Supplimentary Materials

A wearable microwave absorption cloth

Wei-Li Song,[a,b] Li-Zhen Fan,[a,] Zhi-Ling Hou,[d,*] Kai-Lun Zhang,[d] Yongbin Ma,[b] Mao-Sheng Cao,[c]*

[a]*Institute of Advanced Materials and Technology, University of Science and Technology Beijing, Beijing, 100083, China*

[b]*Institute of Advanced Structure Technology, Beijing Institute of Technology, Beijing 100081, P.R. China.*

[c]*School of Materials Science and Engineering, Beijing Institute of Technology, Beijing, 100081, China*

[d]*School of Science, Beijing University of Chemical Technology, Beijing 100029, China*

*Corresponding authors: E-mail: fanlizhen@ustb.edu.cn; Tel./fax: +86-10-62334311; houzl@mail.buct.edu.cn

Figure S1 SEM images of the cross-section views for the neat NW (a and b);

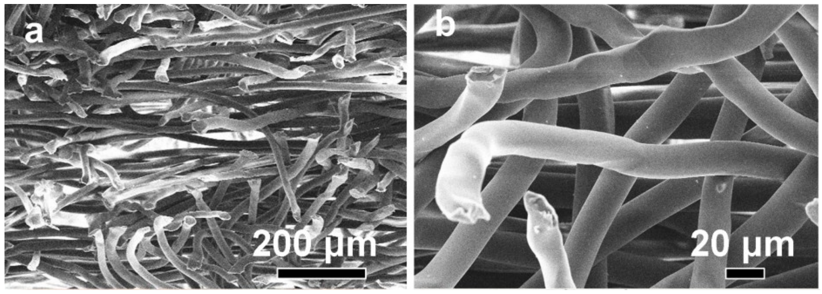


Figure S2 SEM and TEM images of the samples: cross-section SEM views of RGO-NW (a and b) and RGO-NW-4CNT (e and f); Interface SEM views of RGO-NW (c) and RGO-NW-4CNT (g); TEM image of RGO surface in RGO-NW (d) and RGO-NW-4CNT (h).

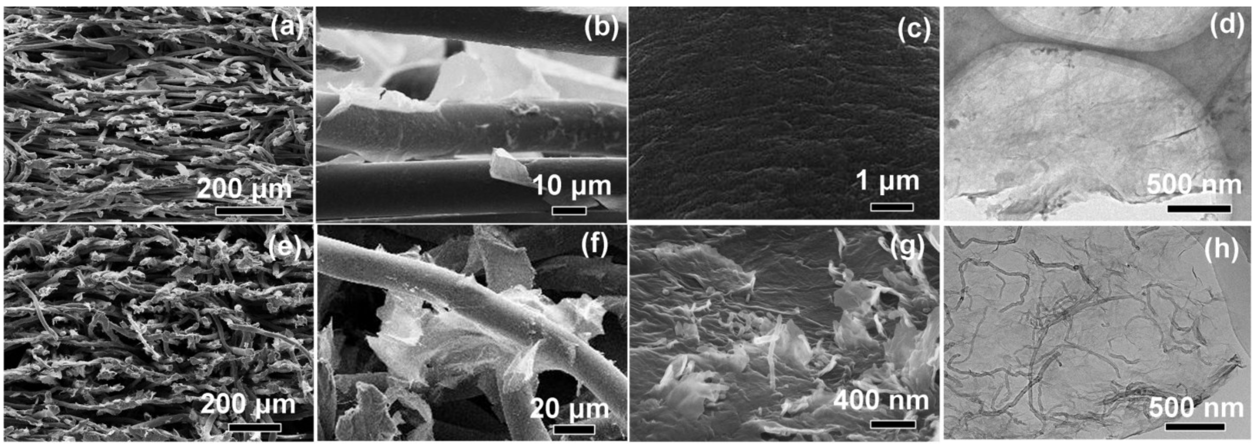


Figure S3 Mass percentage (a), XRD spectra (b) and surface resistivity (c) of the samples as marked.

