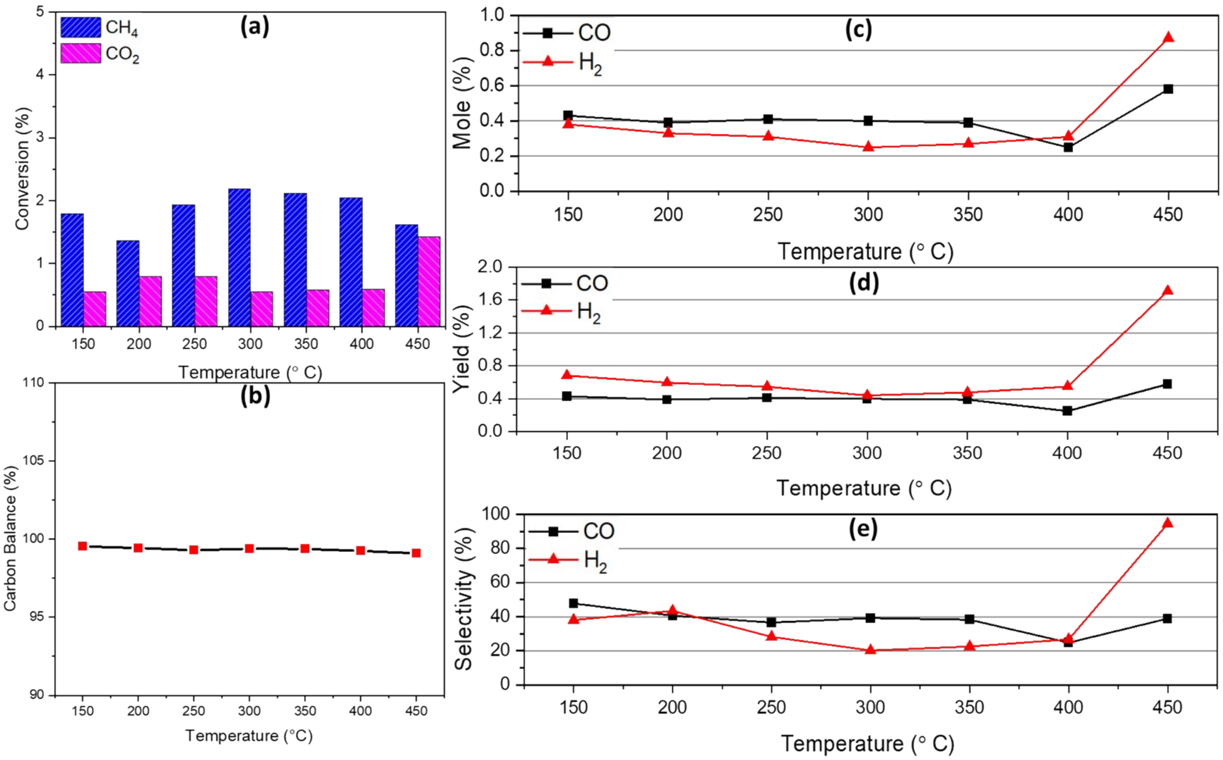

Fig. S6 DRM reaction performance under plasma + bare CeO_2 NR condition: (a) CH_4 and CO_2 conversion, (b) Carbon balance, (c) CO and H_2 mole concentration, (d) yield and selectivity, from 150 °C to 450 °C. (Catalyst weight: ~200 mg, Power: 17.66 to 22.73 W, Flow rate: CO_2: 250 sccm and CH_4: 100 sccm, and Frequency: 20 kHz).

