Electronic Supplementary Information

Particle size effect on millimeter-wave absorption, rotation, and ellipticity of gallium-substituted epsilon iron oxide

Shoma Shimizu, Asuka Namai,* Shin-ichi Ohkoshi*

Department of Chemistry, School of Science, The University of Tokyo,

7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan

*To whom correspondence should be addressed
E-mail: asuka@chem.s.u-tokyo.ac.jp, ohkoshi@chem.s.u-tokyo.ac.jp

Contents: **Page**

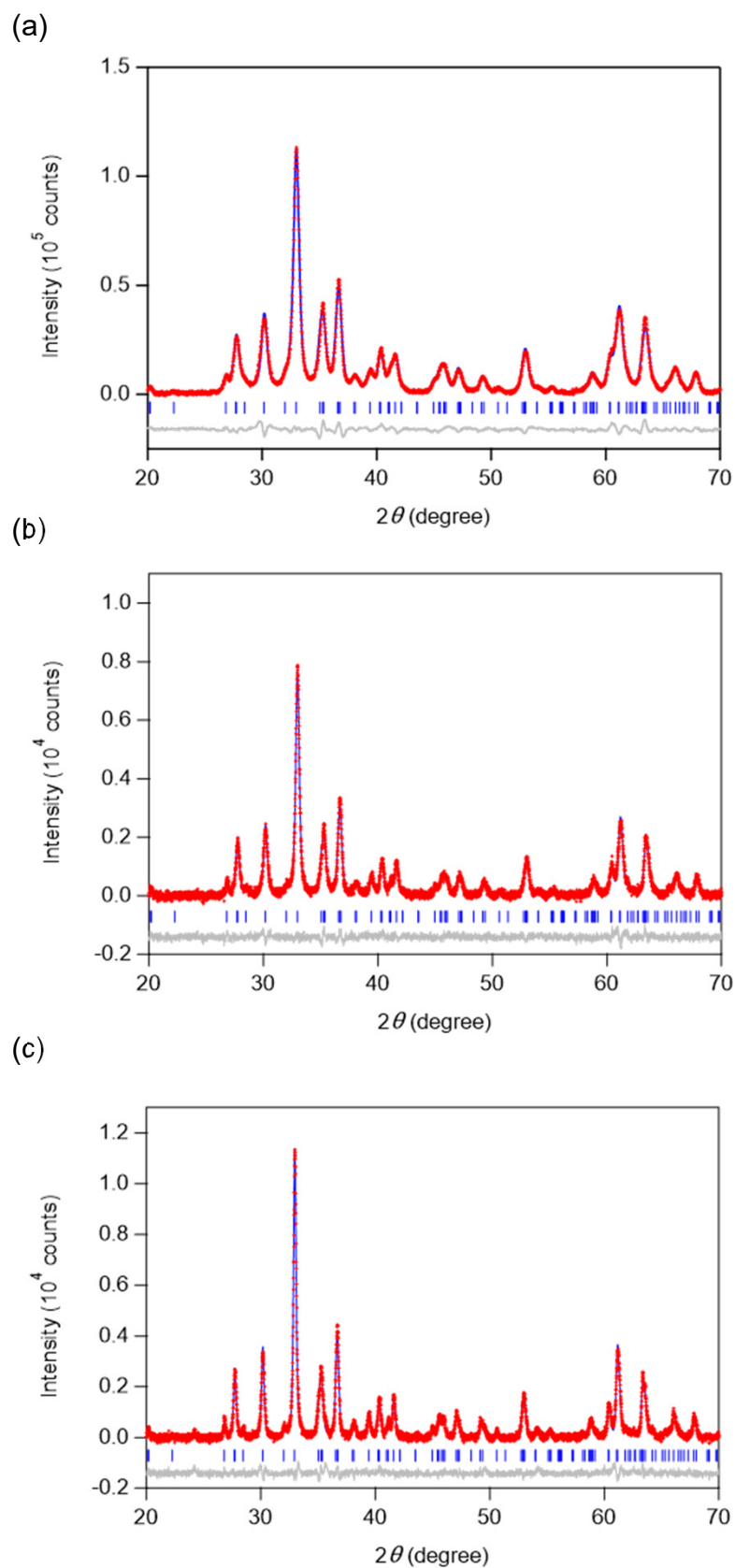# § 1. PXRD patterns with Rietveld analyses

(a)

(b)

(c)

Figure S1. PXRD patterns and Rietveld analyses for (a) **1**, (b) **2**, and (c) **3**. Red dots, blue lines, and gray lines are the observed, calculated, and their residual patterns, respectively. Blue bars represent the calculated Bragg reflection positions.