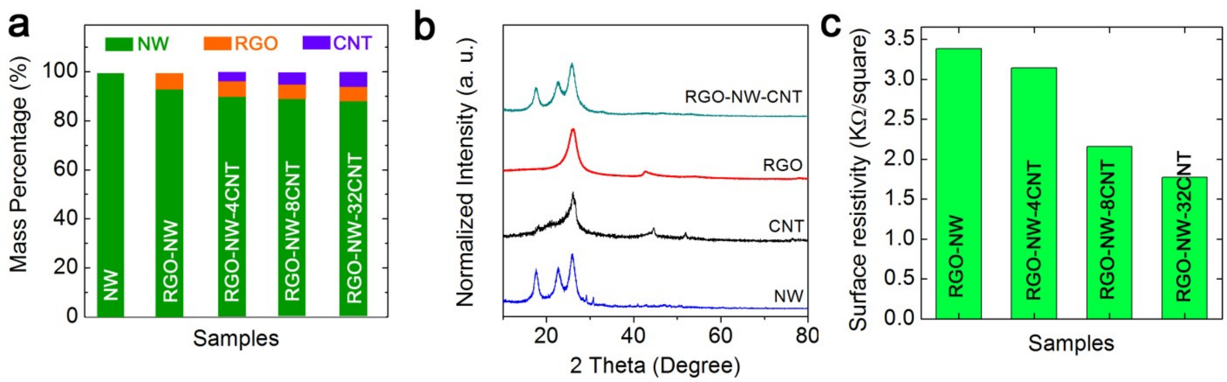


Figure S4 3D and 2D plots of the microwave absorption for the samples as marked. The