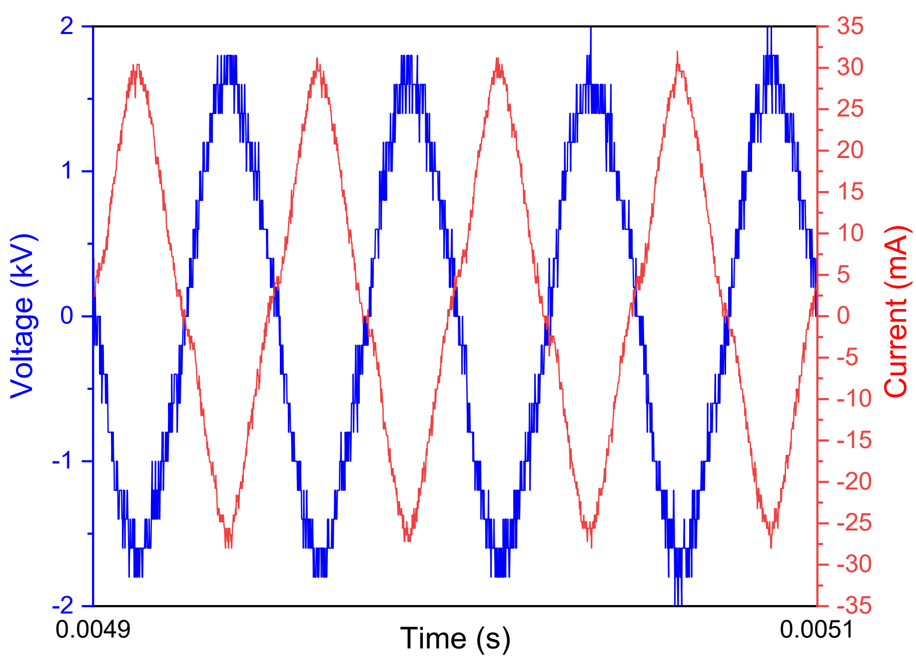

Fig. S7 Applied voltage and current signals in the plasma catalytic system.

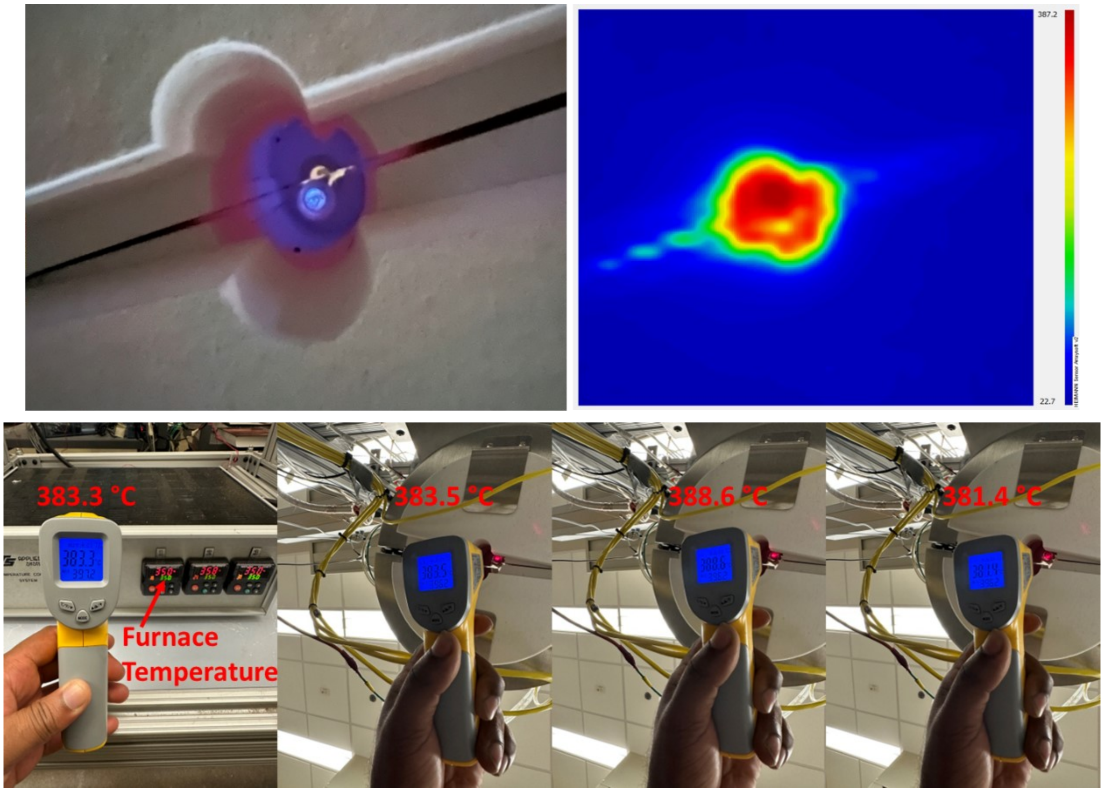

Fig. S8 Temperature measurement at plasma catalytic reaction zone with thermopile infrared array sensor and infrared thermometer.

