Microwave Absorbing Properties of Heat Reduced Graphene Oxide/Fe_3O_4/Epoxy Hybrid Composites

Hsien-Kuang Liu[1], Ruey-Bin Yang[2], and Y. S. Wu[3]

[1,3]Department of Mechanical and Computer Aided Engineering, [2]Department of Aerospace and Systems Engineering, Feng Chia University, Taichung 407, **Taiwan, R.O.C.**

07/30~08/04/2023 Presented at
TWENTY-THIRD INTERNATIONAL CONFERENCE ON COMPOSITE MATERIALS (ICCM23)

ICCM 23
BELFAST 2023

Outline

- Introduction
- Literature reviews
- Experimental procedures
- Results and discussion
- Conclusions

Introduction

a. Preface

b. Objectives

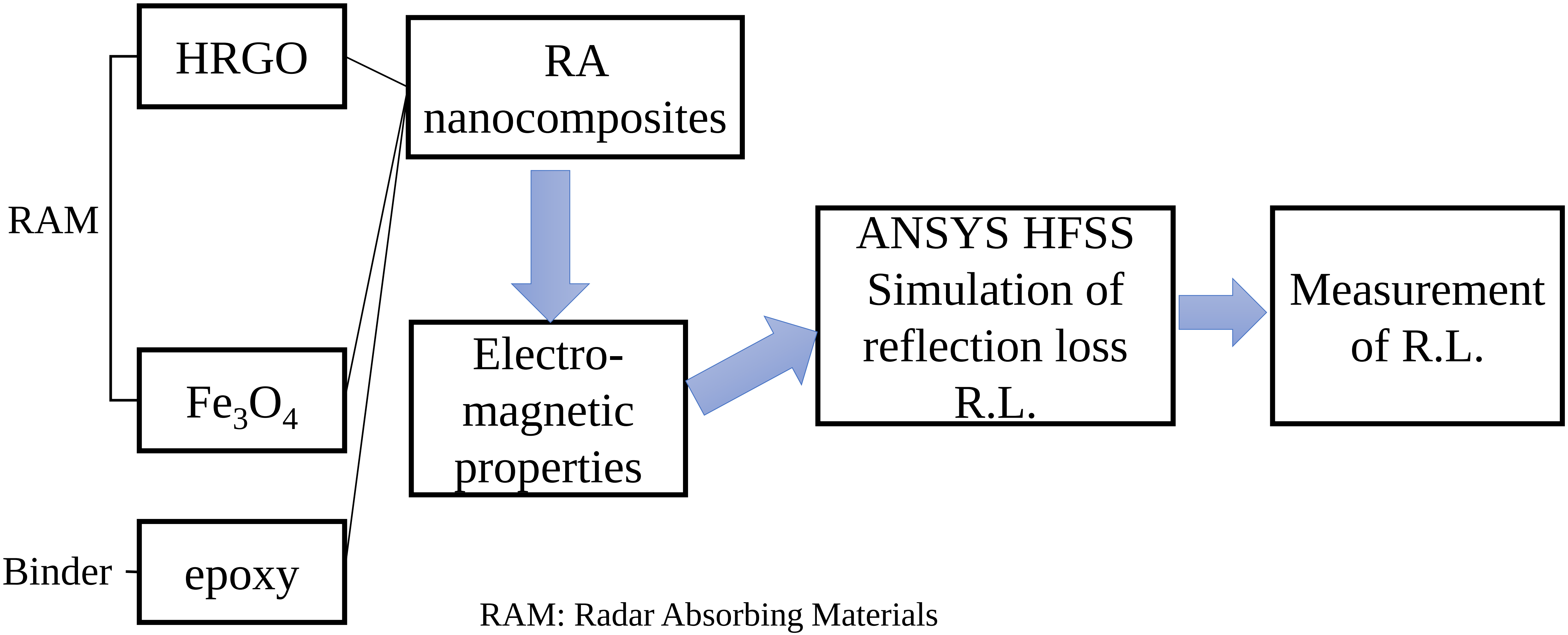
a. Preface

Commericals

EMI

Military

b. Objectives

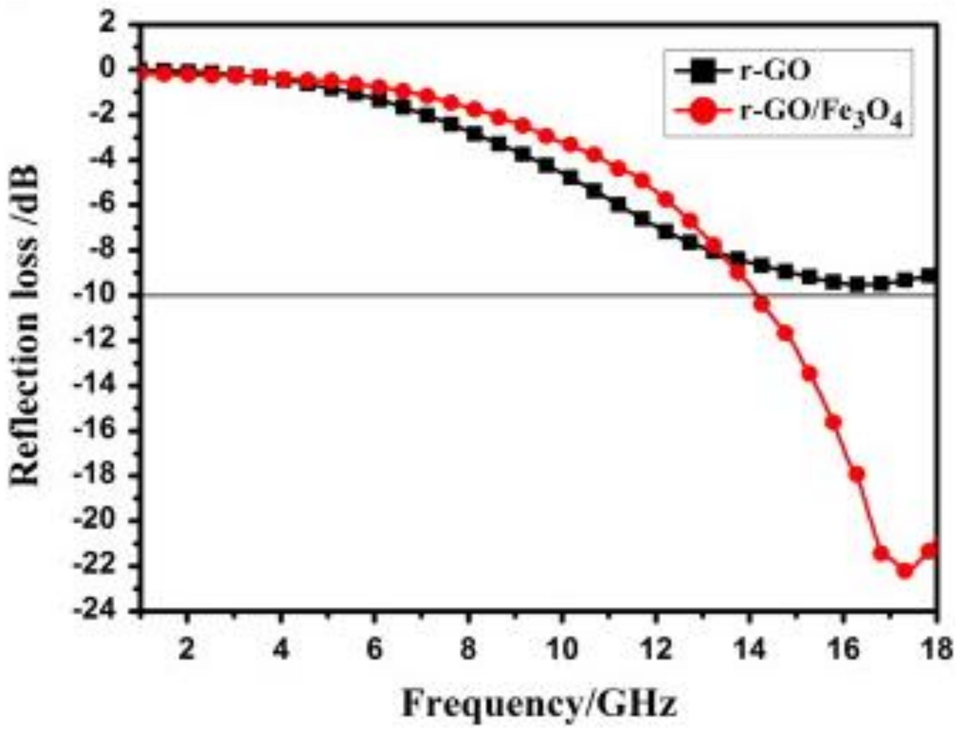


RAM: Radar Absorbing Materials

Literature reviews

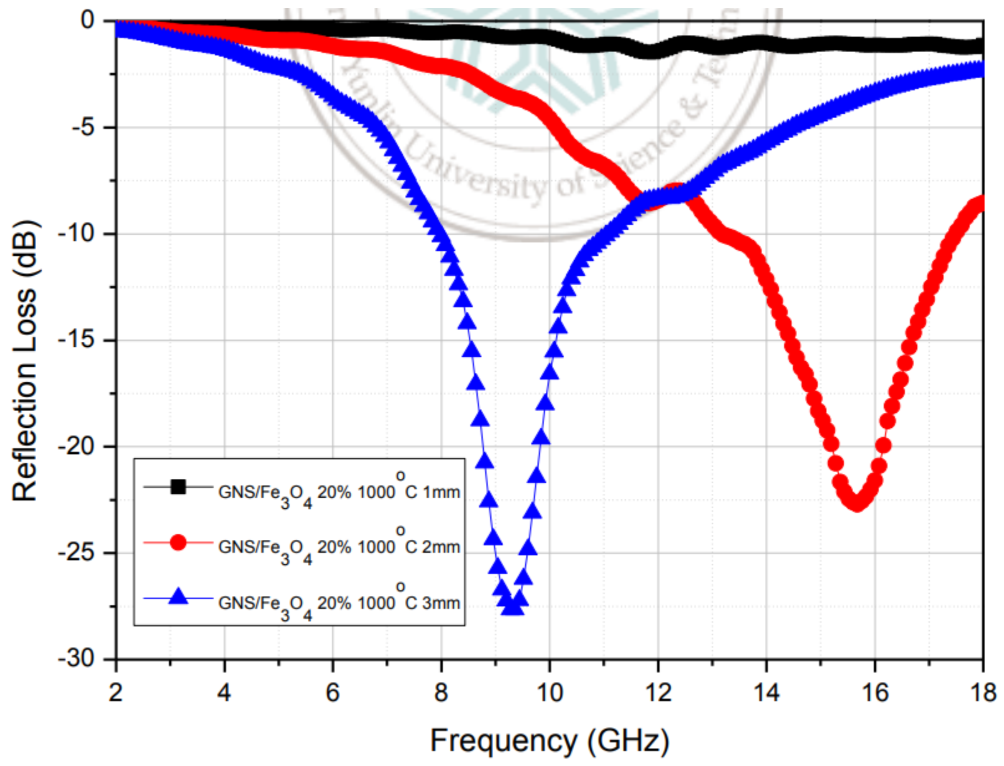
Microwave absorbing applications (1/4)

- Ma et al., 2013
- SDS and SDBS were mixed with GO and Fe_3O_4 and high temperature reduced as RGO/Fe_3O_4 by flowing hydrogen and Ar.
- For 2 mm thickness specimen, R.L. of RGO is only -10 dB; while R.L. of RGO/Fe_3O_4 is -22.2 dB at 17.3 GHz



