Effective Heat Transfer Pathways of Thermally Conductive Networks Formed by One-Dimensional Carbon Materials with Different Sizes

Yun Seon Lee[1,2,†], Seung-Yong Lee[1,3,†], Keun Soo Kim[4], Suguru Noda[5], Sang Eun Shim[2,*], Cheol-Min Yang[1,*]

[1] Institute of Advanced Composite Materials, Korea Institute of Science and Technology (KIST), 92 *Chudong-ro*, Wanju-gun, Jeonbuk 55324, Republic of Korea; t14225@kist.re.kr (Y.S.L.); seungyong@lginnotek.com (S.-Y. L.)

[2] Department of Chemical Engineering, Inha University, 100 Inha-ro, Nam-gu, Incheon 22212, Republic of Korea

[3] Magok R&D, LG Innotek, 30 Magokjungang 10-ro, Gangseo-gu, Seoul 07796, Republic of Korea

[4] Department of Physics and Graphene Research Institute, Sejong University, 209 Neungdong-ro, Gwangjin-gu, Seoul 05006, Republic of Korea; kskim2676@sejong.ac.kr

[5] Department of Applied Chemistry, School of Advanced Science and Engineering, Waseda University, 3-4-1 Okubo, Shinjuku-ku, Tokyo 169-8555, Japan; noda@waseda.jp

[*] Correspondence: seshim@inha.ac.kr (S.E.S.); cmyang1119@kist.re.kr (C.-M. Y.)

[†] These authors contributed equally to this work and should be considered co-first authors.

Table S1. Summary of the detailed preparation conditions and thermal conductivity values of carbon-based films prepared in this study.

Sample	FWCNT content (wt%)	MPCF content (wt%)	Ag content (mg)	Sonication time (h)	Heat treatment (1000 °C)	Thickness (㎛)	Bulk density (kg/m^3)	Thermal conductivity (W/mK)
1	100	-	-	0.5	X	248	210	1.65
2	100	-	-	2	X	228	286	2.70
3	100	-	-	4	X	135	316	4.02
4	100	-	-	8	X	138	360	4.71
5	80	20 (200 μm)	-	0.5	X	236	220	2.30
6	60	40 (200 μm)	-	05	X	182	280	3.29
7	40	60 (200 μm)	-	0.5	X	166	360	4.91
8	20	80 (200 μm)	-	0.5	X	149	350	4.63
9	10	90 (200 μm)	-	0.5	X	173	300	4.22
10	5	95 (200 μm)	-	0.5	X	179	290	3.60
11	100	-	-	4	O	145	305	4.80
12	100	-	-	0.5	O	250	200	2.02
13	80	20 (200 μm)	-	0.5	O	229	213	2.71
14	60	40 (200 μm)	-	0.5	O	190	272	4.02
15	40	60 (200 μm)	-	0.5	O	161	327	5.41
16	20	80 (200 μm)	-	0.5	O	150	298	4.84
17	10	90 (200 μm)	-	0.5	O	158	289	4.25
18	5	95 (200 μm)	-	0.5	O	134	322	3.65
19	40	60 (6 mm)	-	0.5	X	185	274	10.7
20	40	60 (6 mm)	5	0.5	X	197	234	14.9
21	40	60 (6 mm)	10	0.5	X	188	333	21.0
22	40	60 (6 mm)	15	0.5	X	200	310	23.7
23	40	60 (6 mm)	20	0.5	X	270	316	25.1
24	40	60 (6 mm)	25	0.5	X	249	343	25.8