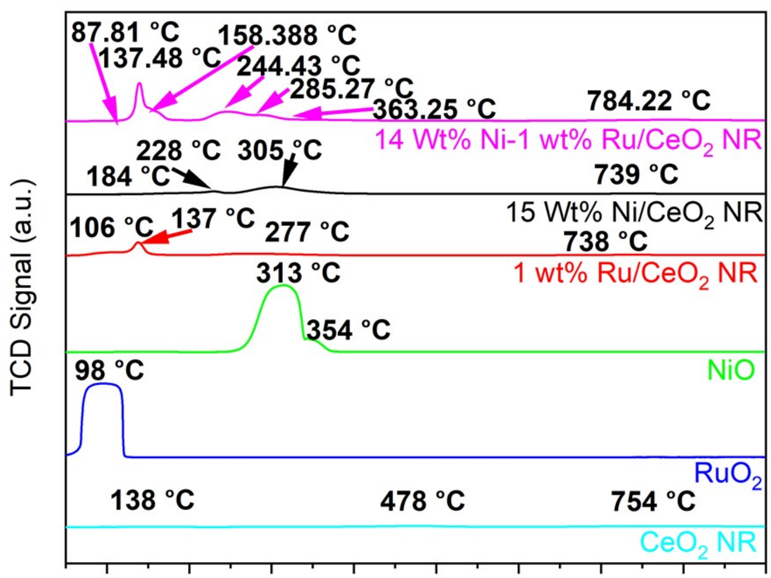

Fig. S9 H_2-TPR profiles of the CeO_2 NR, RuO_2, NiO, 1 wt% RuO_x/CeO_2 NR, 15 wt% NiO/CeO_2 NR and bimetallic 14 wt% Ni-1 wt% Ru/CeO_2 NR catalysts.

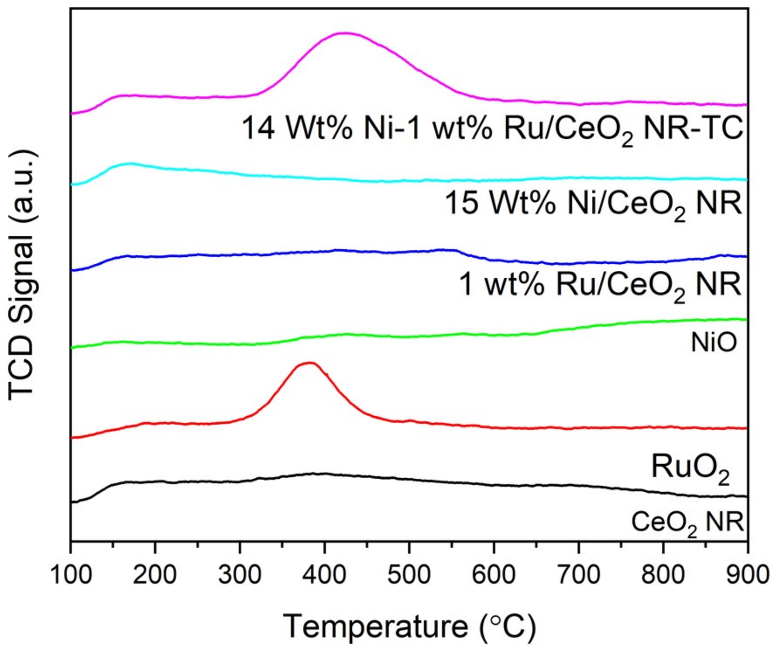

Fig. S10 CO_2-TPD profiles of the CeO_2 NR, RuO_2, NiO, 1 wt% RuO_x/CeO_2 NR, 15 wt% NiO/CeO_2 NR and bimetallic 14 wt% Ni-1 wt% Ru/CeO_2 NR catalysts.

