Electronic Supplementary Material (ESI) for Nanoscale.

Supplementary Information for:

A general approach to multicomponent metal-decorated crumpled reduced graphene oxide nanocomposites using a flame-based process

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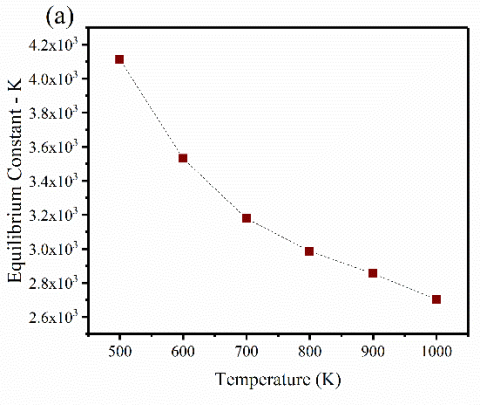

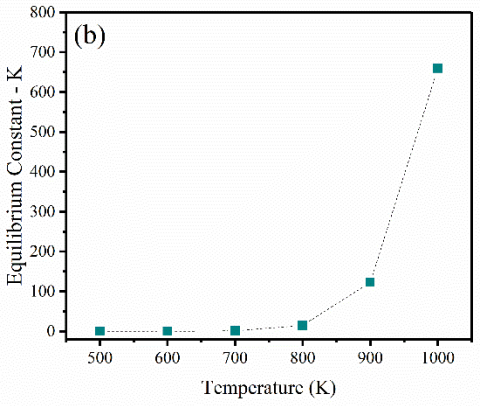

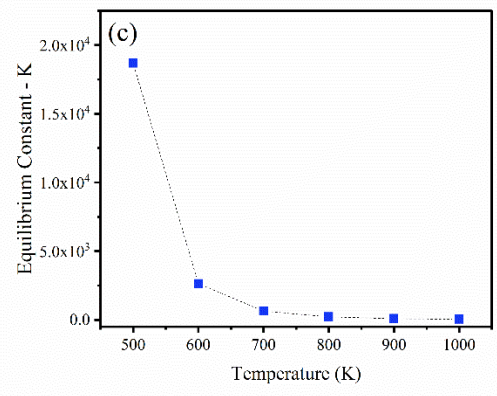

Fig. S1: Equilibrium constant vs. temperature for cobalt reduction in the presence of water with: **a)** hydrogen; **b)** graphitized carbon; **c)** carbon monoxide. (data from Table S2 were used for calculating the equilibrium constants)