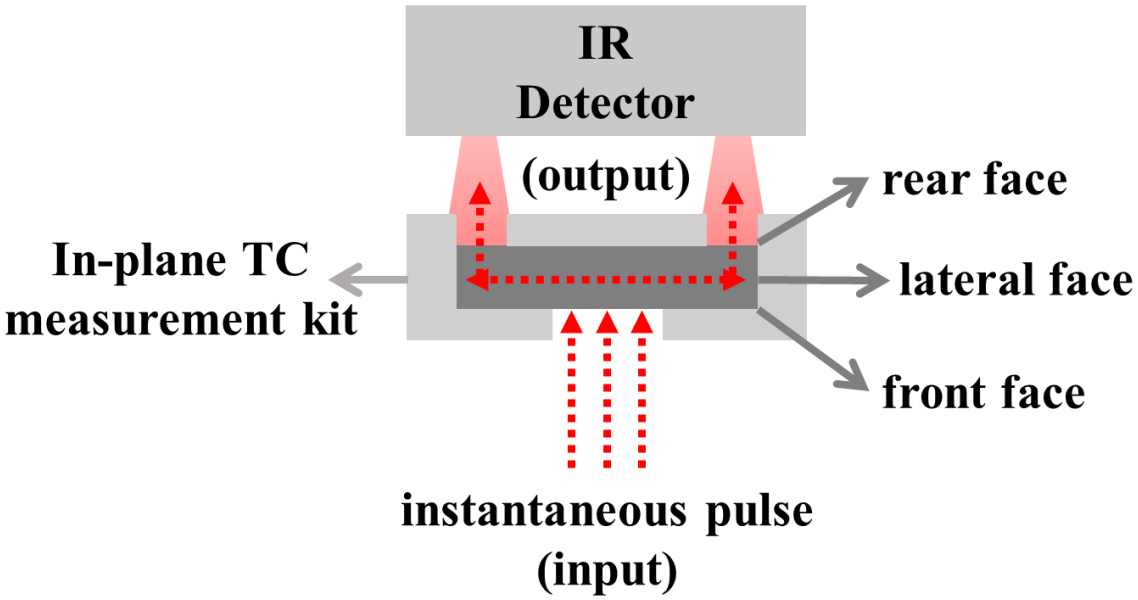

Figure S1. Schematic of the thermal conductivity measurement system using the modified laser flash technique.