calculated RL was based on waveguide method.

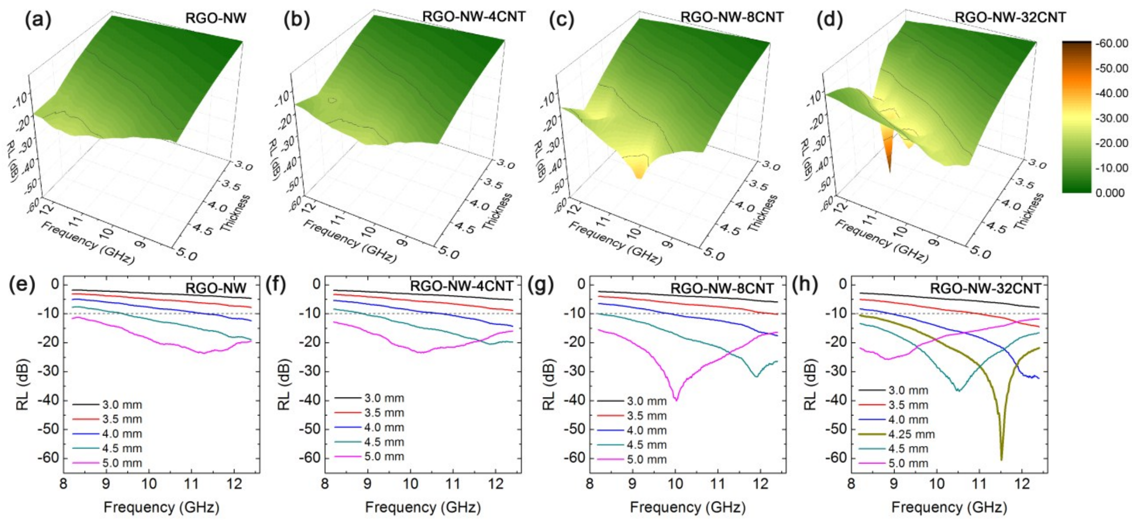
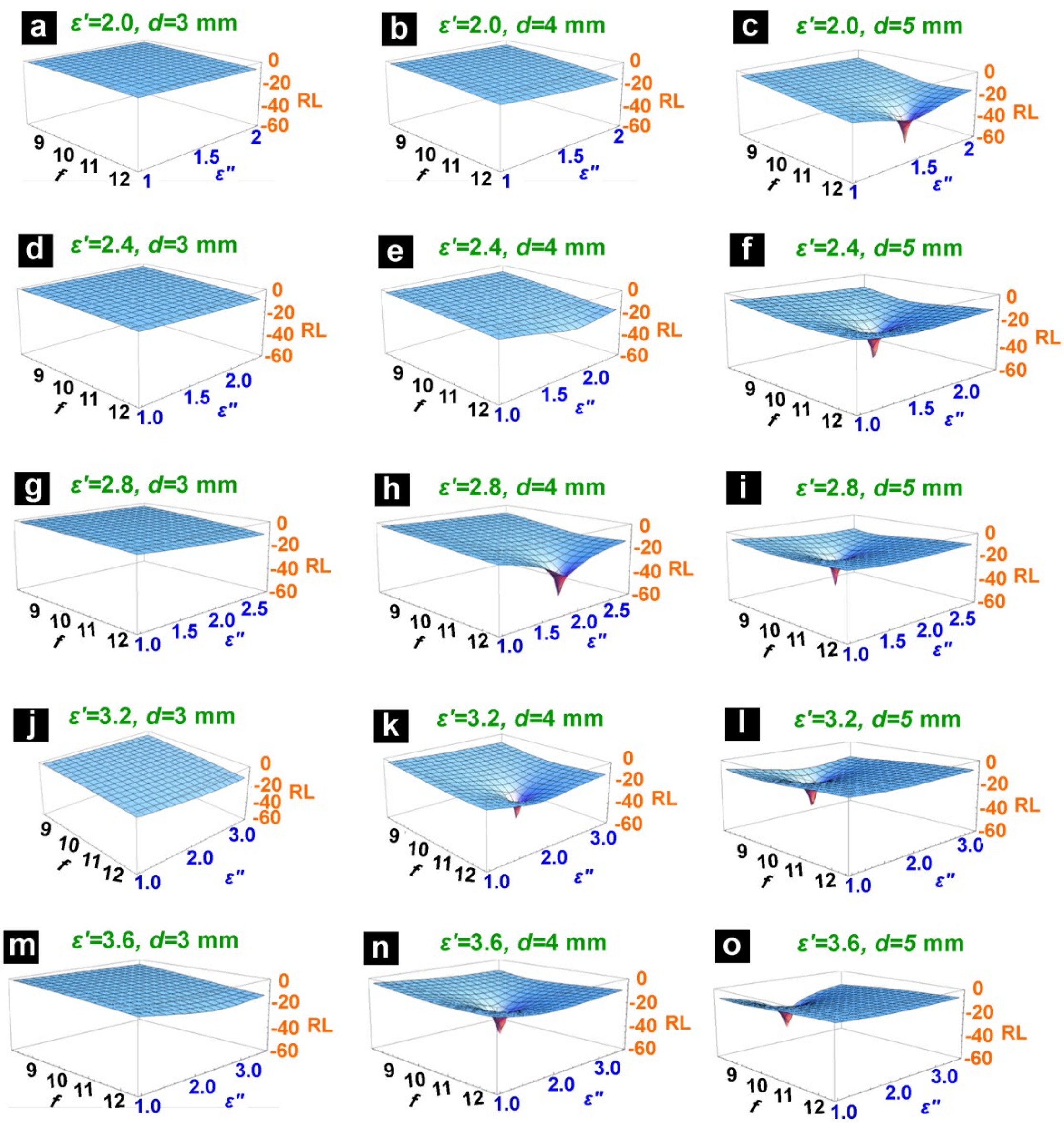