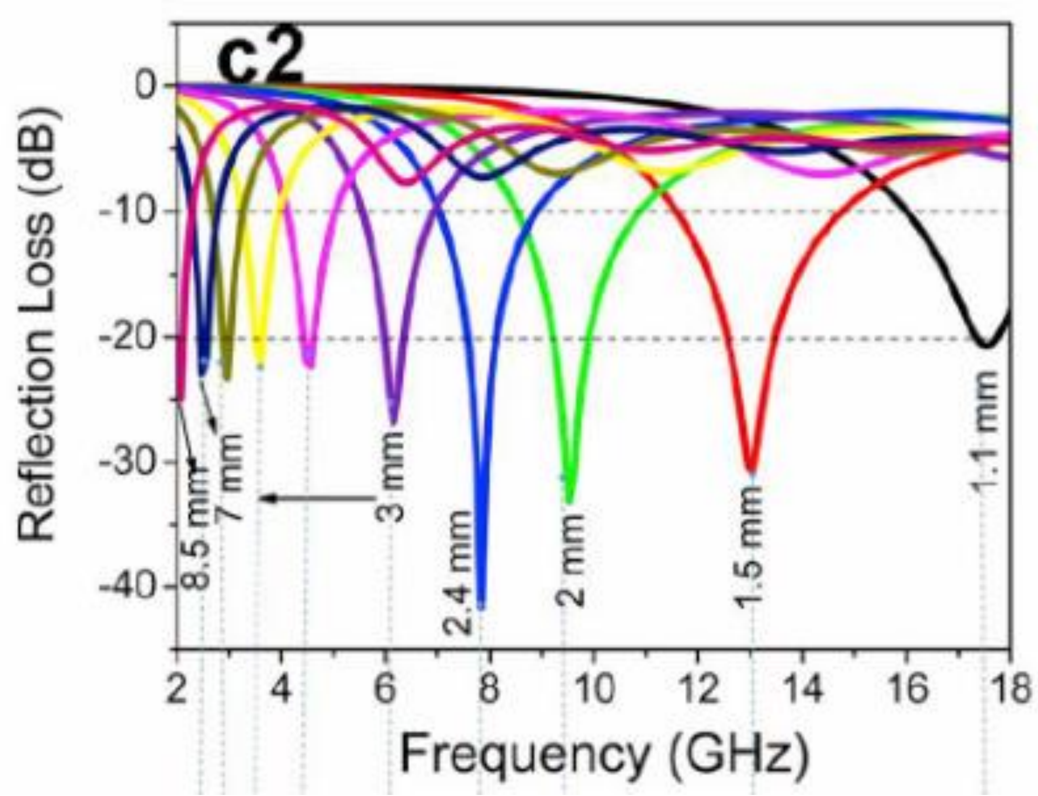
Microwave absorbing applications (2/4)

- Yeh et al., 2014
- GNS/Fe_3O_4/SEBS composites were fabricated by heat reduction and chemical grafted methods.
- 3 mm thick heat reduced 20% GNS/Fe_3O_4 composites have -27.65 dB R.L. at 9.36 GHz.



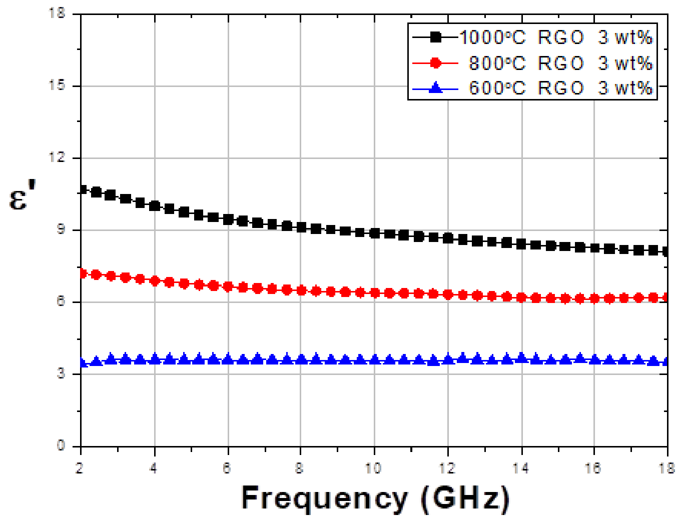
Microwave absorbing applications (3/4)

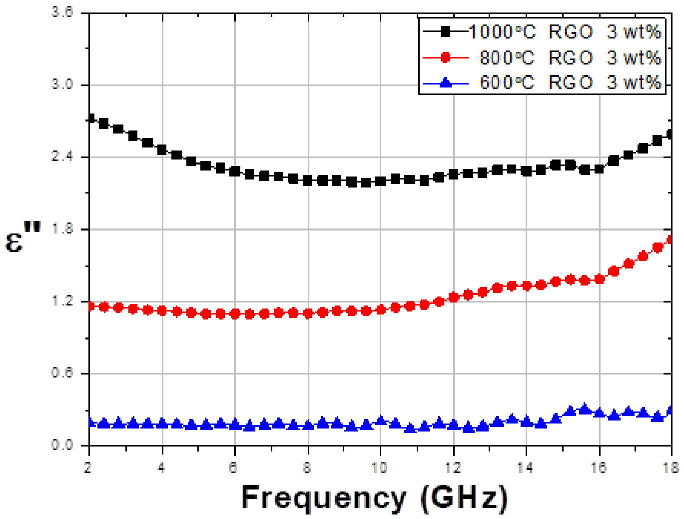
- Liu et al., 2018
- CVD was used to fabricate EG/Fe/Fe_3O_4 composites.
- EG/Fe/Fe_3O_4 achieved better R.L. than raw EG.
- The 2.4 mm thick composite has R.L. of −41.6 dB at 7.8 GHz.

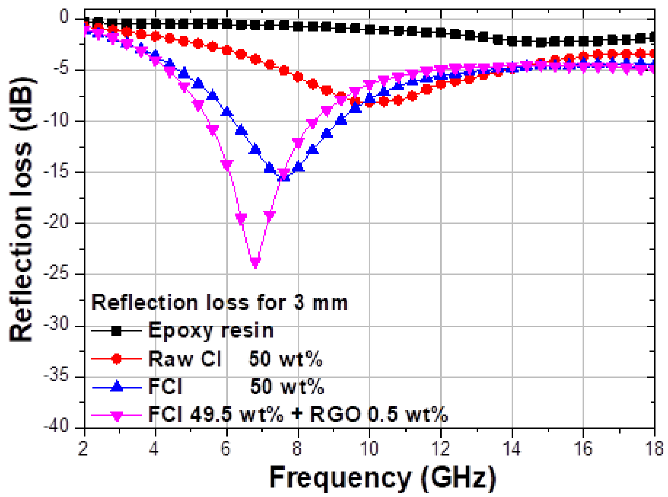


Microwave absorbing applications (4/4)

- ◆ HK Liu, 2017
- ◆ HRGO was achieved by heat reduction method and complex permittivity is proportional to temperature.
- ◆ With same weight fraction, ball milled FCl/RGO has better complex permittivity and R.L. than those of raw FCl/RGO.





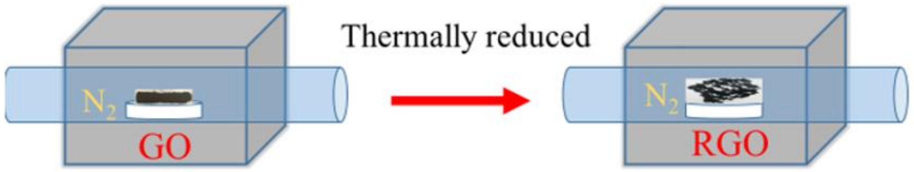


Experimental procedures

1. Fabrication of HRGO
2. Fabrication of radar absorbing nanocomposites
3. Measurement of electromagnetic properties

Fabrication of HRGO

1. 5-gram GO was placed into Lindberg Blue/M UP-150 tube furnace
2. Apply vacuum, and keep nitrogen flow in the furnace
3. Heat the GO at 1000°C for 1 hr and cool



GO

tube furnace

HRGO

Fabrication of radar absorbing nanocomposites

HRGO/ Fe_3O_4

control weight fraction

epoxy resin

heat at 60°C for 10 min

add 1 ml acetone as dispersant

mixing

5 min sonication for uniform dispersion

vacuum to remove air bubble

heat to remove acetone

add hardener and mix

resin:hardener 2:1

vacuum to remove air bubble

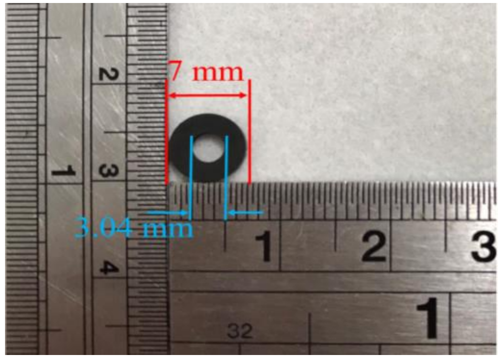
molding as donut shape

curing at 80°C/90 min

polishing

donut composite

donut composite



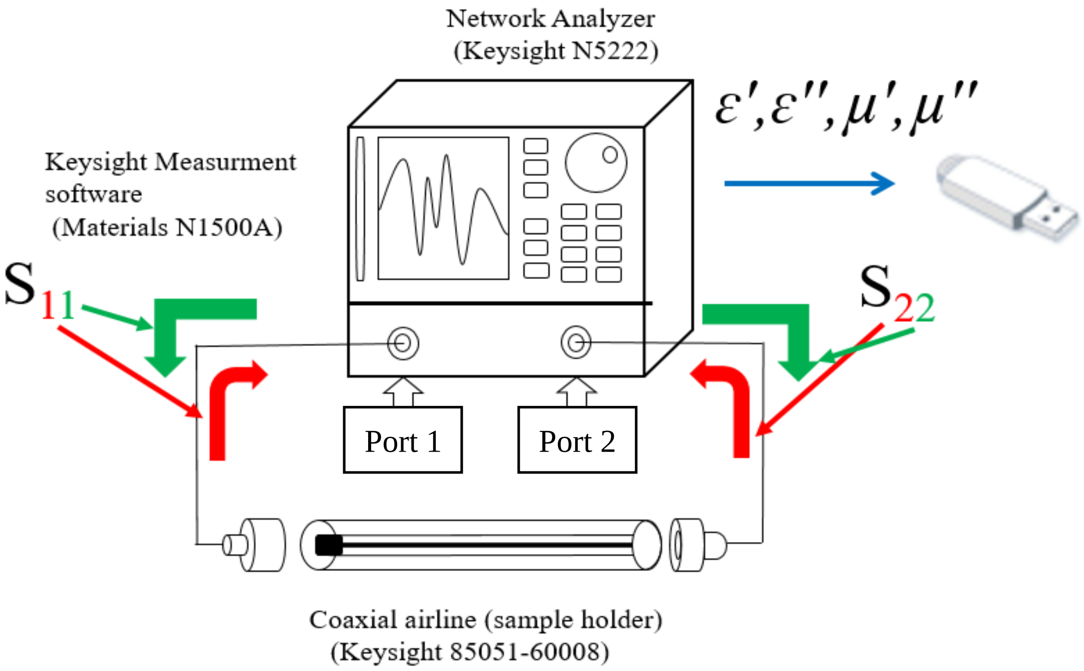
Composition of nanocomposites

Type \ Material	HRGO	Fe_3O_4	Epoxy
1、HRGO	1 wt%	-	99 wt%
	2 wt%	-	98 wt%
	3 wt%	-	97 wt%
2、HRGO+Fe_3O_4	-	40 wt%	60 wt%
	0.3 wt%	39.7 wt%	
	0.5 wt%	39.5 wt%	
	0.7 wt%	39.3 wt%	
	0.9 wt%	39.1 wt%	