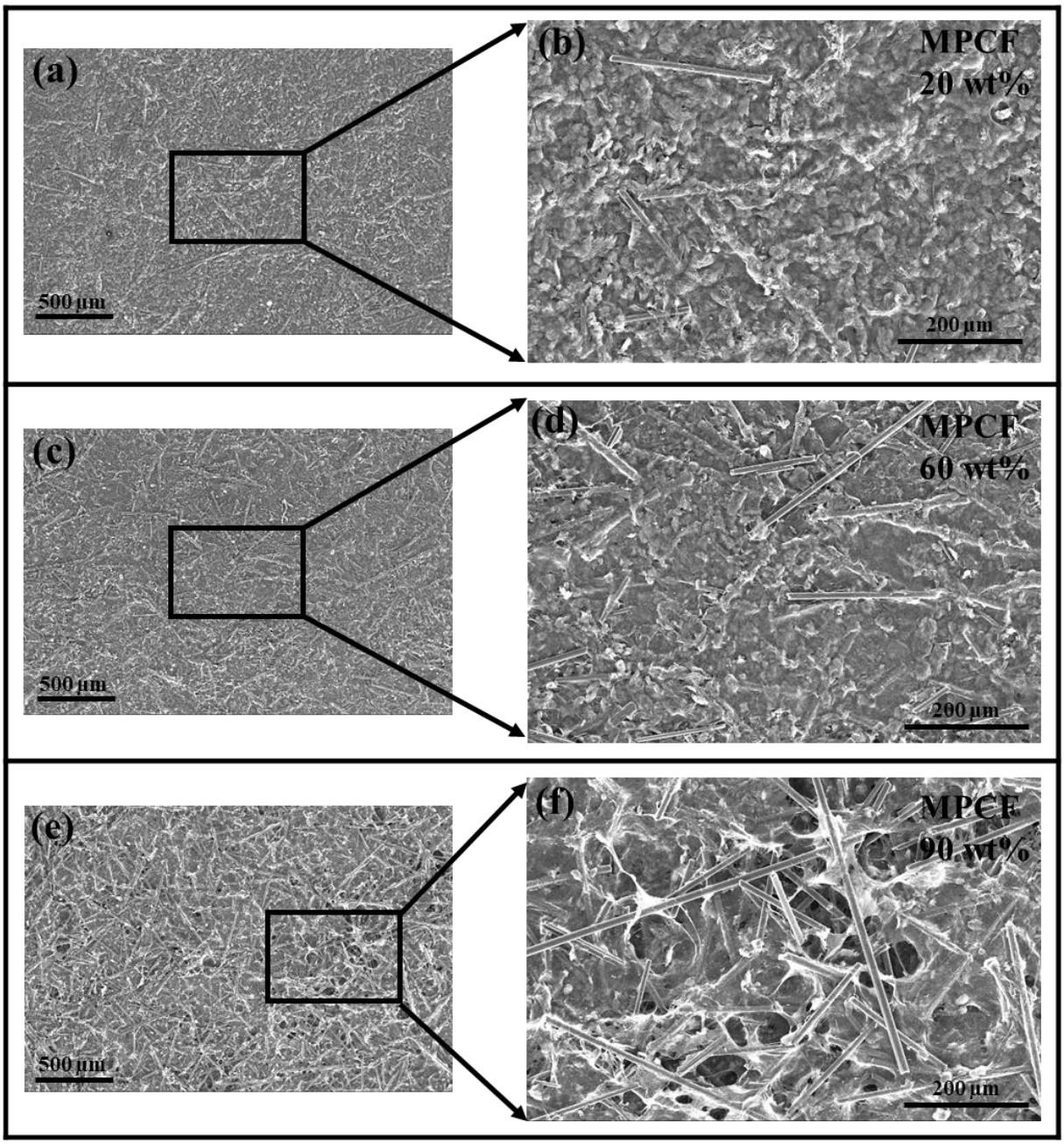

Figure S2. HR-SEM images of the FWCNT-MPCF hybrid films with different MPCF (length: 200 μm) contents: (a) and (b) 20 wt%, (c) and (d) 60 wt%, and (e) and (f) 90 wt%. (a), (c), and (e) are low-magnification images, while (b), (d), and (f) are high-magnification images.