Figure S5 Microwave absorption simulations: calculations of the reflection loss vs. frequency and imaginary permittivity at fixed real permittivity and thickness.



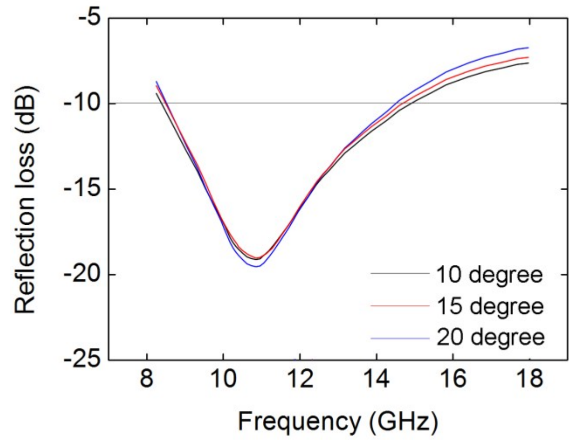


Figure S6 Reflection loss performance via various incident angles.

Table S1 Optimal imaginary permittivity at fixed real permittivity and thickness according to the plots in Figure S4. The term of "–" indicates no peak observed in the plot.

Fixed real permittivity	Optimal imaginary permittivity at fixed thickness=3 mm (Corresponding Frequency)	Optimal imaginary permittivity at fixed thickness=4 mm (Corresponding Frequency)	Optimal imaginary permittivity at fixed thickness=5 mm (Corresponding Frequency)
2.0	–	–	~1.5 (12.2 GHz)
2.4	–	–	~1.7 (10.5 GHz)
2.8	–	~1.9 (12.2 GHz)	~1.8 (9.6 GHz)
3.2	–	~2.0 (11.2 GHz)	~1.9 (9 GHz)
3.6	–	~2.2 (10.4 GHz)	~2.0 (8.4 GHz)

Table S2 Overal performance of the wearable cloth fabricated in this work

Catagories	Features	Qualification	Description
Mechanical	Light weight	Yes	Absorbing layer: density<0.17 g/cm^3
Mechanical	Flexibility	Yes	
Mechanical	Durability	Yes	Absorbing layer: excellent retention upon 200 bending cycles
Mechanical	Robustness	Yes	Absorbing layer: tensile strength >5 MPa
Functional	Effective absorption band	Yes	8.2~14.5 GHz
Functional	Weak surface reflection	Yes	ε'<3.5 (see snell's law)
Functional	Breathability	Yes	All porous structures
Manufacturing	Cost	Medium	GO to be potentially reduced
Manufacturing	Scalability	Yes	
Manufacturing	Small loading	Yes	0.92 vol% filler loading in NW
Manufacturing	Processible	Yes	

Table S3 The state-of-the-art in microwave absorption materials with wave guide method (X band or Ku band) and coaxial method (2-18 GHz). The absorption performance is based on calculation.

Fillers of microwave absorption composites	Filler loadings in matrices	Features andmechanical properties	Flexibility and Durability	Density [a] (g/cm^3)	Absorption peak/span of absorption >10 dB (Investigated regions)	Scalability and (processibility)	Breathability	Refs.
RGO-NW-CNT32	0.92 vol% in Porous NW	Robust; Tensile strength >5 MPa	Highly flexible and excellent performance retention upon bending for 200 cycles	<0.17	-60 dB / 8.2-12.4 GHz (8.2-12.4 GHz)	Scalable (could be freely processed into any shape)	Sufficiently porous for breathing	This work
RGO/Ni	60 wt% in paraffin	Soft	–	>0.8	-17 dB/ 3.0–4.0 GHz, 12.0–	–	–	1

	wax				14.0 GHz (2-18 GHz)			
RGO/Fe_3O_4	40 wt% in paraffin wax	Soft	–	>0.8	-27 dB / 4.5–6.5 GHz (2-18 GHz)	–	–	2
$NiFe_2O_4$ nanorod–RGO	60 wt% in paraffin wax	Soft	–	>0.8	-44.6 dB / 6.5-9.2 GHz (2-18 GHz)	–	–	3
SiO_2@Fe_3O_4 core/shell nanorod array/RGO	20 wt% in paraffin wax	Soft	–	>0.8	-31.9 dB / 5-8 GHz (2-18 GHz)	–	–	4
MnO_2@Fe/RGO	50 wt% in paraffin wax	Soft	–	>0.8	-17 dB/ 14-18 GHz (2-18 GHz)	–	–	5
RGO/γ-Fe_2O_3	45 wt% in	Soft	–	>0.8	−59.7 dB/	–	–	6

	paraffin wax				8.9-11.8 GHz (8.2-12.4 GHz)			
$RGO@Fe_3O_4$ NC@carbon@MnO_2	25 wt% in paraffin wax	Soft	–	>0.8	-38.8 dB/ 12.3 to 17.7 (2-18 GHz)	–	–	7
$RGO@Fe_3O_4@SiO_2@NiO$	25wt% in paraffin wax	Soft	–	>0.8	-52 dB / 12-17 GHz (2-18 GHz)	–	–	8
PEDOT−RGO−Co_3O_4	50 wt% in paraffin wax	Soft	–	>0.8	-51 dB / 9.1-12.8 (2-18 GHz)	–	–	9
carbonyl iron/RGO	60 wt% in paraffin wax	Soft	–	>0.8	-52 dB/ 8-12 GHz (2-18 GHz)	–	–	10
$RGO@Fe_3O_4@$ C@polyaniline(	25 wt% in paraffin	Soft	–	>0.8	- 44.2 dB/ 9.5-15.5 GHz	–	–	11