Measurement of electromagnetic properties

1. Using software Keysight Materials N1500A
2. Calibrate Port 1 and Port 2 on MMS
3. Calibrate using air and teflon
4. Measurement

Materials Measurement System



Coaxial waveguide MMS

Results and discussion

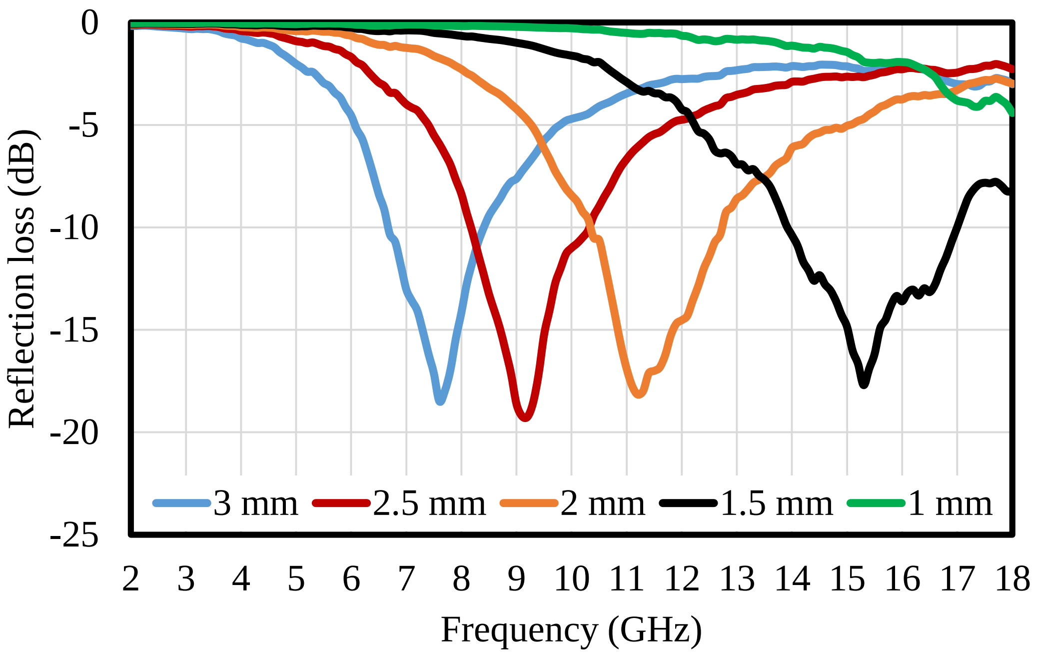
1. Absorbing performance of HRGO/epoxy nanocomposites

2. Absorbing performance of HRGO/ Fe_3O_4 /epoxy nanocomposites

3. Microstructure analysis

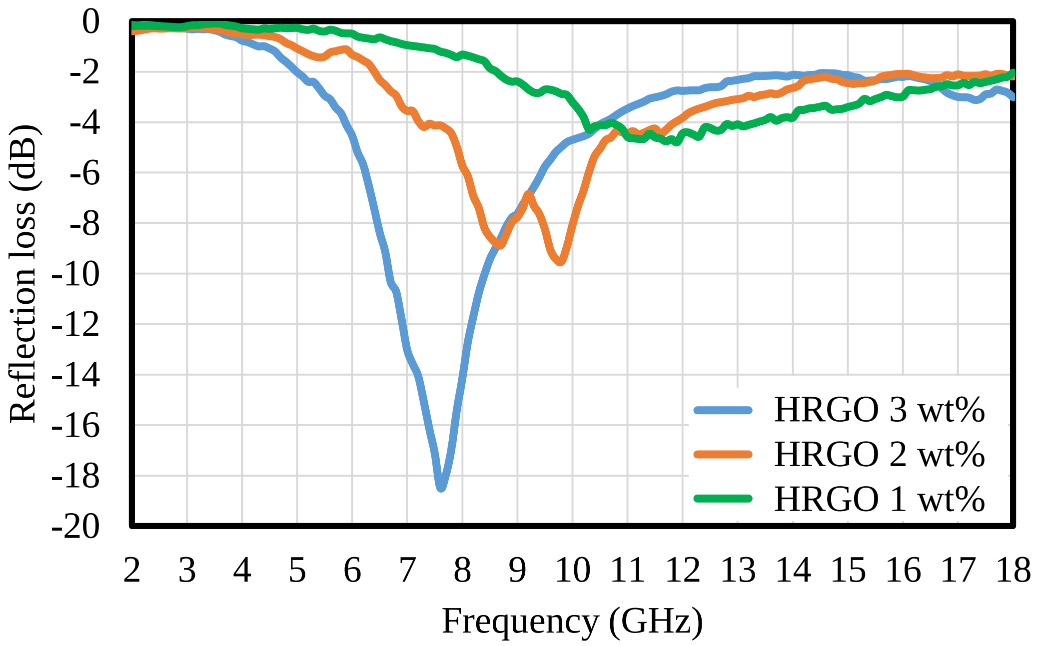
1. Absorbing performance of HRGO/epoxy nanocomposites

Thickness effect on R.L. simulation of HRGO (3 wt%)/epoxy nanocomposites



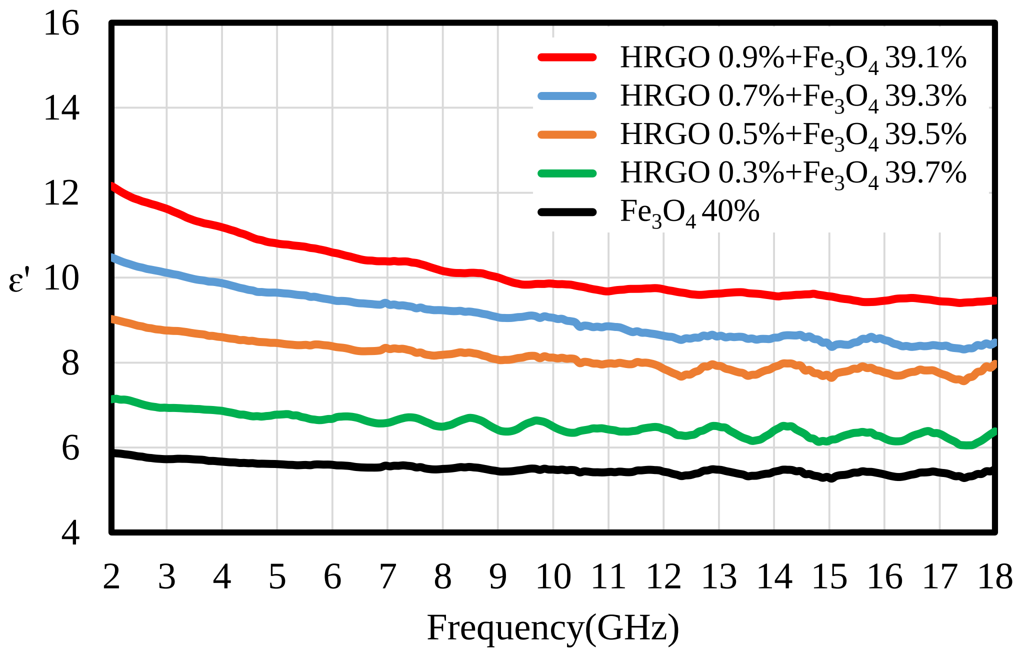
Thickness (mm)	Frequency (GHz)	R.L. (dB)	−10 dB bandwidth (GHz)
1	-	-	-
1.5	15.3	−17.70	3.0
2	11.2	−18.17	2.4
2.5	9.2	−19.24	2.2
3	7.6	−18.50	1.8

Effect of HRGO weight fraction on R.L. of 3 mm thick HRGO/epoxy

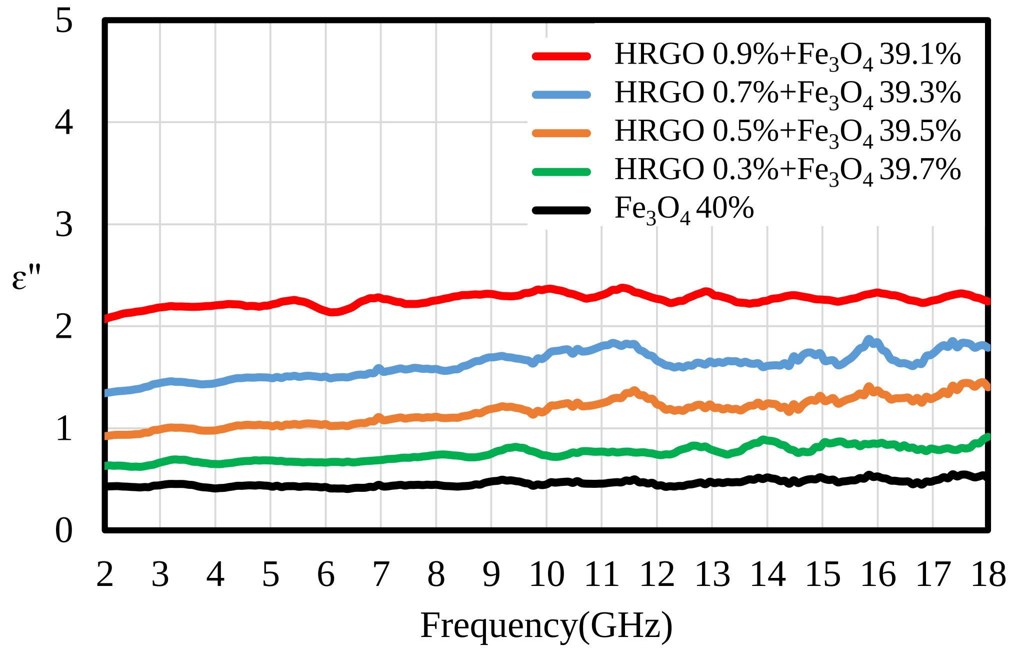


2. Microwave absorbing performance of HRGO/ Fe_3O_4/epoxy annocomposites

Electromagnetic properties of HRGO/Fe_3O_4/epoxy (1/2)