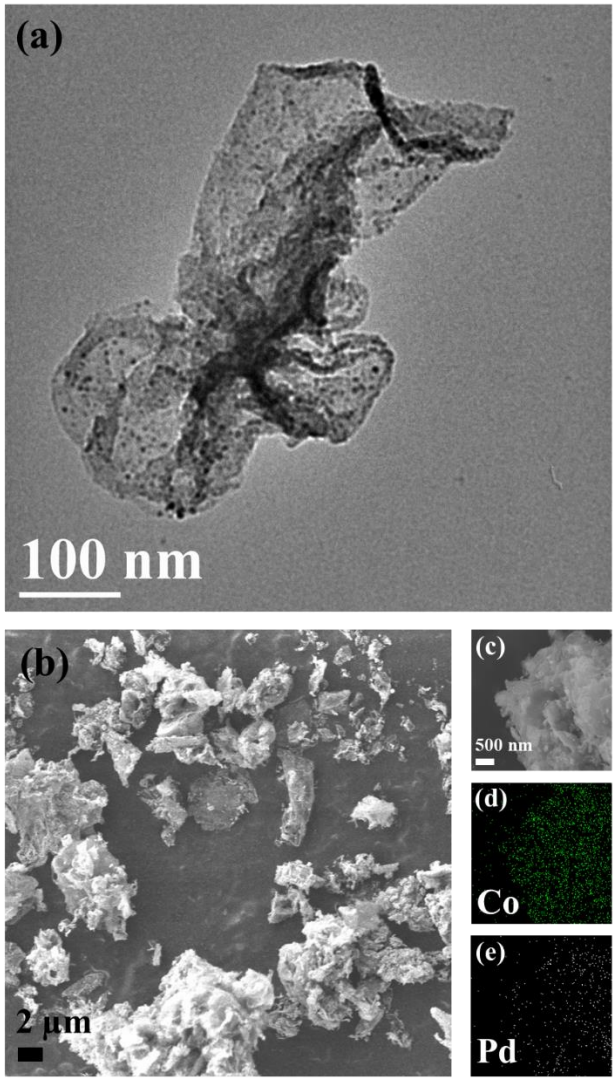

Fig. S2: CoPd (50:50 mass%)-CGB: **a)** TEM image; **b,c)** SEM image; elemental mapping of **d)** Co; **e)** Pd.

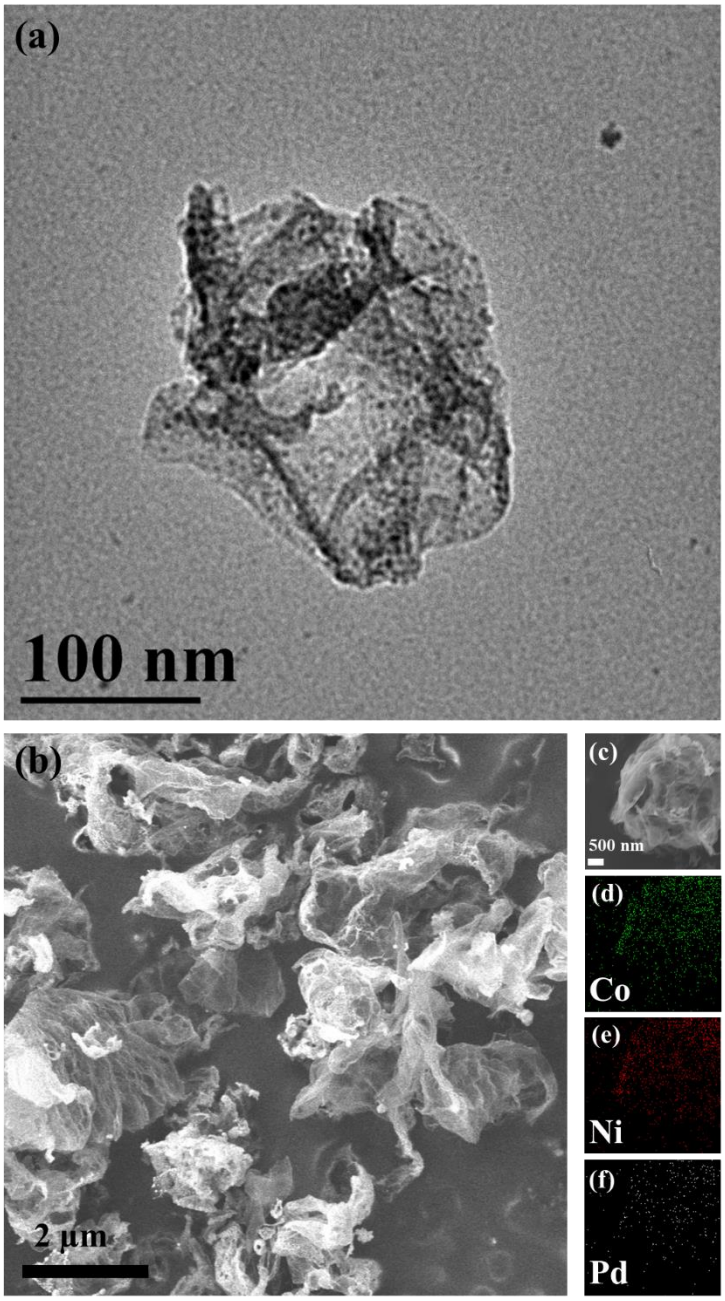

Fig. S3: CoNiPd (33:33:34 mass%)-CGB: **a)** TEM image; **b,c)** SEM image; elemental mapping of **d)** Co; **e)** Ni; **f)** Pd.