PANI)	wax				(2-18 GHz)			
PEDOT–RGO–$NiFe_2O_4$	50 wt% in paraffin wax	Soft	–	>0.8	-45.4 dB/ 12.5-17 GHz (2-18 GHz)	–	–	12
3DRGO/ ZnO	10 wt% in paraffin wax	Soft	–	>0.8	-25 dB/ 11.5-18 GHz (2-18 GHz)	–	–	13
iron oxides/RGO	50 wt% in paraffin wax	Soft	–	>0.8	-21 dB/ 7-10.5 GHz (2-18 GHz)	–	–	14
RGO	2 wt% in paraffin wax	Soft	–	>0.8	-42.4 dB/ 9.44–15.58 (2-18 GHz)	–	–	15
RGO/polypyrrol e	15 wt% in paraffin wax	Soft	–	>0.8	-54.4 dB/ 10-17 GHz (2-18 GHz)	–	–	16

RGO	10 wt% in NBR	Robust	flexible	~1	-57 dB / 7.5–12 GHz (2-18 GHz)	–	–	17
CNT/RGO	5 wt% in PDMS	Robust	flexible	~1	-55 dB/ 8.4-12 GHz (8.2-12.4 GHz)	–	–	18
porous Fe_3O_4@ZnO sphere/RGO	30 wt% in epoxy	Tough	–	>1	-37 dB/ 3-4 GHz, 10.3-12 GHz (2-18 GHz)	–	–	19
GN–Fe_3O_4	30 wt% in epoxy	Tough	–	>1	-20 dB/ 4.5-6.5 GHz, 16.2-18 GHz (0.1-18 GHz)	–	–	20
RGO-$MnFe_2O_4$	5 wt% in PVDF	Tough	–	>1	-29 dB / 8.0-12.88 GHz	–	–	21

					(2-18 GHz)			
RGO	7 wt% in silica	Tough	–	>1	-42 dB/ 8.2-12.4 GHz (8.2-12.4 GHz)	–	–	22
RGO	2.6 vol% in PEO	–	–	>1	38.8 dB/ 14-18 GHz (2-18 GHz)	–	–	23
RGO foam [b]	14 mg/cm−3	Soft	Flexible	14 mg/cm^3	-35.51 dB/ 6.0–18.0 GHz; 26.5–40.0 GHz; 75–110 GHz (2.0–18.0 GHz; 26.5–40.0 GHz; 75–110 GHz)	Scalable	Sufficiently porous for breathing	24
Fe_3O_4/Al_2O_3/CNCs in wax	25 wt% in wax	Soft	–	>0.8	-28.3 dB/ 10.5-14 GHz	–	–	25

					(2-18 GHz)			
HOPC	5 wt% in wax	Soft	–	>0.8	-17.4 dB/ 11.7–16.2 GHz (2-18 GHz)	–	–	26
Porous carbon/Co	30 wt% in wax	Soft	–	>0.8	-40 dB/ 3.5–5.0 GHz (2-18 GHz)	–	–	27
Carbon coated Ni	50 wt% in wax	Soft	–	>0.8	-32 dB/ 11.2–15.5 GHz (2-18 GHz)	–	–	28
SWCNT	5 wt% in PU	Tough	–	>1	-18.5 dB/ 9.0–12.0 GHz (8.2-12.4 GHz)	–	–	29
Fe@MWCNT	20 wt% in epoxy	Tough	–	>1	-16 dB/ 2-18 GHz (2-18 GHz)	–	–	30

MWCNTs/Fe	60 wt% in epoxy	Tough	–	>1	-39 dB/ >2.04–3.47 GHz (2-18 GHz)	–	–	31
MWCNTs/Co	60 wt% in epoxy	Tough	–	>1	-37 dB/ > 2.35–3.51 GHz (2-18 GHz)	–	–	31
MWCNTs/Ni	60 wt% in epoxy	Tough	–	>1	-37 dB/ > 1.83–3.07 GHz (2-18 GHz)	–	–	31
MWCNT/CI	50 vol% CI, 0.5 vol% MWCNT in epoxy silicone	Tough	–	>1	-16.9 dB/ 3.4–18.0 GHz (2-18 GHz)	–	–	32

