

Supplementary information

In situ growth of CoNi bimetallic alloys inside polyetheretherketone-derived hierarchical porous carbon as a broadband and efficient electromagnetic wave absorber

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SI-1: The characterization section

The component information of the samples was verified by X-ray diffraction (XRD, PANalytical B.V. Empyrean system, Cu K α , 10°–95°), Raman spectroscopy (LabRAM HR Evolution, Horiba, 523 nm laser), X-ray photoelectron spectroscopy (XPS, ESCALAB 250Xi), thermogravimetric analysis (TGA, PerkinElmer) and energy dispersion X-ray spectrometry (EDS, Oxford X-Max system). The morphologies of synthetic materials were determined by scanning electron microscopy (SEM, Nova Nano 450, field emission) and transmission electron microscopy (TEM, JEM-1200EX). The pore structure of the products was characterized by nitrogen adsorption and desorption experiment (Micromeritics ASAP 2020). The magnetic property of the products was measured on a vibrating sample magnetometer (VSM, SQUID, 298 K). The electromagnetic parameters (complex permeability and permittivity) were obtained on a network analyzer (85054D PNA-X, Agilent, toroidal shapes samples with 30 wt% of products in a paraffin wax matrix, coaxial method, frequency range: 2.00–18.00 GHz). The reflection loss (RL) of samples was calculated based on the transmission line theory.

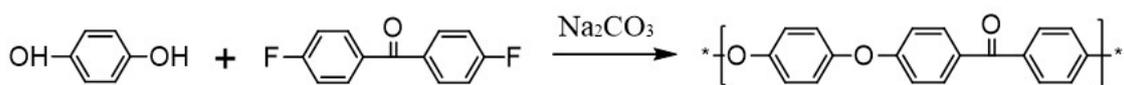
$$RL = 20 \lg \left| \frac{Z_{in} - Z_0}{Z_{in} + Z_0} \right| \quad (S1)$$

$$Z_{in} = Z_0 \sqrt{\mu_r / \epsilon_r} \tanh \left[j(2\pi f d / c) \sqrt{\mu_r \epsilon_r} \right] \quad (S2)$$

among them, Z_{in} is the normalized input impedance of absorption layer, Z_0 refers to the impedance of free space, ϵ_r and μ_r refer to the relative complex permeability and the complex permittivity, respectively, f , d and c stand for the frequency of EMW, the thickness of an absorber, and the velocity of EMW in free space, respectively.

SI-2: The synthesis and characteristic viscosity measurement of PEEK/NaCl and PEEK

605.45 g Diphenyl sulfone and 196.38 g 4,4'-difluorobenzophenone were placed in a 1000 mL three-necked flask, melted, and raised to 180 °C under the protection of high purity N₂. Then 99.10 g hydroquinone and 114.47 g Na₂CO₃ were added, and the mixture was slowly heated to 250 °C and kept for 30 min. After that, the reaction temperature was raised to 320 °C and kept for 3 h. After that 9.82 g 4, 4-difluorophenone was added to seal the end, and then 259.48 g NaCl was added after thorough stirring, the product was quickly poured into the prepared mold and cooled to room temperature. Finally, the diphenyl sulfone was removed by Soxhlet extraction using acetone as solvent and the product obtained was named PEEK/NaCl after natural drying. For comparison, the same preparation method was used and the product without the addition of NaCl was denoted as PEEK. The reaction equation of polymer synthesis is as follows.



The reactive molecular formula of PEEK

The characteristic viscosity ($[\eta]$) of PEEK/NaCl and PEEK was determined by eqn.1. The pure solvent efflux time (t_0) and the PEEK solution efflux time (t) were measured with a Ubbelohde viscometer. In eqn.S3, the relative viscosity $\eta_r = t/t_0$ and C is the concentration of the solution to be measured.

$$[\eta] = [(\ln \eta_r)/C] \times \eta_r^{1/9} \quad (\text{S3})$$

In this experiment, C (sulphuric acid solution) for all three samples was 0.50 g/dl, the water bath temperature (25 °C ± 0.2 °C), and the capillary diameter of the Ubbelohde viscometer was 0.8 mm. The characteristic viscosity of PEEK/NaCl and PEEK was 1.06 g/dl.