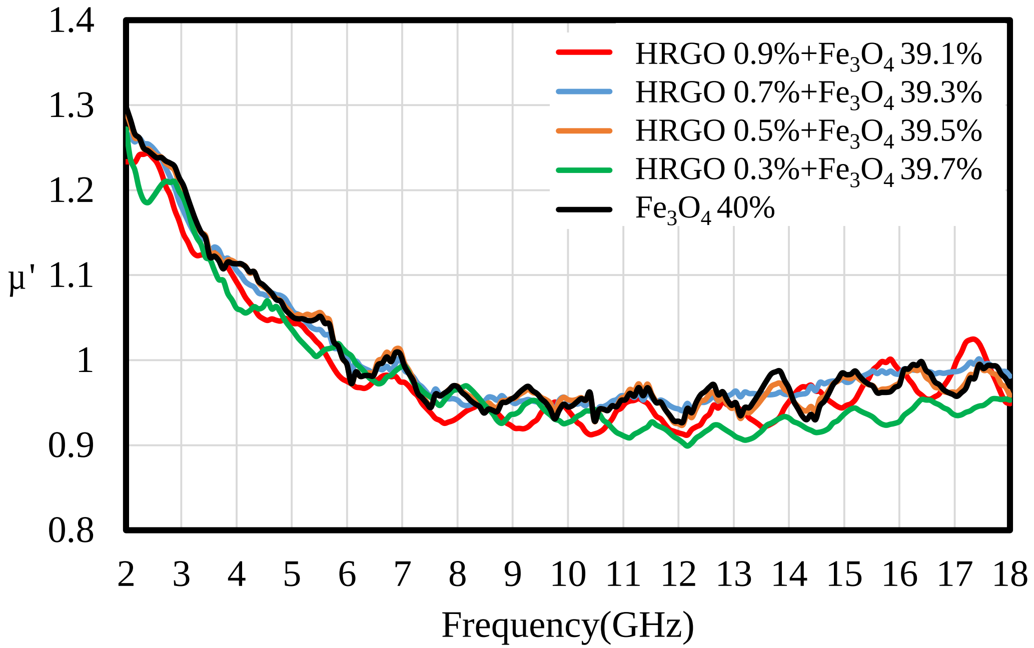


HRGO/Fe_3O_4 weight fraction effect on complex permittivity ε'

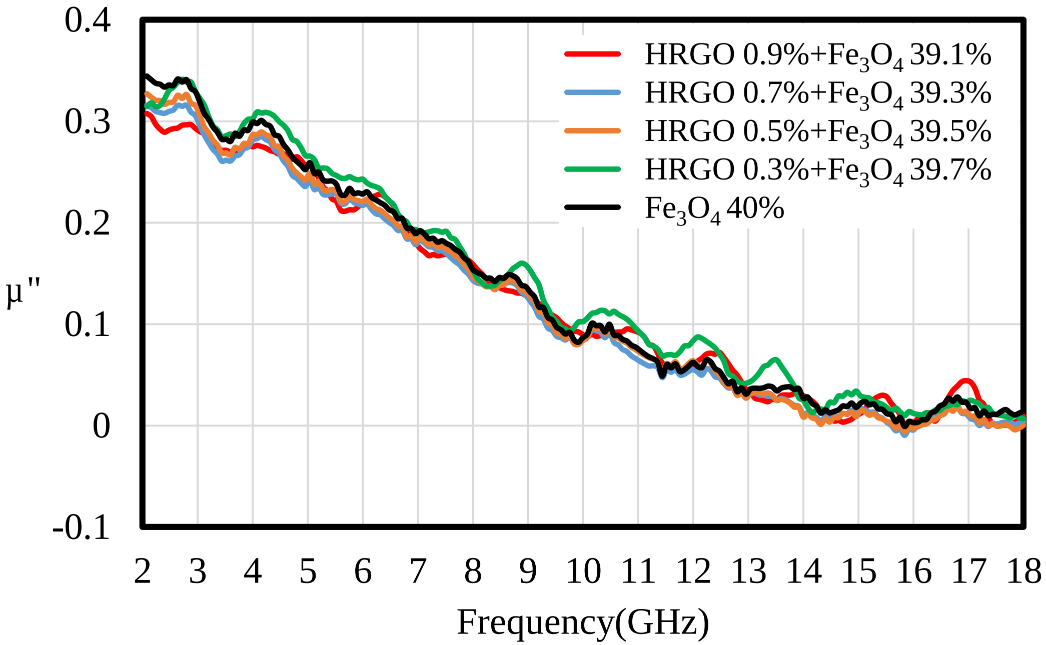


HRGO/Fe_3O_4 weight fraction effect on complex permittivity ε''

Electromagnetic properties of HRGO/Fe_3O_4/epoxy (2/2)

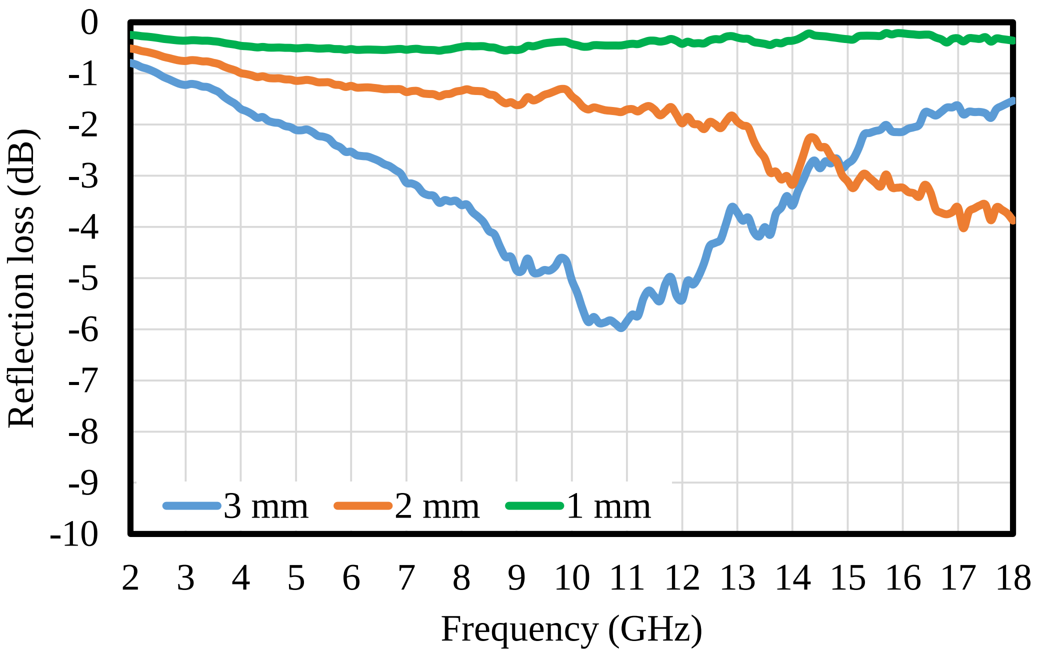


HRGO/Fe_3O_4 weight fraction effect on complex permeability μ’



HRGO/Fe_3O_4 weight fraction effect on complex permeability μ’’

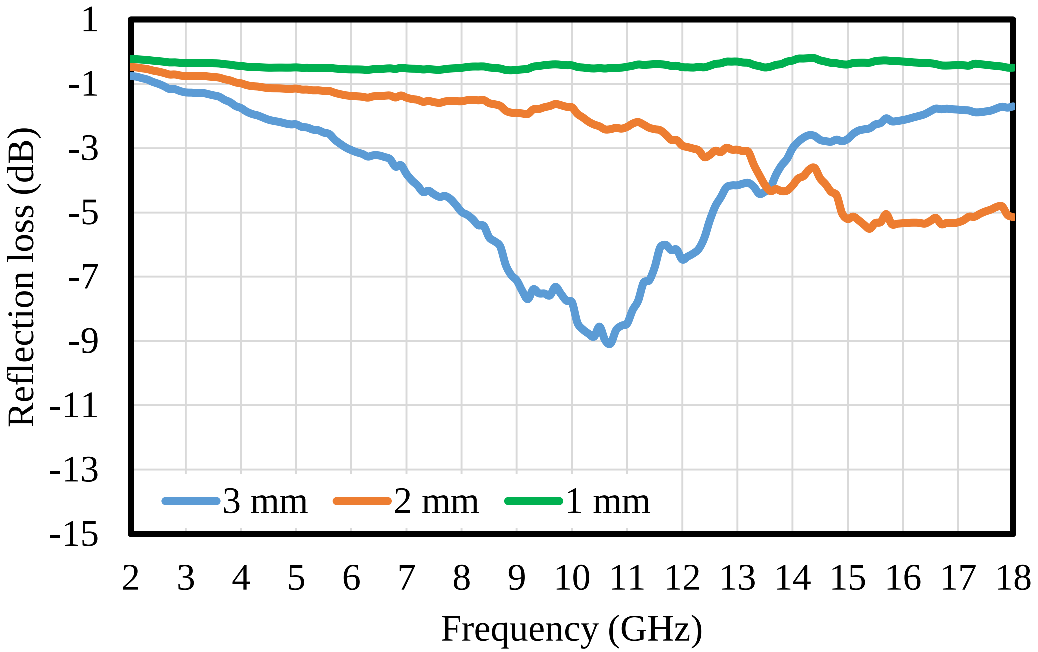
R.L. simulation of HRGO/Fe_3O_4/epoxy (1/5)



Thickness (mm)	Frequency (GHz)	R.L. (dB)	−10 dB bandwidth (GHz)
1	-	-	-
2	-	-	-
3	10.9	−5.98	-