Sm-Co/SWNT	2 wt% in epoxy	Tough	–	>1	-27 dB/ 8.2–18 GHz (2-18 GHz)	–	–	33
CNTs/Fe_3O_4/PANI	20 wt% in wax	Soft	–	>0.8	-48 dB/ 9.1–18 GHz (2-18 GHz)	–	–	34
Graphite-coated FeNi	40 wt% in wax	Soft	–	>0.8	-23 dB/ 9.5–18.0 GHz (2-18 GHz)	–	–	35
G/Fe_3O_4@Fe/ZnO	20 wt% in wax	soft	–	>0.8	-32.5 dB/ 11.2–18.0 GHz (2-18 GHz)	–	–	36
(Fe, Ni)/C nanocapsules	40 wt% in wax	soft	–	>0.8	-26.9 dB/ 12.3–18.0 (2-18 GHz)	–	–	37
PMMA-g-CMK-	19 wt% in	-	-	>1	-27 dB/	–	–	38

3	PMMA				9.2–12.4 GHz (8.2–12.4 GHz)			
α-Co/GN	60 wt% in wax	soft	−	>0.8	47.5 dB/ 9.2–14.0 GHz (2-18 GHz)	−	−	39
Cross-stacking aligned CNT films coated with PANI	70 wt%	robust	Flexible	1.97 g/m^2	47.66 dB/ 10.8–15.2 GHz (2-18 GHz)	−	−	40
MWCNT-ZnO	ZnO: 15wt% MWCNT: 3wt% in silica	tough	−	>1	21.6 dB/ 9.2–12.4 GHz (8.2–12.4 GHz)	−	−	41
Carbon coils–	10 wt% in	soft	−	>0.8	-30 dB/	−	−	42

CFs	wax				8.4–18 GHz (2-18 GHz)			
HCNFs/CF	15 wt% in wax	soft	–	>0.8	-32 dB/ 8.2–18 (2-18 GHz)	–	–	43
CI/CF	CI 65wt%, CF: 2wt%in epoxy/silic one resin	Tough	–	>1	-12 dB/ 8-18 GHz (2-18 GHz)	–	–	44
Fe-C nanofibers	50 wt% in wax	soft	–	>0.8	-36 dB/ 3.8–4.7 GHz (1-15 GHz)	–	–	45
Fe_3O_4@Carbon nanorods	55 wt% in wax	soft	–	>0.8	-27.9 dB/ 13.1–17.8 GHz (2-18 GHz)	–	–	46

$FeCo/C/BaTiO_3$	40 wt% in wax	soft	–	>0.8	-41.7 dB/ 9.8–14.0 GHz (2-18 GHz)	–	–	47
Activated CF	0.76wt% in epoxy	Tough	–	>1	-15.7 dB/ 5.8–18 GHz (2-18 GHz)	–	–	48
Activated CF felt dipole array	Epoxy matrix	Tough	–	>1	-32 dB/ 4.5–6.8 GHz; 8.1–18 GHz (2-18 GHz)	–	–	49
Fe_3C/C(a)	40 vol% in epoxy	Tough	–	>1	-31 dB/ 14.2–21.8 GHz (0.05–26.5 GHz)	–	–	50
PANI/ferrocene/ C-dots	30 wt% in wax	soft	–	>0.8	-25 dB/ 4.5-6.3 GHz (2-18 GHz)	–	–	51

MWCNT/Fe_3O_4/PANI/Au	40 wt% in wax	soft	–	>0.8	-60 dB/ 10-13 GHz (2-18 GHz)	–	–	52
M-$BaFe_{12}O_{19}$	50 vol% in wax	soft	–	>0.8	-28.52 dB/ 9.3–18 GHz (8-18 GHz)	–	–	53
Fe/SiO_2	15 vol% in wax	soft	–	>0.8	-75 dB/ 9.0–13.7 GHz (2-18 GHz)	–	–	54
PANI/NiZn	66.7 wt% in epoxy	Tough	–	>1	-20.1 dB/ 12.1–16.6 GHz; 39.7–40.0 GHz (2-40 GHz)	–	–	55
Fe_3O_4@ZnO nanorods	50 wt% in wax	soft	–	>0.8	-30 dB/ 12.7–17.5 GHz (2-18 GHz)	–	–	56