Table S1. Crystal structure parameters of ε-$Ga_xFe_{2-x}O_3$ obtained by the Rietveld analysis of the PXRD patterns.

Sample		1	2	3
Formula		ε-$Ga_{0.43}Fe_{1.57}O_3$	ε-$Ga_{0.45}Fe_{1.55}O_3$	ε-$Ga_{0.45}Fe_{1.55}O_3$
a (Å)		5.0855(3)	5.0871(4)	5.0888(3)
b (Å)		8.7803(5)	8.7771(7)	8.7744(6)
c (Å)		9.4397(4)	9.4377(6)	9.4381(5)
V (Å^3)		421.50(4)	421.39(6)	421.42(4)
Occupancy of Ga (%)	A	0	0	0
	B	0	0	0
	C	18.4(8)	19.0(6)	19.3(5)
	D	67.5(7)	70.8(7)	71.7(8)
FeA cite	x/a	0.308(3)	0.317(2)	0.316(2)
	y/b	0.3490(18)	0.3519(16)	0.3523(13)
	z/c	0.165(4)	0.175(5)	0.153(4)
FeB cite	x/a	0.3215(14)	0.3216(16)	0.3180(13)
	y/b	0.0322(5)	0.0327(6)	0.0340(5)
	z/c	0.371(5)	0.380(5)	0.359(4)
FeC cite	x/a	0.3158(10)	0.3110(12)	0.3082(10)
	y/b	0.6563(7)	0.6567(9)	0.6584(7)
	z/c	0.388(4)	0.398(5)	0.379(4)
FeD cite	x/a	0.187(2)	0.189(2)	0.184(2)
	y/b	0.8429(16)	0.8426(14)	0.8436(12)
	z/c	0.086(4)	0.095(5)	0.072(4)
O1 site	x/a	0.023(5)	0.025(6)	0.036(5)
	y/b	0.322(2)	0.326(3)	0.326(3)
	z/c	0.028(5)	0.026(5)	0.004(5)
O2 site	x/a	0	0	0
	y/b	0	0	0
	z/c	0	0	0
O3 site	x/a	0.026(5)	0.015(7)	0.012(6)
	y/b	0.653(4)	0.652(5)	0.650(4)
	z/c	0.030(5)	0.035(5)	0008(5)
O4 site	x/a	0.174(7)	0.178(8)	0.159(5)
	y/b	0.493(2)	0.496(3)	0.497(2)
	z/c	0.256(4)	0.275(5)	0.264(4)
O5 site	x/a	0.171(6)	0.179(7)	0.170(5)
	y/b	0.842(3)	0.842(4)	0.842(3)
	z/c	0.270(4)	0.274(5)	0.255(4)
O6 site	x/a	0.171(6)	0.163(6)	0.154(5)
	y/b	0.161(4)	0.162(4)	0.166(3)
	z/c	0.239(4)	0.248(5)	0.234(4)
R_{wp}		0.47%	1.32%	1.36%
S		1.9267	1.0233	1.0741

§ 2. TEM images

(a)

1

(b)
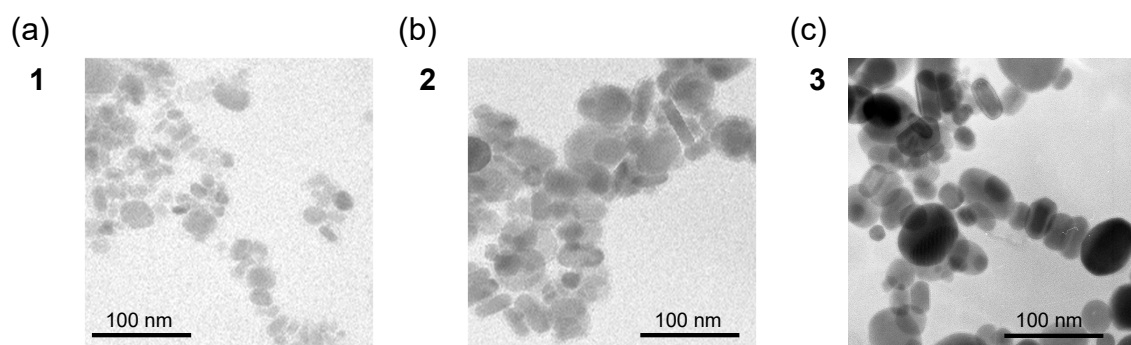
2

(c)

3

100 nm

100 nm

100 nm

Figure S2. The TEM images of (a) **1**, (b) **2**, and (c) **3**.