Thickness effect on R.L. of Fe_3O_4(40 wt%)/epoxy

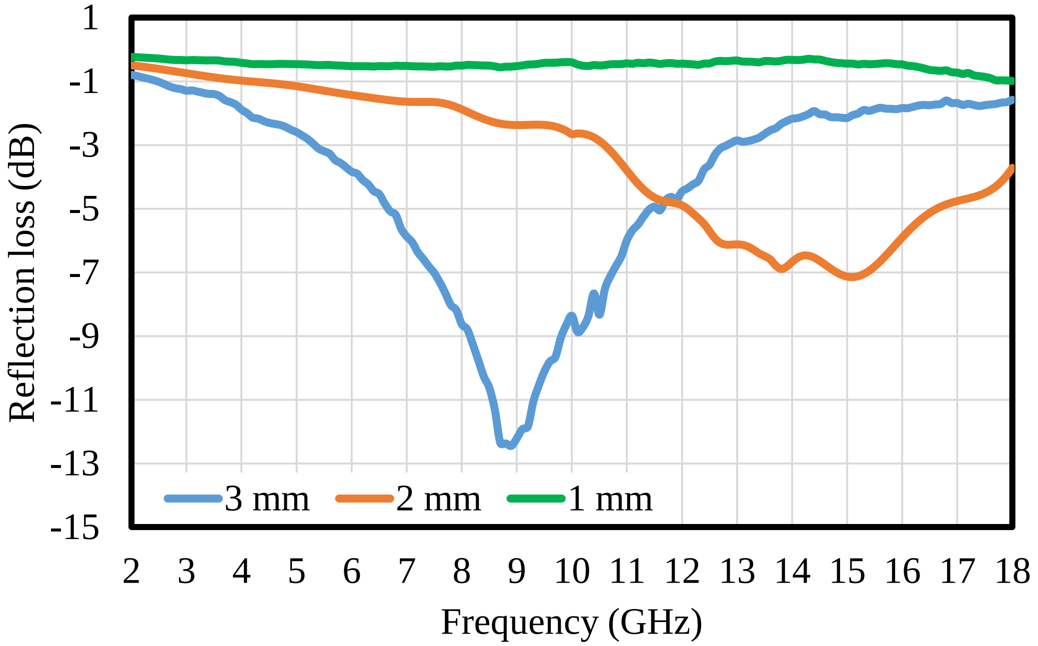
R.L. simulation of HRGO/Fe_3O_4/epoxy (2/5)



Thickness (mm)	Frequency (GHz)	R.L. (dB)	−10 dB bandwidth (GHz)
1	-	-	-
2	-	-	-
3	10.7	−9.08	-

Thickness effect on R.L. of HRGO (0.3 wt%)/Fe_3O_4 (39.7 wt%)/epoxy

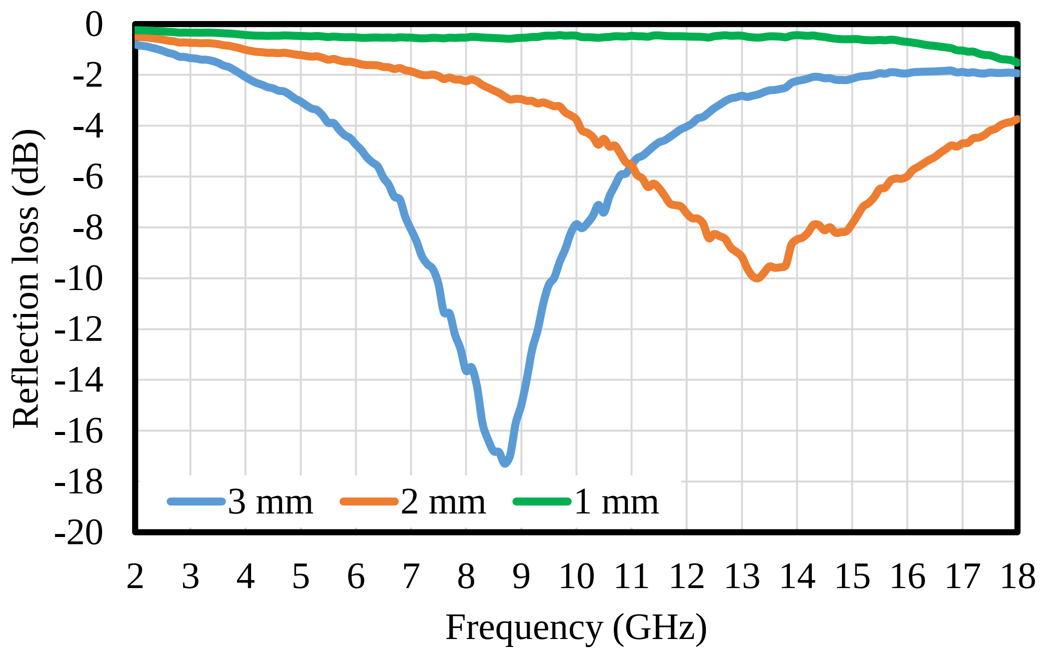
R.L. simulation of HRGO/Fe_3O_4/epoxy (3/5)



Thickness effect on R.L. of HRGO (0.5 wt%)/Fe_3O_4 (39.5 wt%)/epoxy

Thickness (mm)	Frequency (GHz)	R.L. (dB)	−10 dB bandwidth (GHz)
1	-	-	-
2	15.1	-7.15	-
3	8.9	-12.44	1.2

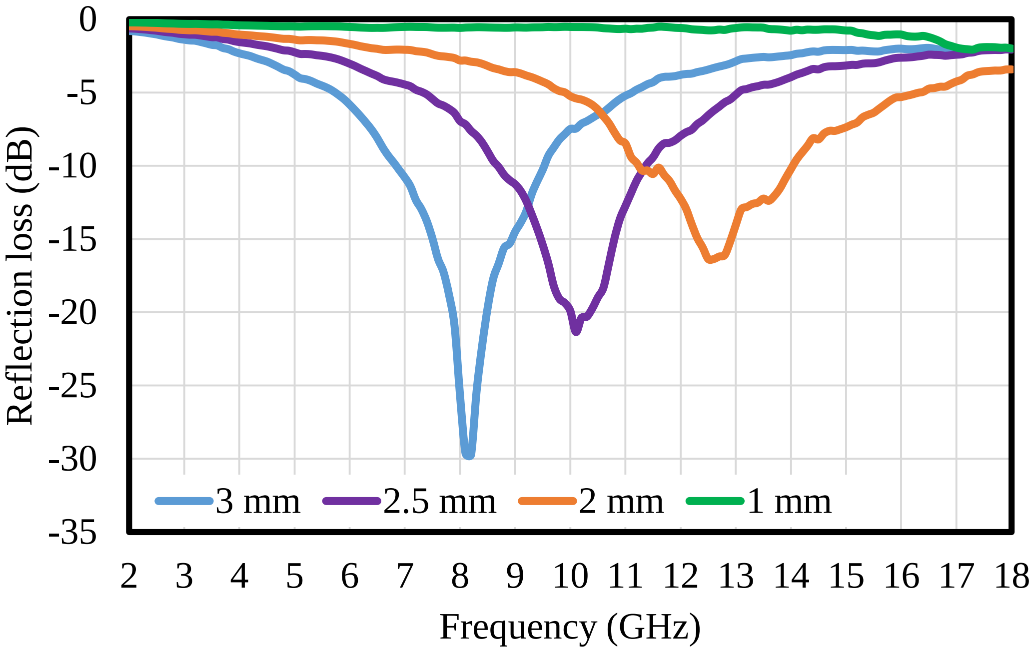
R.L. simulation of HRGO/Fe_3O_4/epoxy (4/5)



Thickness effect on R.L. of HRGO (0.7 wt%)/Fe_3O_4 (39.3 wt%)/epoxy

Thickness (mm)	Frequency (GHz)	R.L. (dB)	−10 dB bandwidth (GHz)
1	-	-	-
2	13.3	−10	-
3	8.7	−17.29	2.1

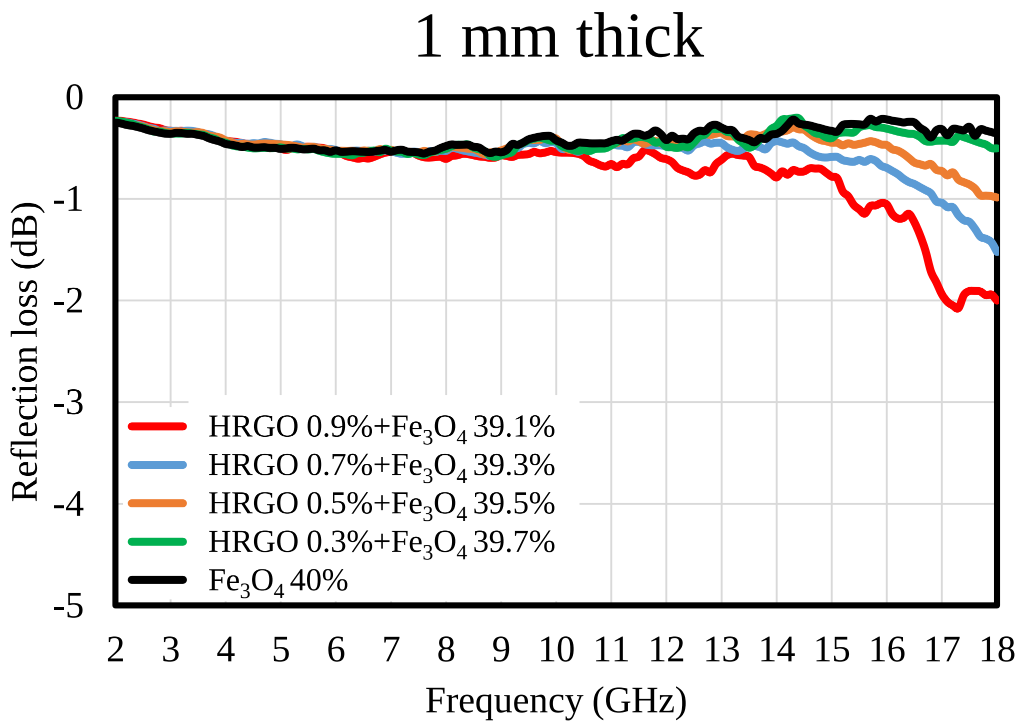
R.L. simulation of HRGO/Fe_3O_4/epoxy (5/5)



Thickness (mm)	Frequency (GHz)	R.L. (dB)	−10 dB bandwidth (GHz)
1	-	-	-
2	12.6	−16.36	2.7
2.5	10.1	−21.35	2.7
3	8.2	−29.74	2.7