Iron submicron cubes	26 vol%in wax	soft	–	>0.8	-56 dB/ 7.0–11.9 GHz (2-18 GHz)	–	–	57
PANI/$BaFe_{11}Ti_{0.5}Co_{0.5}O_{19}$	50 wt% in wax	soft	–	>0.8	-32.5 dB/ 12.1–17.5 GHz (2-18 GHz)	–	–	58
Sendust	53 vol% in PS	Robust	–	>1	-43 dB/ 31.5–37.0 GHz (1-40 GHz)	–	–	59
PANI-PTSA/Fe_3O_4	PANI–PTSA: 15wt%, Fe3O4: 10wt% in epoxy	Tough	–	>1	-37 dB/ 12-18 GHz (12-18 GHz)	–	–	60
Fe_3O_4@PEDOT	50 vol% in	soft	–	>0.8	-29 dB/	–	–	61

	wax				10.3–17.5 GHz (2-18 GHz)			
LAS/LAS–SiC double-layer	-	Tough	-	>1	-42.8 dB/ 11-17 GHz (2-18 GHz)	–	–	62
Flaky carbonyl iron	18 vol% in wax	soft	–	>0.8	-13 dB/ 10-18 GHz (2-18 GHz)	–	–	63
Ni/TiO_2	40 wt% in wax	soft	–	>0.8	-45.2 dB/ 10.2-17.5 GHz (2-18 GHz)	–	–	64
SnO_2-coatedcarbonyliron	50 wt% in wax	soft	–	>0.8	-57.8 dB/ 11.2-13.3 GHz (2-18 GHz)	–	–	65
hexagonal Fe microflakes	15 vol% in wax	soft	–	>0.8	-15.3 dB/ 12.2–16.6 GHz	–	–	66

					(2-18 GHz)			
Silica coated carbonyl iron	80 wt% in wax	soft	–	>0.8	-38.8 dB/ 8-14 GHz (2-18 GHz)	–	–	67
Hydrogenated TiO_2	60 wt% in wax	soft	–	>0.8	-	–	–	68
Nickel/Ti_3SiC_2	60wt% in epoxy	Tough	–	>1	-41.2 dB/ 8.4-11.6 GHz (8.2-12.4 GHz)	–	–	69
$Fe_{0.64}Ni_{0.36}$-$NiFe_2O_4$	50 wt% in wax	soft	–	>0.8	-24.8 dB/ 13-15 GHz (2-18 GHz)	–	–	70
Srhexaferrite/Ni ferrite	45wt% in epoxy	Tough	–	>1	-34.4 dB/ 7.5-11.4 GHz (7-12 GHz)	–	–	71
SnO_2-coated Ni	70 wt% in	soft	–	>0.8	−42.8 dB/	–	–	72

	wax				8.2-12 GHz (2-18 GHz)			
Nd-doped $BiFeO_3$	-	Tough	–	>1	-42 dB/ 8.2-10.5 GHz (8.2-12.4 GHz)	–	–	73
Fe_3O_4@CuSilicate	16.7 wt% in epoxy	Tough	–	>1	-23.5 dB/ 3.5–13.9 GHz (2-18 GHz)	–	–	74
$Co_{0.5}Zn_{0.5}Fe_2O_4$	4 wt% in PANI	–	–	>1	-40 dB/ 16.2–26.5 GHz (8–26.5 GHz)	–	–	75
AgNPs/SCF@B$T_{0.35}$	-	-	Flexible	-	-18.6 dB/ 7.8–12.0 GHz (2-18 GHz)	–	–	76
Basalt fiber@nickel	10 wt% in wax	soft	–	>0.8	-40 dB/ 8.2–12.4 GHz	–	–	77

					(8.2–12.4 GHz)			
NiO@SiC	-	Tough	-	>1	-46.9 dB/ 8.2–12.4 GHz (8.2–12.4 GHz)	–	–	78
$NiFe_2O_4$	Wax matrix	soft	–	>0.8	-24 dB/ 8.5–13.0 GHz (2-18 GHz)	–	–	79
PS@P(Py-PyCOOH)@Ni	50 wt% in wax	soft	–	>0.8	-20.06 dB/ 9.16–13.75 GHz (2-18 GHz)	–	–	80
Hollow CdSe	70 wt% in wax	soft	–	>0.8	-31 dB/ 4.0–6.6 GHz, 17.0–18.0 GHz (2-18 GHz)	–	–	81
$(Mn_{0.5}Co_{0.5})_3O_4$	16.7 wt% in epoxy	Tough	-	>1	-20.7 dB/ 7.4–10.4 GHz	–	–	82