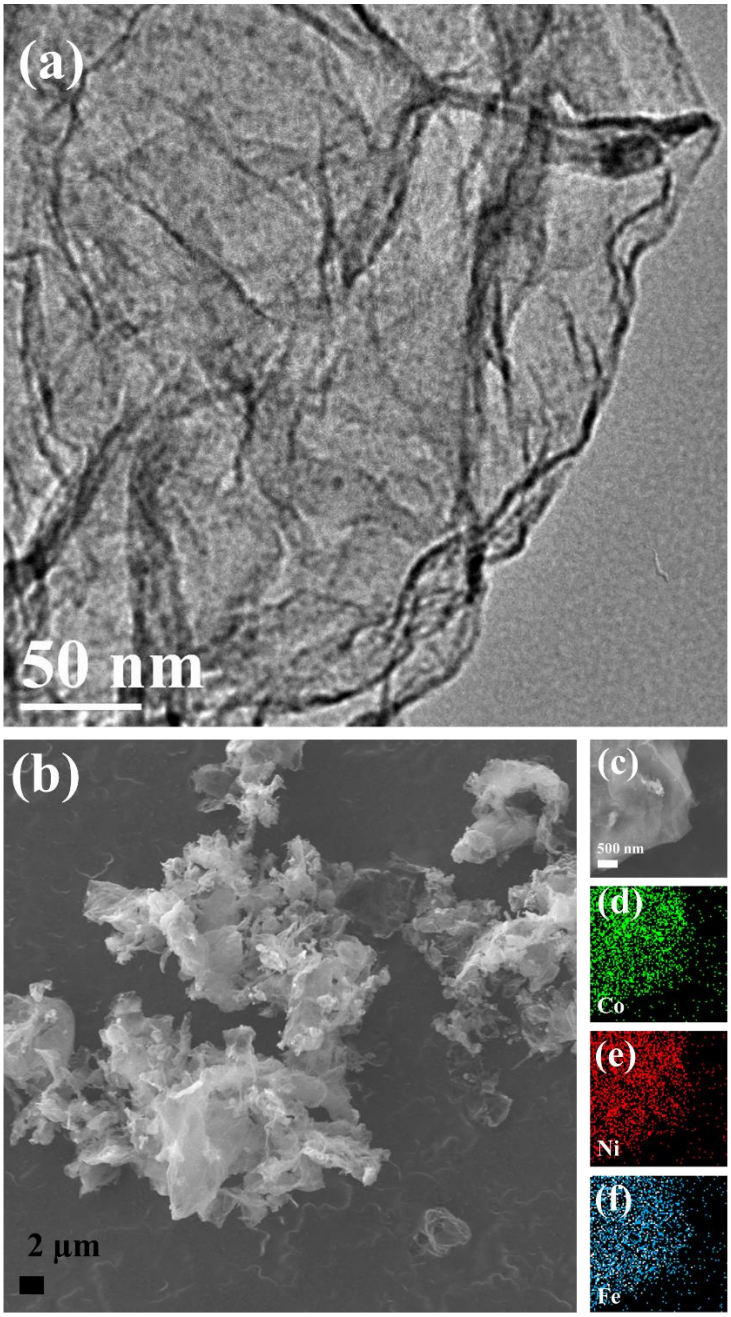

Fig. S4: CoNiFe (33:33:34 mass%)-CGB: **a)** TEM image; **b,c)** SEM image; elemental mapping of **d)** Co; **e)** Ni; **f)** Fe.