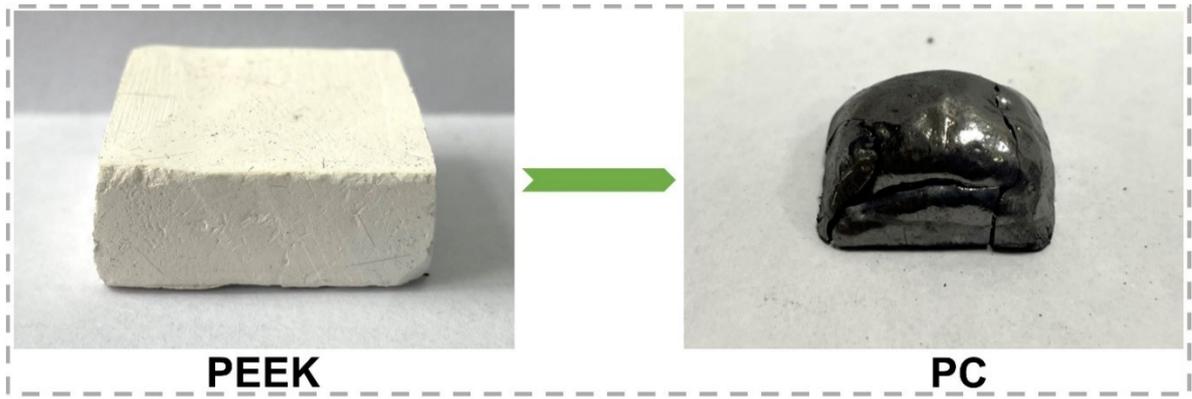


Fig. S1 Digital photos of the process from PEEK to PC.

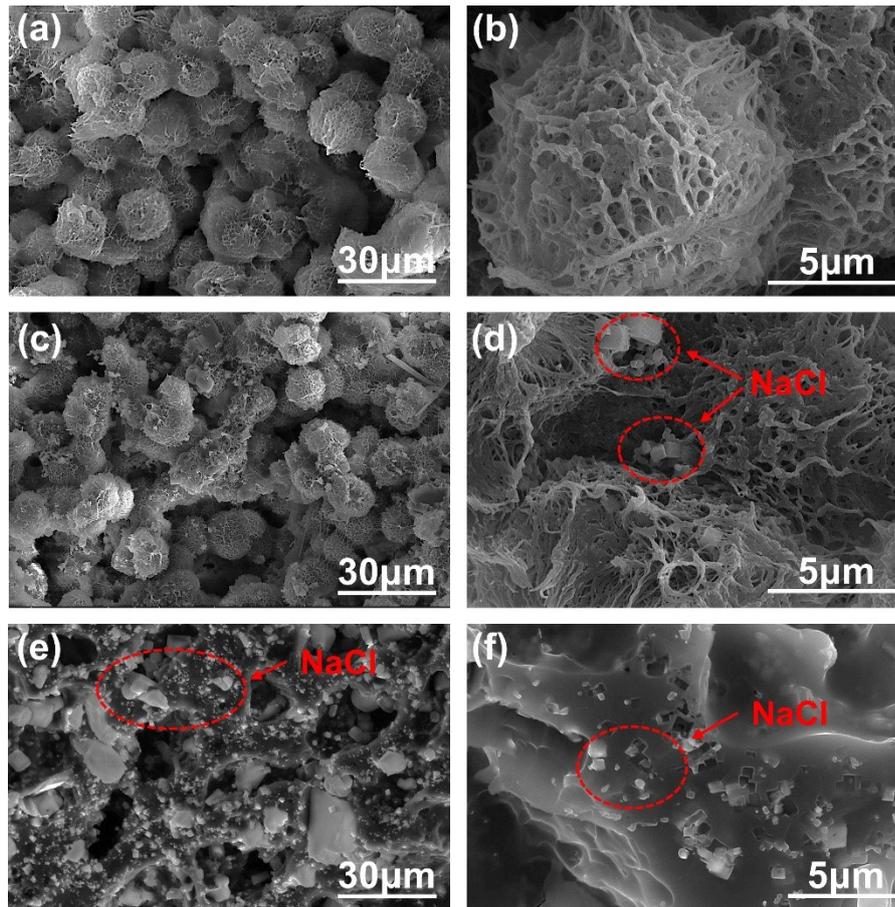


Fig. S2 The SEM image of cross-sectional view of (a, b) PEEK, (c, d) PEEK/NaCl, and (e, f) PCP/NaCl.