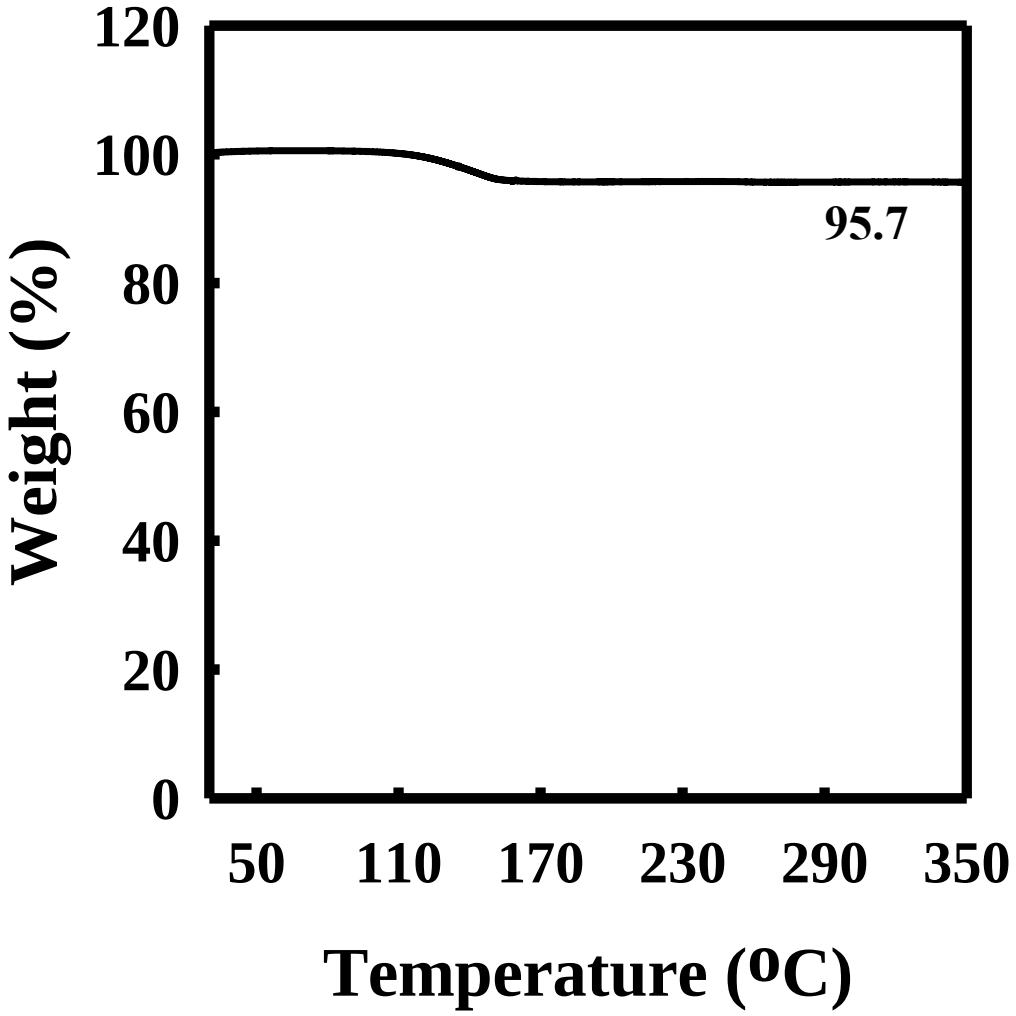

Figure S3. TGA curve of Ag nanoparticles under air atmosphere to 350 ºC (heating rate of 10ºC min^{-1}).

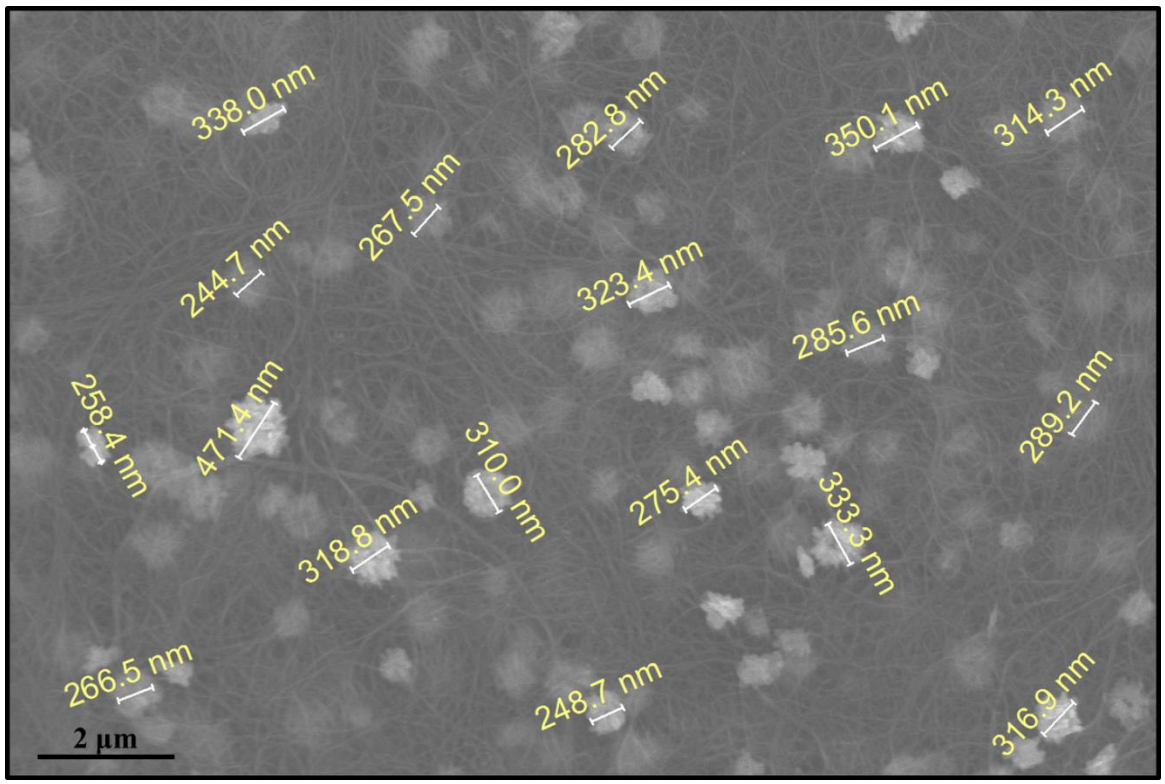

Figure S4. Measurement of the Ag nanoparticle sizes using HR-SEM image of the FWCNT-MPCF-Ag hybrid film incorporated with Ag content of 20 mg (MPCF length: 6 mm; MPCF content: 60 wt%; ultrasonication for 0.5 h).