					(2-18 GHz)			
$BaTiO_3$ nano-torus	16.7 wt% in epoxy	Tough	-	>1	-28.38 dB/ 10.1–13.1 GHz (2-18 GHz)	–	–	83
Fe_3O_4@SnO_2 nanorods	80 wt% in wax	soft	–	>0.8	-27.38 dB/ 3.6–5.4 GHz; 16.2–17.5 GHz (2-18 GHz)	–	–	84
$(BaFe_{12}O_{19}+BaTiO_3)$/PANI	66.7 wt% in epoxy	Tough	–	>1	-21.8 dB/ 20.3–22.7 GHz; 34.7–37.6 GHz (2-40 GHz)	–	–	85
Hollow glass@nickel flowers	30 vol% in wax	soft	–	>0.8	-15.5 dB/ 4.2–5.0 GHz (2-18 GHz)	–	–	86
TiN	45 wt% in	soft	–	>0.8	-27 dB/	–	–	87

	wax				6.1–7.5 GHz (2-18 GHz)			
$BaTiO_3$ nanotube	70 wt% in wax	soft	–	>0.8	-21.8 dB/ 13.3–15.0 GHz (0.5–15 GHz)	–	–	88
$BaTiO_3$ nanowire	16.7 wt% in epoxy	Tough	–	>1	-24.6 dB/ 8.0–10.4 GHz (2-18 GHz)	–	–	89
SiC nanowires	35 wt% in epoxy	Tough	–	>1	-31.7 dB/ 7.1–9.7 GHz (2-40 GHz)	–	–	90
$BaCo_{0.5}Ti_{0.5}Fe_{11}O_{19}$	50 wt% in wax	soft	–	>0.8	-24 dB/ 28.5–39.5 GHz (26.5-40 GHz)	–	–	91
$BaFe_{11}Ti_{0.5}Co_{0.5}O_{19}$	80 wt% in in silicone	Tough	–	>1	-29 dB/ 27.3–38.4 GHz	–	–	92

	rubber				(26.5-40 GHz)			
$Ba_{0.95}La_{0.05}Fe_{12}O_{19}$ nanofibers	50 wt% in wax	soft	–	>0.8	-23.02 dB/ 2–14.6 GHz (2-18 GHz)	–	–	93
L-PANI/BF	50 wt% in wax	soft	–	>0.8	-30.1 dB/ 26.5–39.3 GHz (26.5–40 GHz)	–	–	94
BFO/NZFO	67wt% in wax	soft	–	>0.8	-27 dB/ 4.9–18 GHz (2-18 GHz)	–	–	95
Dendrite-like Fe	70 wt% in wax	soft	–	>0.8	-22.5 dB/ 3.6–18.0 GHz (2-18 GHz)	–	–	96
Fe_3O_4@TiO_2	16.7wt% in epoxy	Tough	–	>1	-23.3 dB/ 2.6-18 GHz	–	–	97

					(2-18 GHz)			
Fe_3O_4@BS/BTO	16.7wt% in epoxy	Tough	–	>1	-37.6 dB/ 2-18 GHz (2-18 GHz)	–	–	98
Ni_3Ag	44.4wt% in epoxy	Tough	–	>1	-22 dB/ 7.2–16.4; 32.8–40 (2-40 GHz)	–	–	99
Patterned CIF	72.9wt% in epoxy	Tough	–	>1	-25.7 dB/ 4.2-40 GHz (2-40 GHz)	–	–	100

[a] Density of typical matrices: wax: 0.8~0.9g/cm^3; polymers: 0.9~2.0 0.8~0.9g/cm^3(nitrile butadiene rubber (NBR):~1.0 g/cm^3; poly(dimethyl siloxane) (PDMS): 1.04 g/cm^3; epoxy:~1.1 g/cm3; polyvinylidenefluoride (PVDF):~1.8 g/cm^3;poly(methyl methacrylate) (PMMA):~1.2 g/cm^3; polyaniline (PANI): ~1.36 g/cm^3; poly-(ethylene oxide) (PEO): ~1.2 g/cm^3;Polystyrene (PS): ~1g/cm^3; polyurethane (PU): ~1.2 g/cm^3); Silica: 2.2g/cm^3.

[b] The measurement was based on the arch method and the absorption performance was achieved directly from the measurement, rather than the calculation.

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