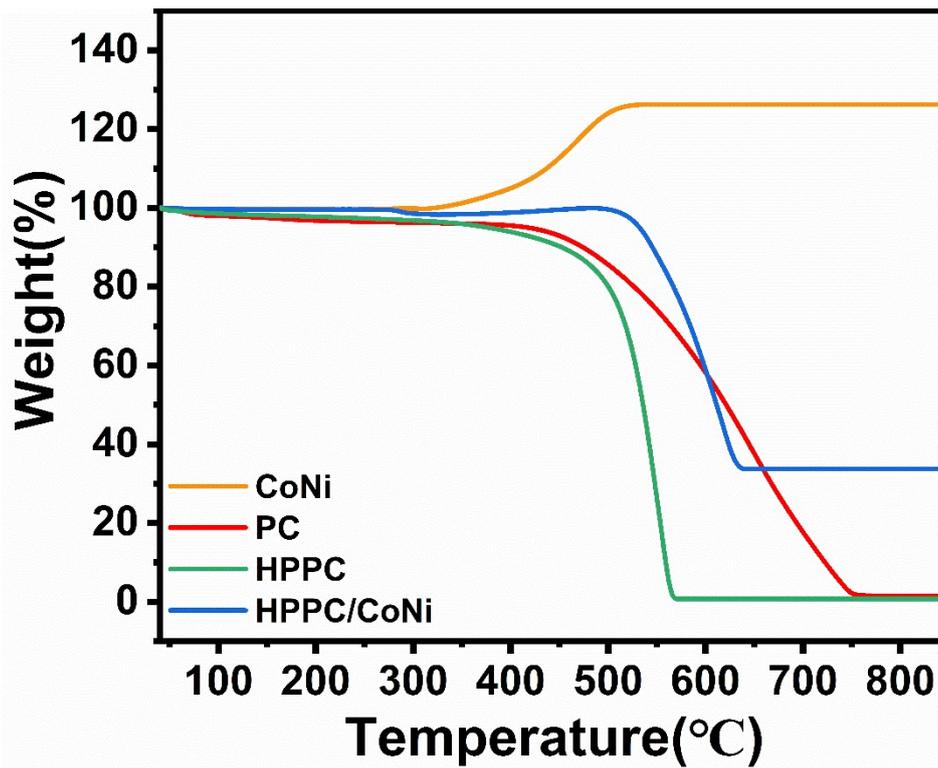


Fig. S3 TGA curves of CoNi, PC, HPPC, and HPPC/CoNi in air.

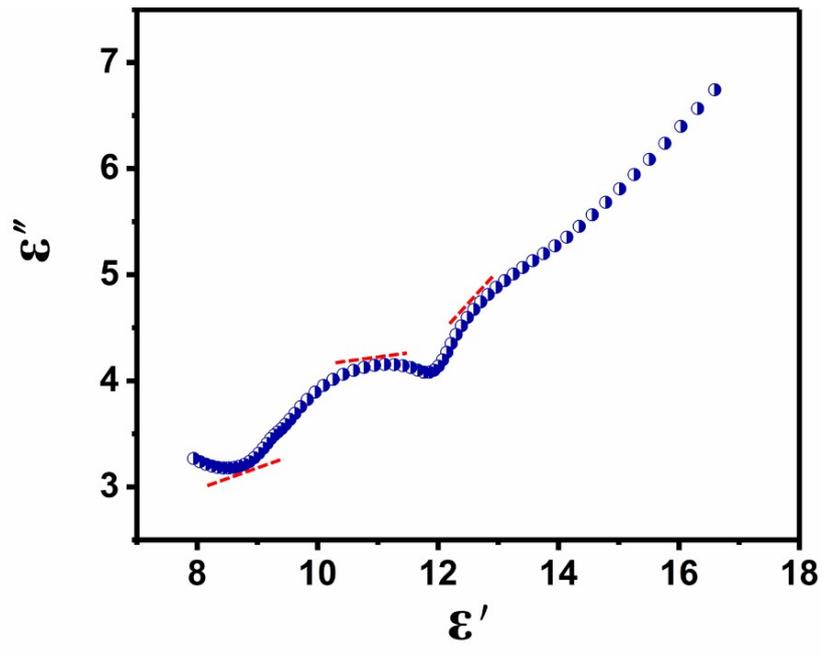


Fig. S4 Cole–Cole plots of HPPC/CoNi.

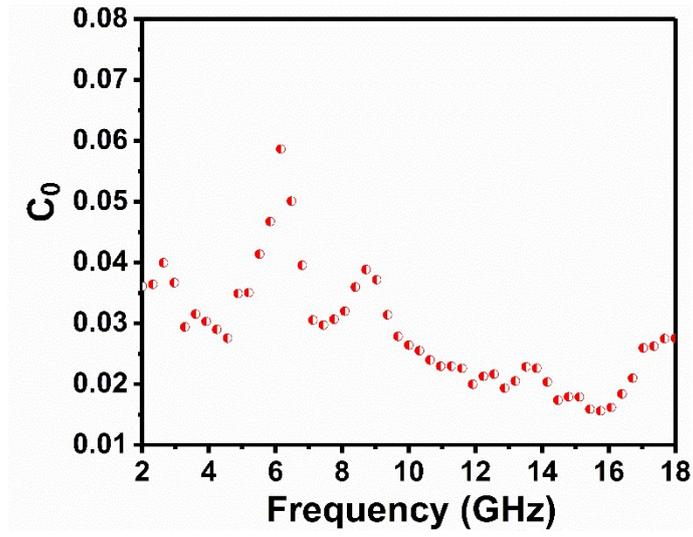


Fig. S5 The value of the eddy current C_0 ($\mu''(\mu')^{-2}f^{-1}$) of HPPC/CoNi.