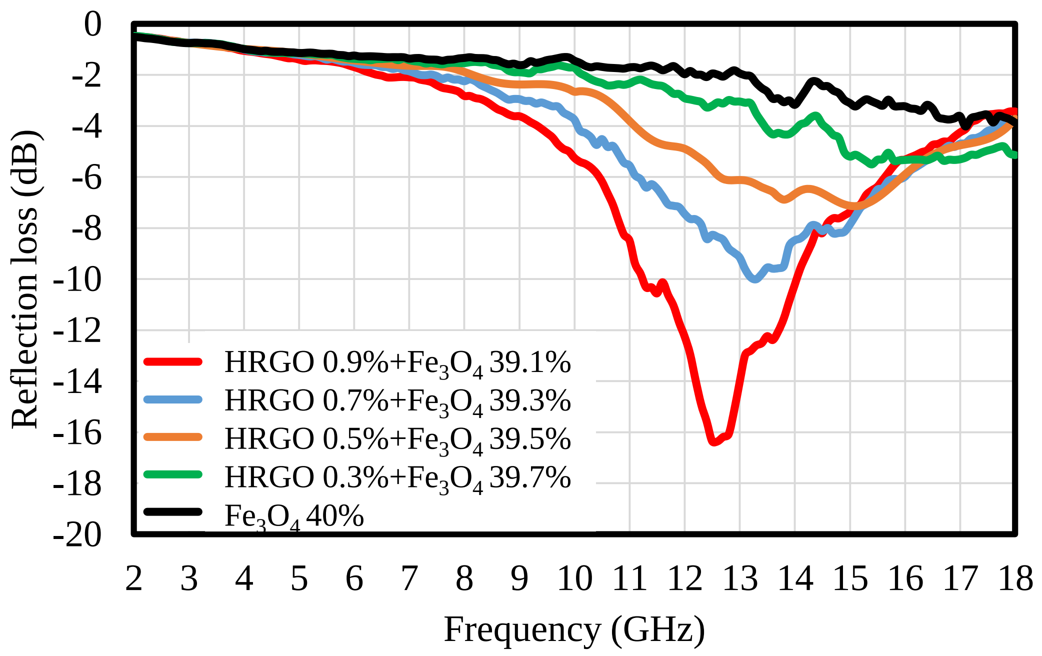
Thickness effect on R.L. of HRGO (0.9 wt%)/Fe_3O_4 (39.1 wt%)/epoxy

Weight fraction effect on R.L. of HRGO/Fe_3O_4/epoxy (1/3)

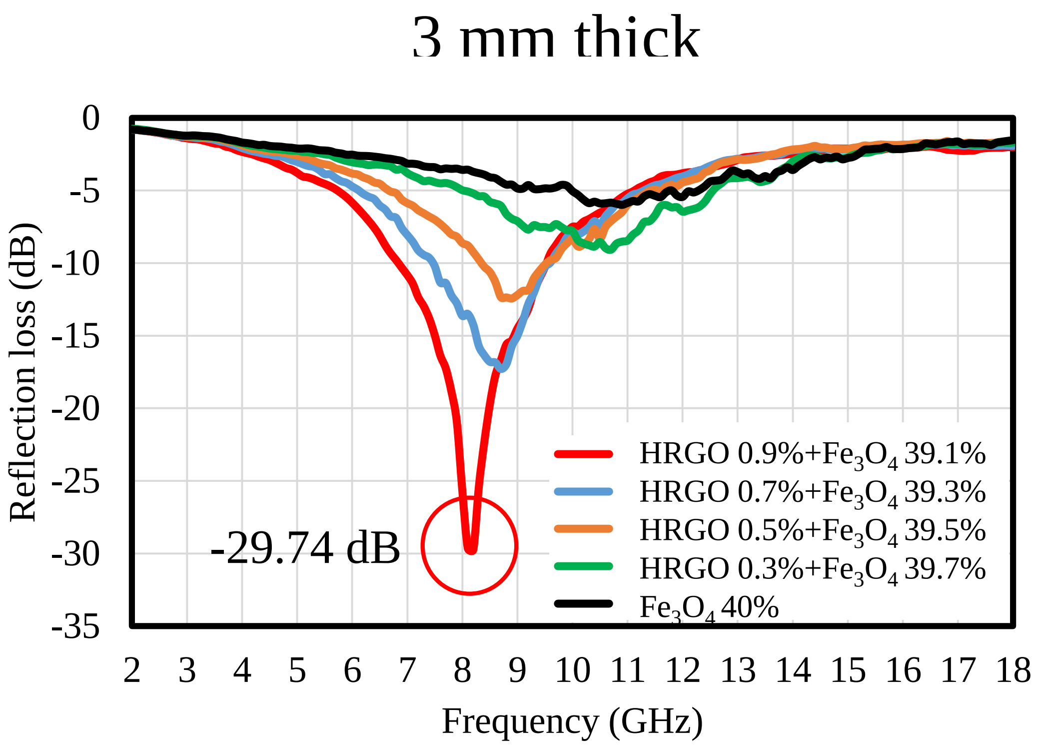


Weight fraction effect on R.L. of HRGO/Fe_3O_4/epoxy (2/3)

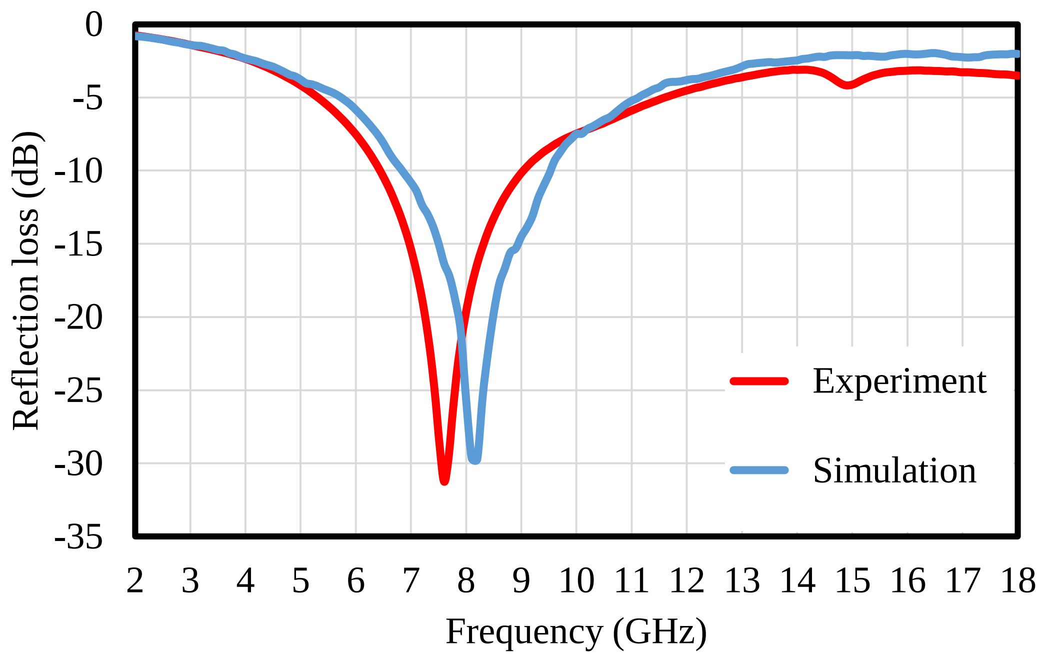
2 mm thick



Weight fraction effect on R.L. of HRGO/Fe_3O_4/epoxy (3/3)



Simulation and experimental results comparison

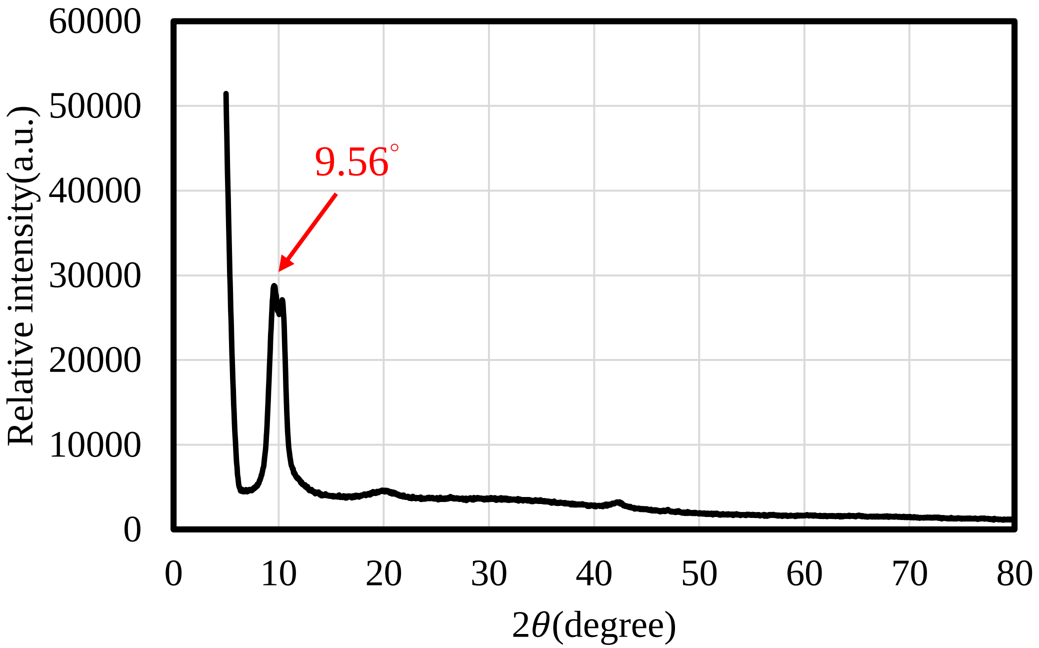


RLs of 3 mm thick HRGO (0.9 wt%)/Fe_3O_4 (39.1 wt%)/epoxy

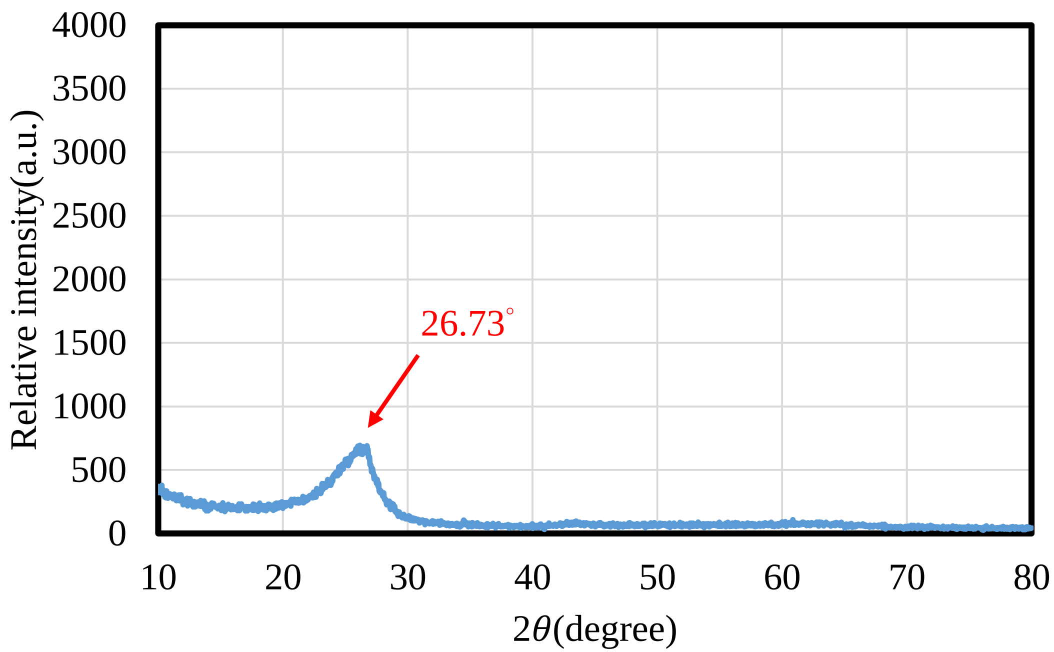
	Frequency (GHz)	**R.L. (dB)**	**−10 dB bandwidth (GHz)**
Experiment	7.6	−31.25	2.6
Simulation	8.2	−29.74	2.7
Difference	0.6	1.51	0.1