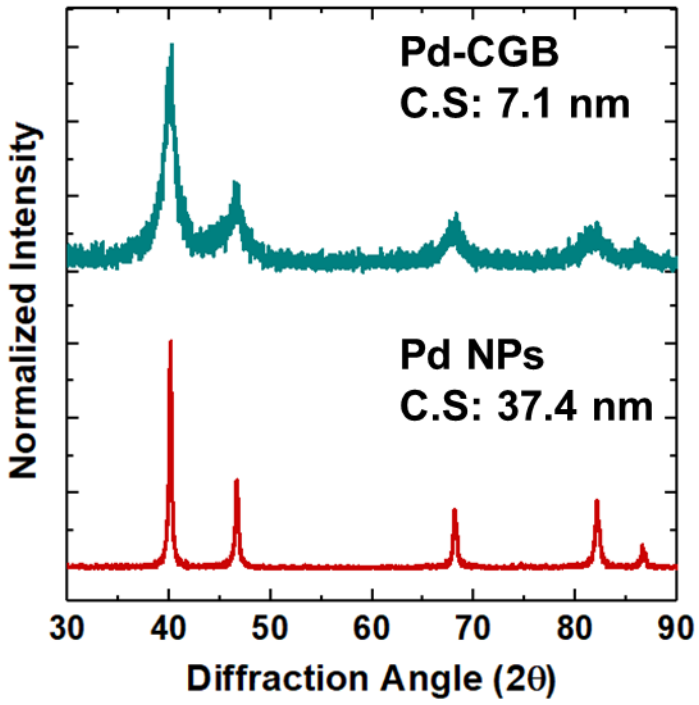

Fig. S5: XRD patterns of Pd-CGB and Pd nanoparticles synthesized using the HTRJ process. (C.S: Crystalline Size)

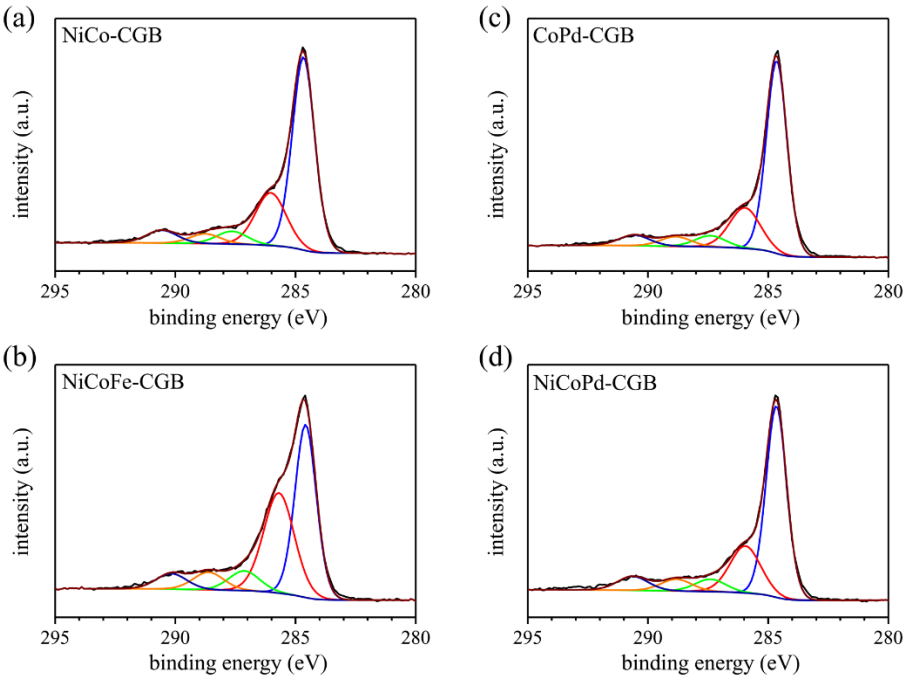

Fig. S6: C 1s spectra of M-CGB: **a)** NiCo-CGB; **b)** NiCoFe-CGB; **c)** CoPd-CGB; and **d)** NiCoPd-CGB.