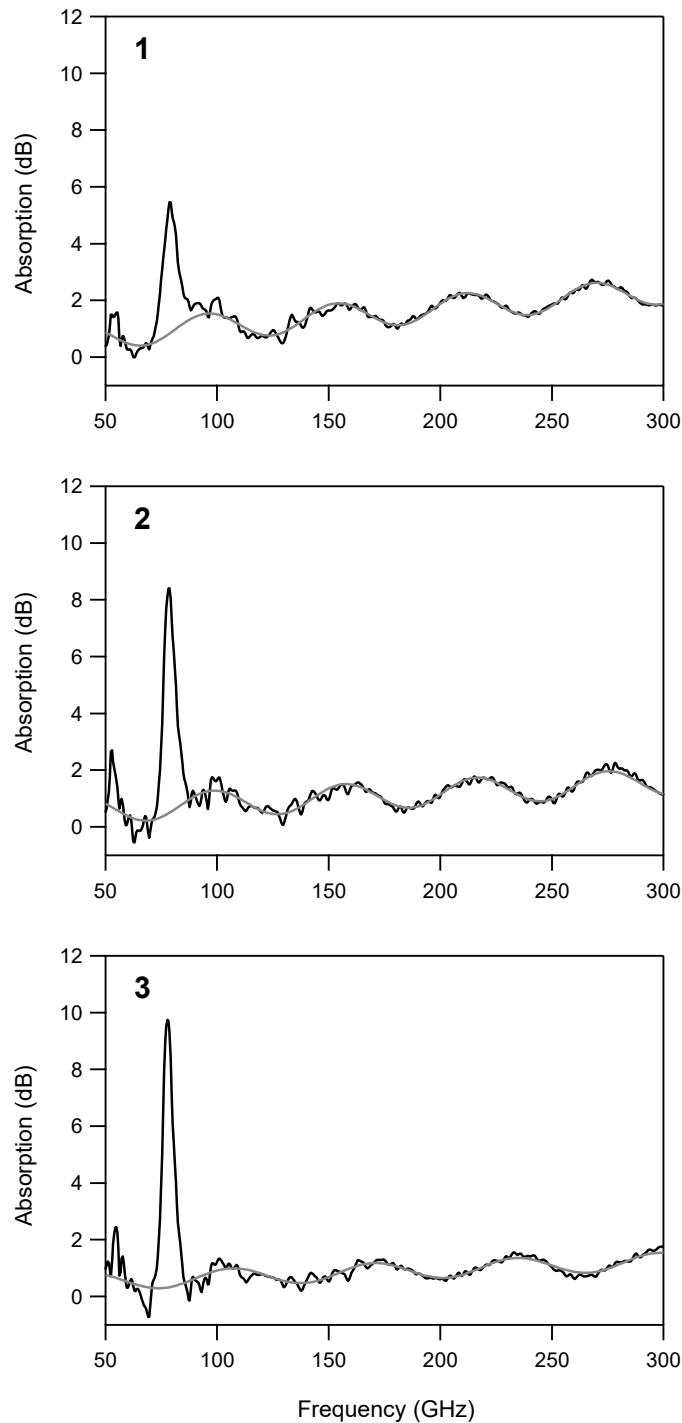## § 3. Millimeter wave absorption spectrum analyses

Figure S3. Millimeter wave absorption spectra of **1**–**3**. Absorption $A = -10\log_{10}(|T|^2/(1-|R|^2))$ was obtained from the transmittance T and the reflectance R, which are measured with transmittance and reflection mode, respectively. The black lines represent the observed spectrum. The gray lines represent the calculated background caused by the interference between transmission and reflection.

§ 4. Summary of the characteristics of **1**−**3**

Table S2. Summary of the characteristics of **1**−**3**.

Sample	1	2	3
Formula	$\varepsilon\text{-Ga}_{0.43}\text{Fe}_{1.57}\text{O}_3$	$\varepsilon\text{-Ga}_{0.45}\text{Fe}_{1.55}\text{O}_3$	$\varepsilon\text{-Ga}_{0.45}\text{Fe}_{1.55}\text{O}_3$
Crystalline size			
d_{FP} (nm)	16.9(1)	28.8(2)	41.4(1)
Millimeter wave absorption			
Frequency (GHz)	78.7	78.2	77.7
Absorption (dB)	4.6	7.9	9.4
Absorption area (dB·GHz)	44	60	66
Millimeter wave rotation			
Rotation angle (deg.)	9.1	14.1	18.4
Ellipticity	0.27	0.39	0.52