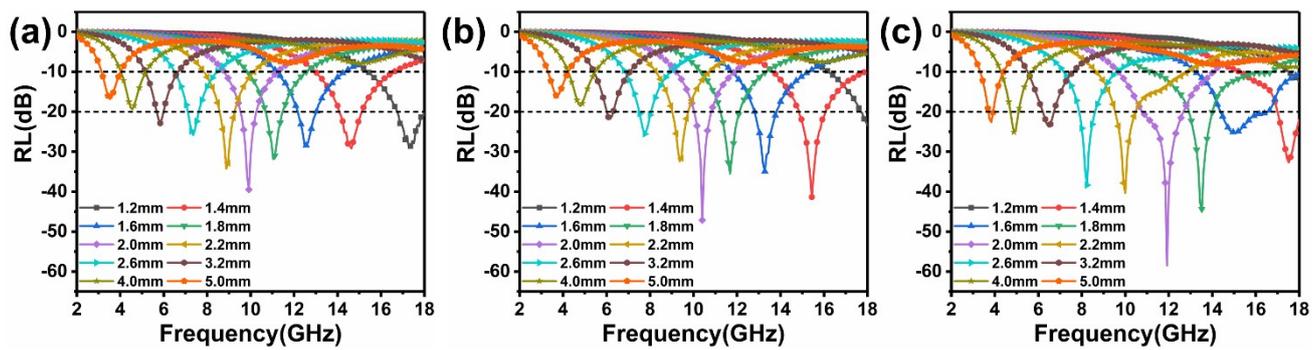


Fig. S6 2D absorption spectrum of (a) PC, (b) HPPC, and (c) HPPC/CoNi.

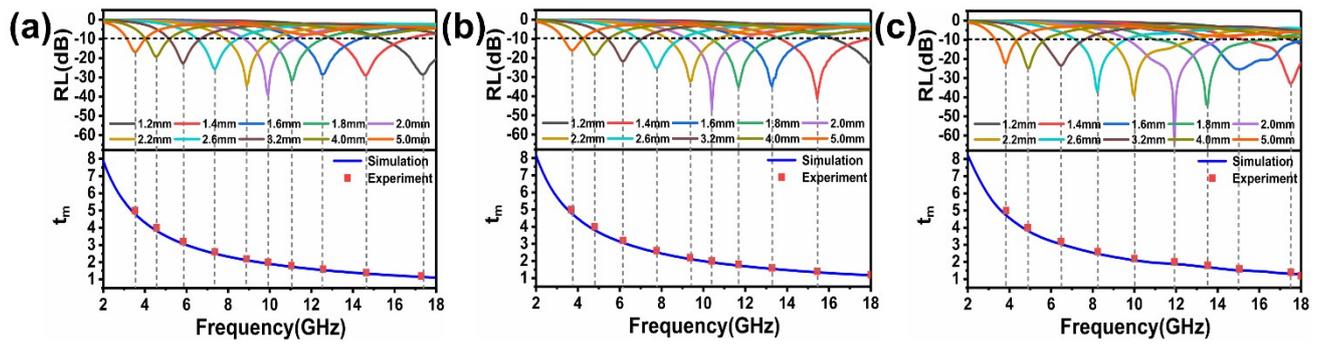


Fig. S7 The RL–Frequency curves and the relationship between simulation thickness and peak frequency of (a) PC, (b) HPPC, and (c) HPPC/CoNi in 2.00–18.00 GHz.

Table S1 The EMW absorption performance of polymer carbon-based composite absorbers

Absorber	RL_{min} (dB)	Thickness (mm)	EAB (GHz)	Frequency (GHz)	Ref
Co/C	-42.43	2.65	3.94	8.46–12.40	[44]
Porous C/Ni	-47.60	1.75	3.80	12.00–15.80	[39]
WPC/MNPs-80	-47.90	2.20	5.20	12.80–18.00	[45]
CuNi /Carbon foam	-50.20	1.60	–	–	[46]
Dopamine-derived cavities /Fe ₃ O ₄ /SA-derived carbon	-50.80	1.50	3.52	14.48–18.00	[47]
Co/Si/C/N700	-50.90	1.90	5.72	12.28–18.00	[43]
Co/CNTs/CS	-51.20	2.20	5.30	12.70–18.00	[23]
MnO@CNWs	-55.00	2.00	6.20	–	[48]
Ni/NiP@NC	-56.10	1.30	4.30	13.70–18.00	[28]
Fe ₃ C/N-doped carbon	-57.90	4.10	2.20	4.80–7.00	[4]
PPC/CoNi	-65.56	2.00	5.92	10.96–16.88	This work