3. Microstructure analysis

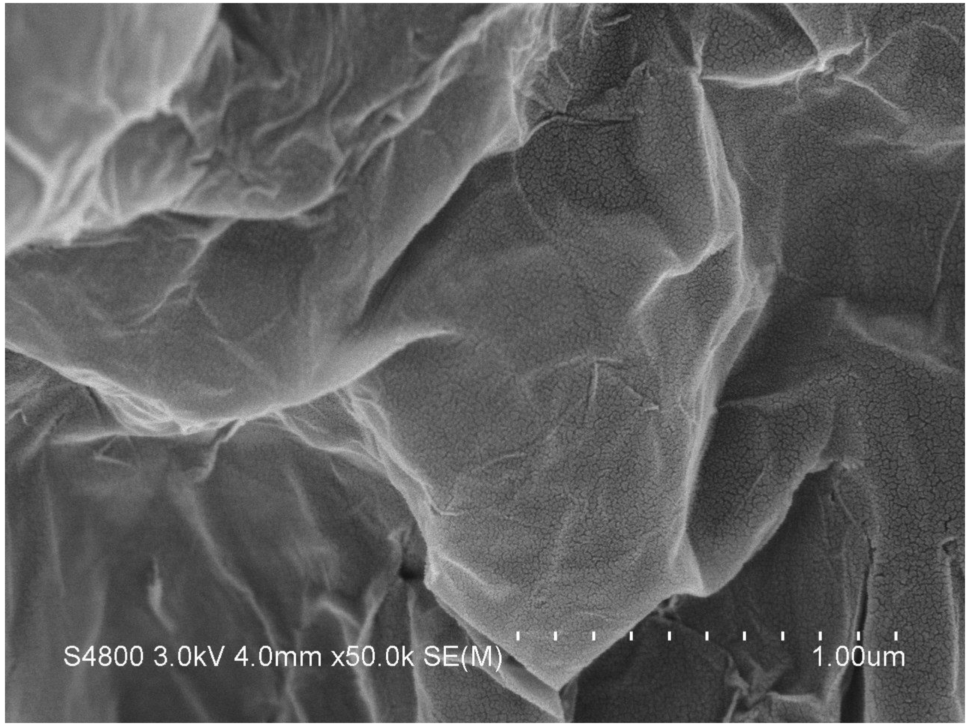
XRD analysis of GO



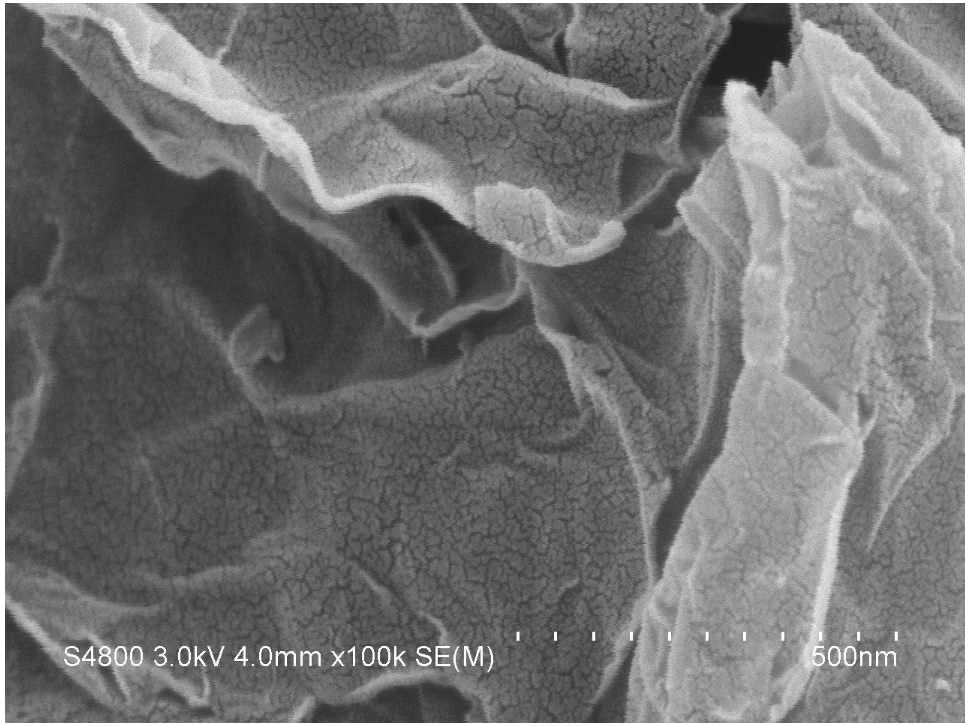
XRD analysis of HRGO



SEM of HRGO

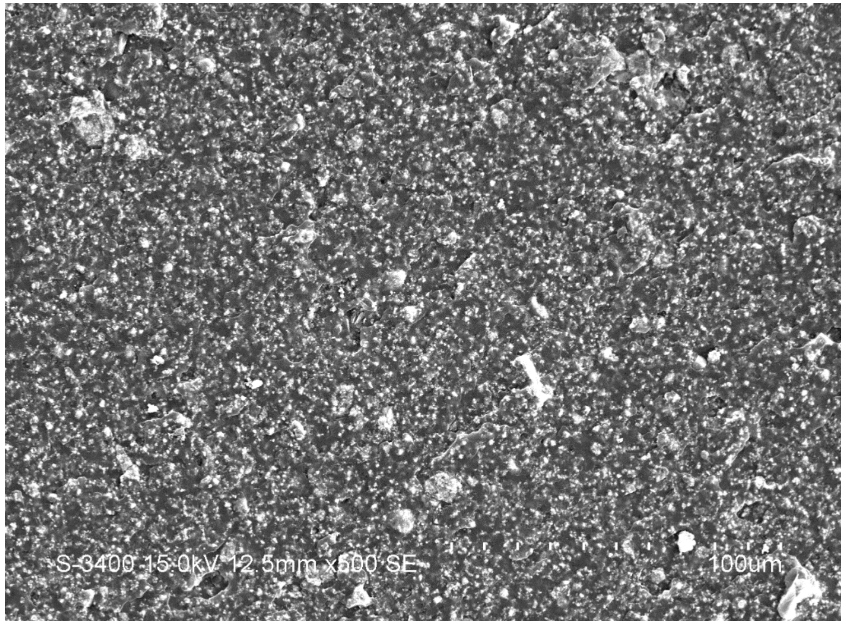


5×10^4 times

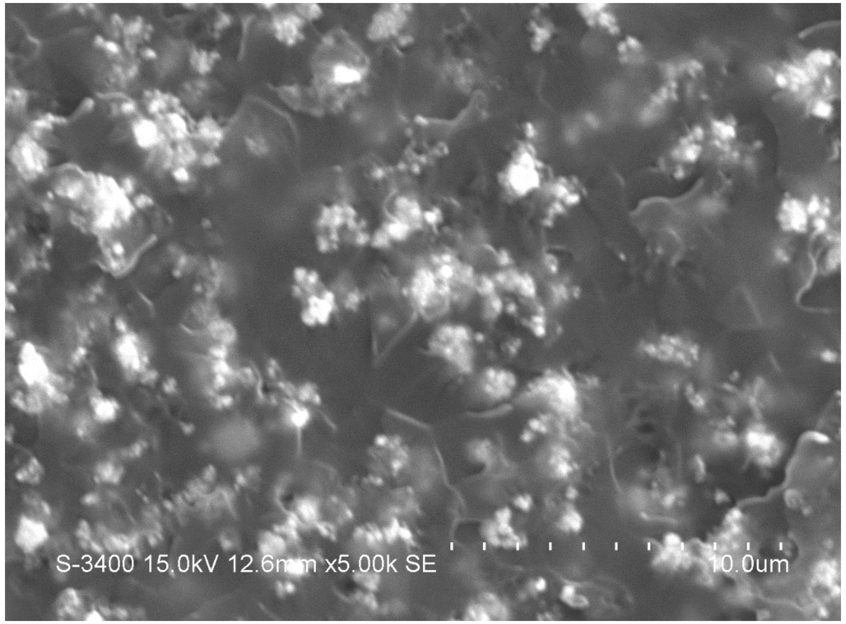


10^5 times

SEM of Fe_3O_4 (40 wt%)/epoxy

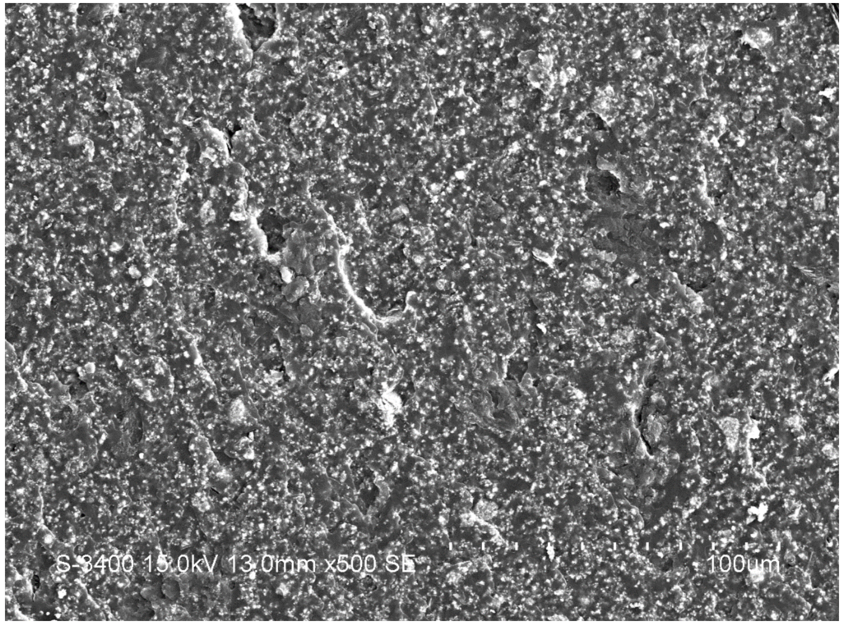


500 times

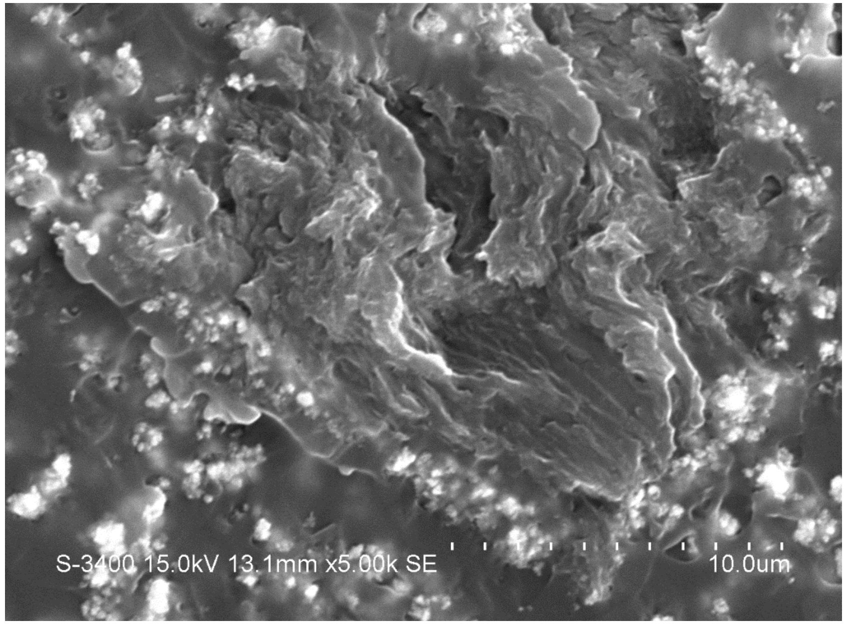


5000 times

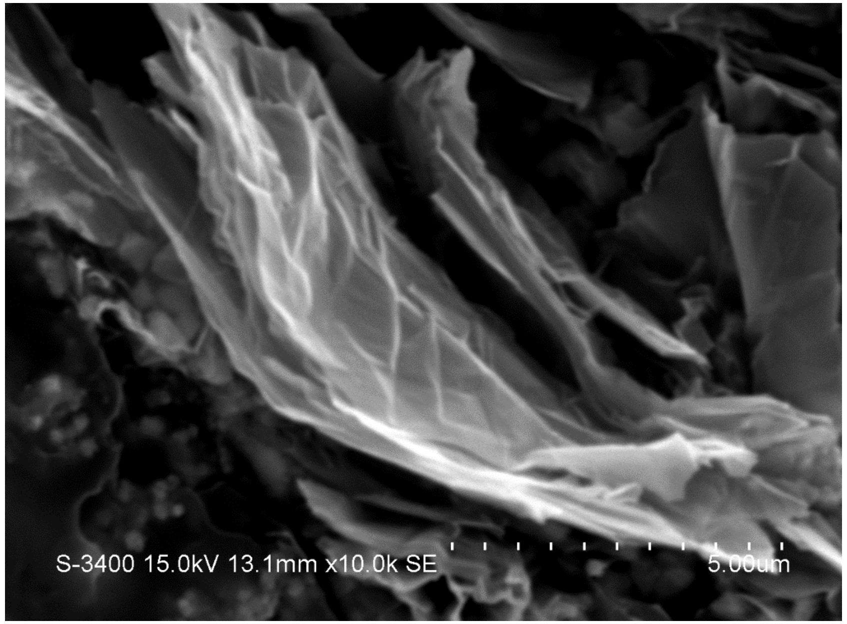
SEM of HRGO (0.3 wt%)/Fe_3O_4 (39.7 wt%)/epoxy



500 times

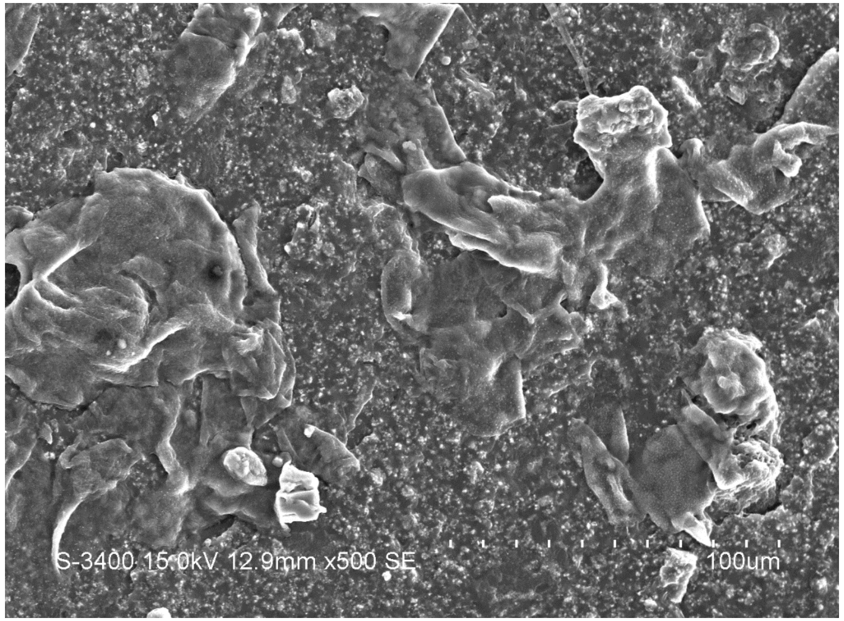


5000 times

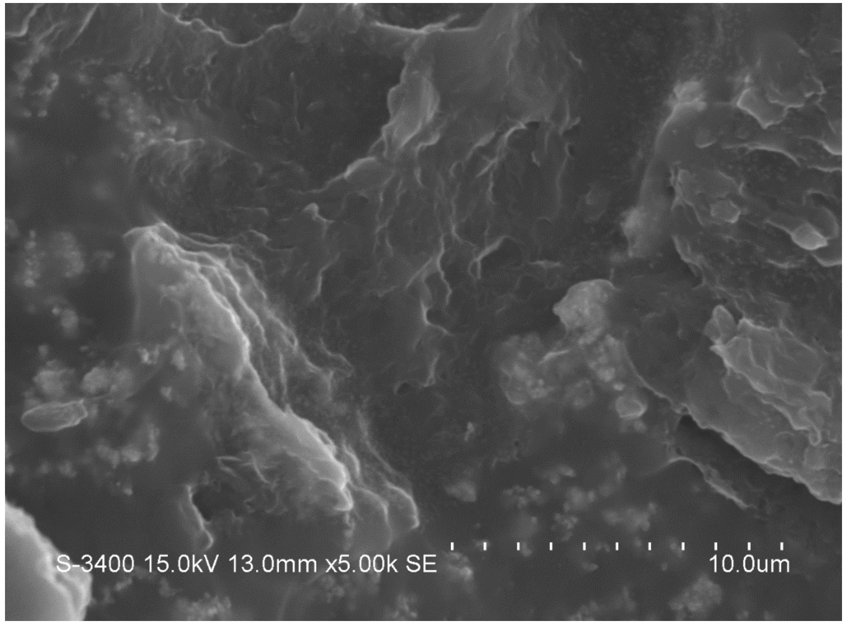


10^4 times