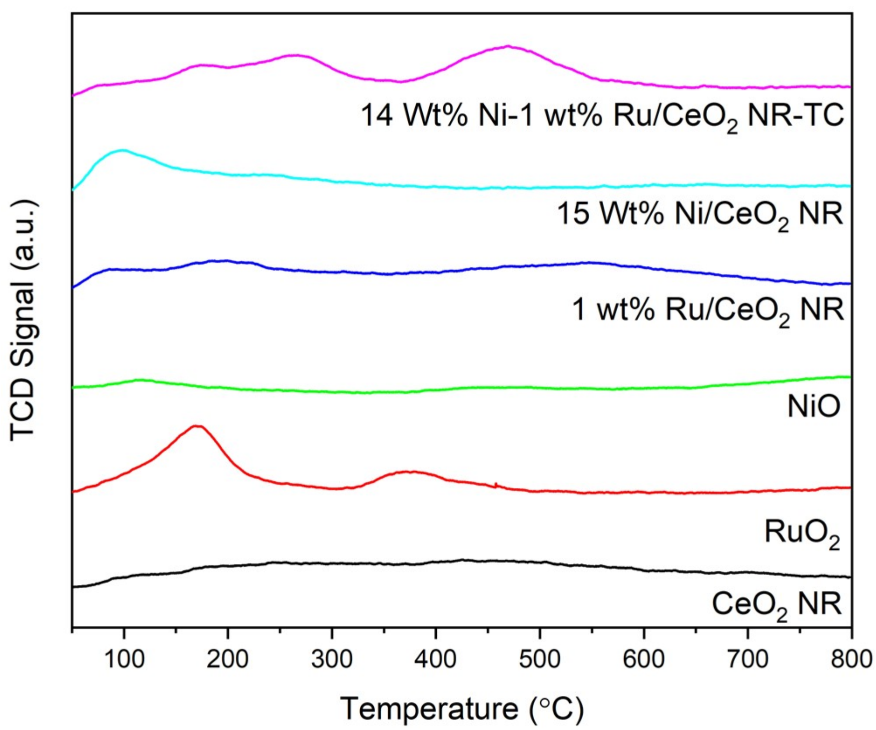

Fig. S11 CO-TPD profiles of the CeO_2 NR, RuO_2, NiO, 1 wt% RuO_x/CeO_2 NR, 15 wt% NiO/CeO_2 NR and bimetallic 14 wt% Ni-1 wt% Ru/CeO_2 NR catalysts.

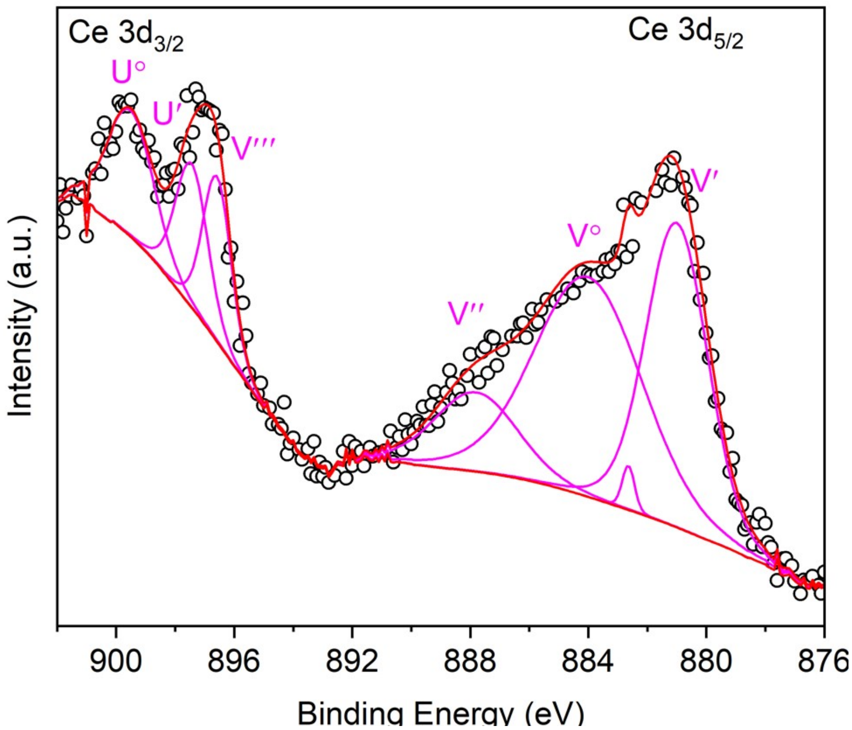

Fig. S12 XPS profile of Ce 3d for the spent 14 wt% Ni-1 wt% Ru/CeO_2 NR catalyst.