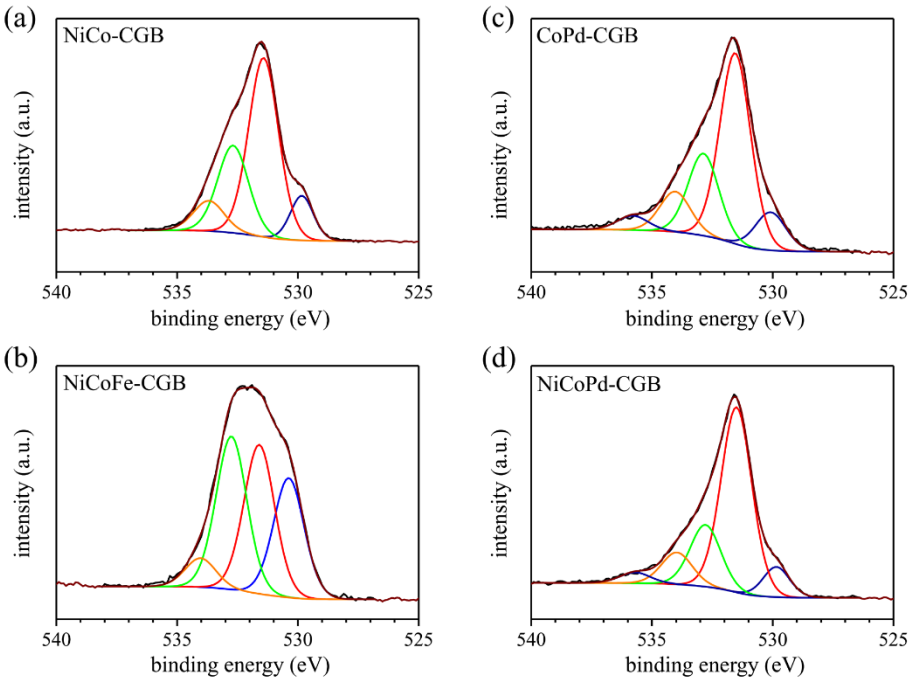

Fig. S7: O 1s spectra of M-CGB: **a)** NiCo-CGB; **b)** NiCoFe-CGB; **c)** CoPd-CGB; and **d)** NiCoPd-CGB.

Table S1. XPS element contents (at. %) of GO, CGB, and M-CGBs

Material	C 1s	O 1s	N 1s	Co 2p	Ni 2p	Pd 3d	Fe 2p
GO	70.30±0.72	29.06±0.92	0.64±0.38	-	-	-	-
CGB	81.37±2.90	15.06±2.42	3.57±0.50	-	-	-	-
CoNi-CGB	59.76±3.18	29.91±5.53	3.51±0.75	3.39±0.88	3.43±1.05	-	-
CoPd-CGB	64.90±6.53	27.26±7.08	1.66±0.56	3.46±0.46	-	2.72±0.53	-
CoNiFe-CGB	58.39±5.88	31.87±4.47	3.63±0.36	2.24±0.37	1.94±0.29	-	1.93±0.89
CoNiPd-CGB	64.04±3.67	26.74±3.65	2.23±0.41	2.91±0.75	2.36±0.41	1.69±0.27	-

*Uncertainties based on mean ±2 standard deviations

Table S2. Phase thermochemistry data for calculating the equilibrium constants of cobalt reduction reactions

Species	Phase	ΔH_f kJ/mol	Entropy J/(mol K)	Shomate Parameters								
				A	B	C	D	E	F	G	H	T range (K)
CoO	solid	-237.74	52.85	43.65	22.38373	-16.89386	6.556161	0.532263	-249.8643	102.6892	-237.7353	298-1600
Co	solid	0	30.07	10.9943	54.375	-55.5132	25.817	0.164533	-4.7033	30.3258	0	298-700
				-204.576	515.582	-421.55	129.558	17.9267	94.6155	-272.856	0	700-1394
Co	liquid	18	41	45.61355	-3.806989	1.031499	-0.096701	-3.33274	-8.135203	78.01905	18.004	1768. - 3184.943
C	graphite	0	5.6	4.487119045								
CO	gas	-110.53	197.66	25.56759	6.09613	4.054656	-2.671301	0.131021	-118.0089	227.3665	-110.5271	298-1300
CO_2	gas	-393.52	213.79	24.99735	55.18696	-33.69137	7.948387	-0.13664	-403.6075	228.2431	-393.5224	298-1200
H_2	gas	0	130.68	33.066178	-11.363417	11.432816	-2.772874	-0.15856	-9.980797	172.707974	0	298-1000
H_2O	gas	-241.83	188.84	30.092	6.832514	6.793435	-2.53448	0.082139	-250.881	223.3967	-241.8264	500-1700

Data from: *NIST Chemistry WebBook, SRD 69*. National Institute of Standard and Technology (NIST), U.S. Department of Commerce.