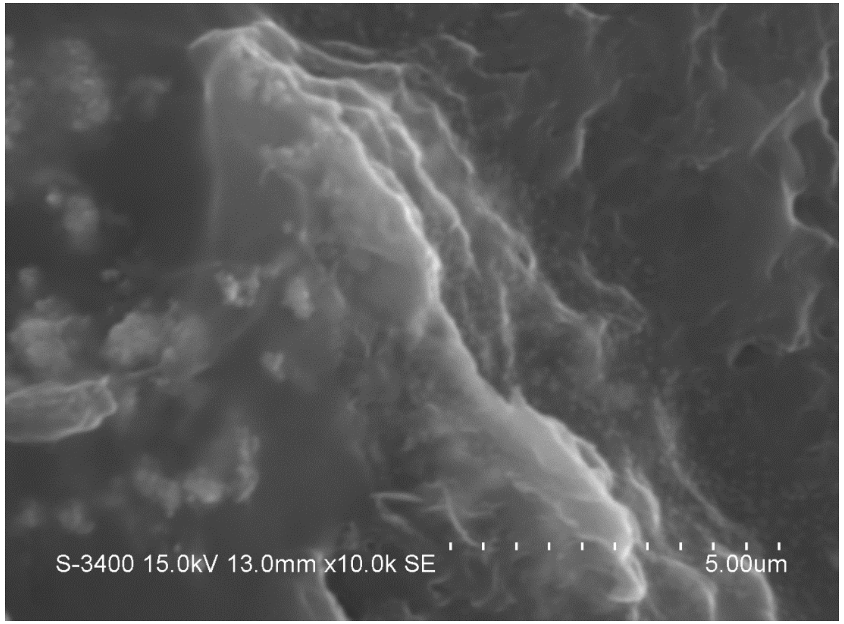
SEM of HRGO (0.9 wt%)/Fe_3O_4 (39.1 wt%)/epoxy



500 times



5000 times



1×10^4 times

Conclusions

Conclusions

1. For the HRGO/Fe_3O_4/epoxy nanocomposite, complex permittivity and reflection loss increase with the increase of HRGO weight fraction.

2. 3 mm thick HRGO (0.9 wt%)/Fe_3O_4 (39.1 wt%)/epoxy has best reflection loss of −29.74 dB at 8.2 GHz and bandwidth of 2.7 GHz; while for 3 mm thick HRGO (3.0 wt%)/ epoxy, the RL -18.5 dB is lower and bandwidth is 1.8 GHz.

3. Correlation between simulation and experimental results is close indicating that the simulation is correct.

Thank you for your attention