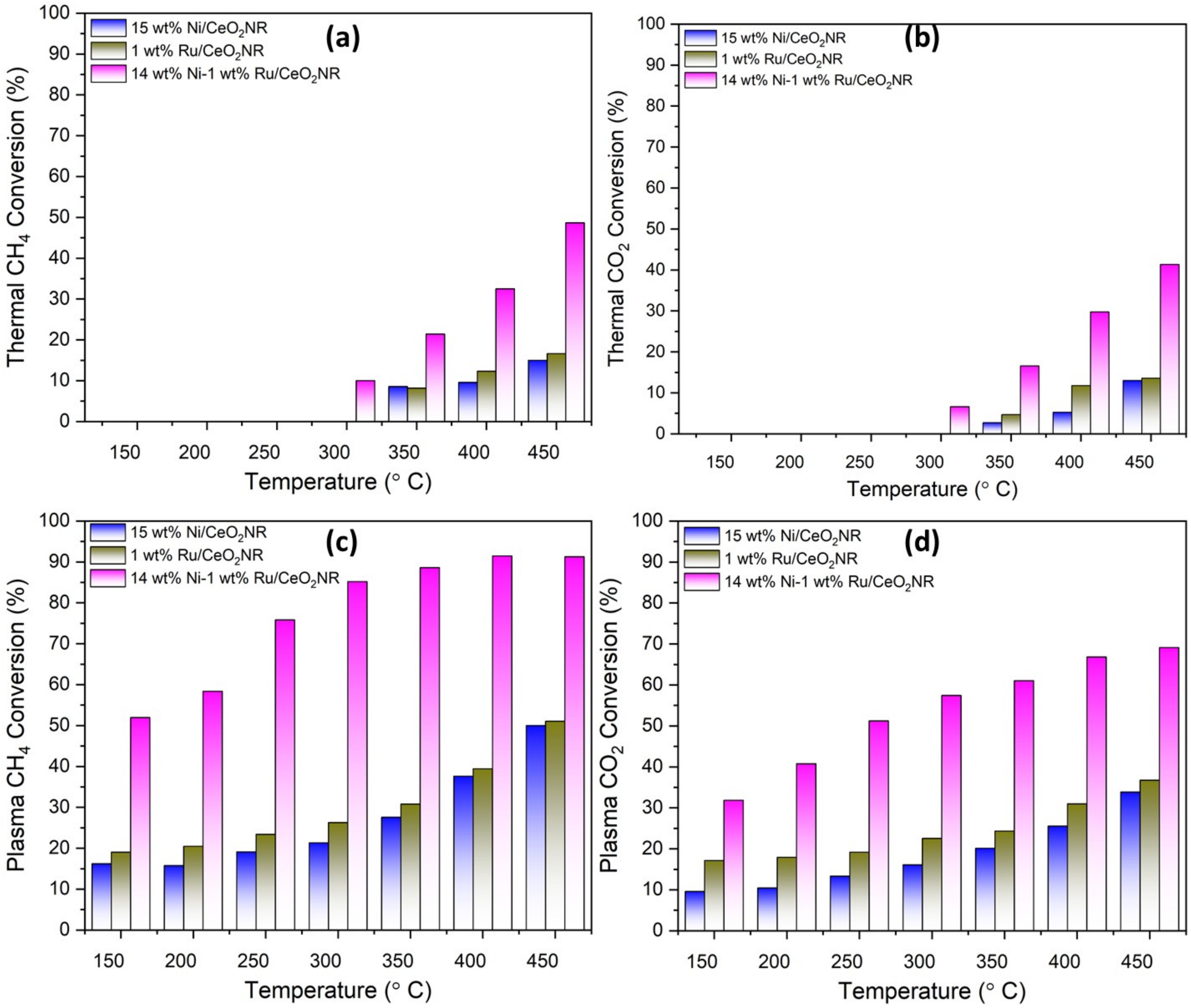

Fig. S13 (a-b) Thermal and (b-c) plasma assisted catalytic CH_4 and CO_2 conversion at various temperatures with 15 wt% Ni/CeO_2 NR, 1 wt% Ru/CeO_2 NR and 14 wt% Ni-1 wt% Ru/CeO_2 NR (Catalyst weight: ~200 mg, Flow rate: CO_2: 250 sccm and CH_4: 100 sccm, and Frequency: 20 kHz).

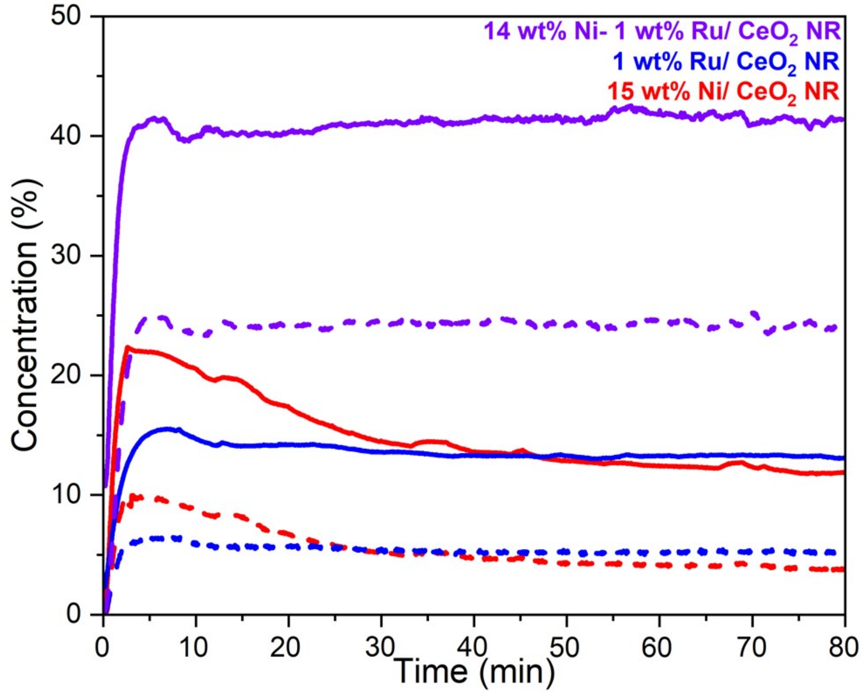

Fig. S14 Stability of 15 wt% Ni/CeO_2 NR, 1 wt% Ru/CeO_2 NR and 14 wt% Ni -1 wt% Ru/CeO_2 NR catalyst at 350 ºC for plasma catalytic DRM (solid line: CO and dashed line: H_2).

Table S1. Plasma properties and experimental parameters for the plasma catalytic systems.

Plasma properties & Experimental parameters	
Plasma power	17.66 W – 22.73 W
Plasma type	Sinusoidal
Frequency	20 KHz
Gas flow rate	350 sccm
CH_4: CO_2	100:250
Furnace temperature range	150 °C – 450 °C

Table S2. Comparison of plasma-assisted DRM activity over different catalysts.

Catalyst	Plasma type	Temperature (° C)	CH_4 Conversion (%)	CO_2 Conversion (%)	References
Commercial Ni/Al_2O_3	DBD	500	59	42	[1]
15 wt% Ni/CeO_2 NR	DBD	500	66	40	[2]
1 wt% Ru /CeO_2 NR	DBD	450	51	37	[3]
14 wt% Ni- 1 wt% Ru/CeO_2 NR	DBD	450	92	70	This work

References

[1] Q. Wang, B.-H. Yan, Y. Jin, Y. Cheng, Dry reforming of methane in a dielectric barrier discharge reactor with Ni/Al2O3 catalyst: interaction of catalyst and plasma, Energy & Fuels. 23 (2009) 4196–4201.

[2] M.R. Ahasan, M.M. Hossain, Z. Barlow, X. Ding, R. Wang, Low-Temperature Plasma-Assisted Catalytic Dry Reforming of Methane over CeO2 Nanorod-Supported NiO Catalysts in a Dielectric Barrier Discharge Reactor, ACS Appl Mater Interfaces. (2023).

[3] M.R. Ahasan, M.M. Hossain, X. Ding, R. Wang, Non-equilibrium plasma-assisted dry reforming of methane over shape-controlled CeO 2 supported ruthenium catalysts, J Mater Chem A Mater. 11 (2023) 10993–11009.