Composites Part A 135 (2020) 105904

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In-situ - ff

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ARTICLE INFO

Keywords:
T -
C ff
S
C
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ABSTRACT

C , - (3DG) w , w . H w - (SLM) - (3D) . G w *in-situ* w (CVD) C , 3DG . A w CVD w SLM ff 3DG - (, ,) - (,) ff . T 3DG/ ff 88% 27% (EMI) ff , . P , EMI ffi- (*SE*) 47.8 B 2.7 GH *SE* 32.3 B 2–18 GH . T SLM .

1. Introduction

G , *sp*^{2} w w (2630 ^{2} $^{-1}$) 1 , (2 10^5 ^{2} V^{-1} $^{-1}$) (5000 W $^{-1}$ K^{-1}) 2 . H w , π-π w w (2D) - , ff , , w , - 3 . A fi ff w - . C w , - (3DG) w (99.7%), w fi (0.6 $^{-2}$) 4 w fi w , w - (2DG), 5 , 6,7 , 4 , (EMI) 8 . V 3DG , 9 , 10 , - 11 , - 12 . H w , - . F , ff 13 . S - ( ) w 14 . D - w 15 . M , w - CVD w , - 16 . B , w w, w

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:// /10.1016/ . .2020.105904
R 31 J 2020; R 1 A 2020; A 13 A 2020
Available online 18 April 2020

. T (., -
), fl fi
(., ,) 3DG. B , -
3DG w (., , ,). H w ,
ffi
, , N
, 3DG w fi 17,18 .
H , , , w
3DG w
19 .
S (SLM), -
(AM) , (3D)
w fl *in-situ* . T ,
SLM T 20 ,
21 , N 22 . C w /
. C w N ,
w
CVD w (< 0.001 . %)
w , w
w 23 . W N
(> 0.1 . %) 17 , fi
24 . H w , -
SLM ffi
w
fl w w
(1000–1100). F ff
SLM 25 .
T , w fi
3DG/ (3DG/C) -
SLM w CVD w
. A w -
SLM -

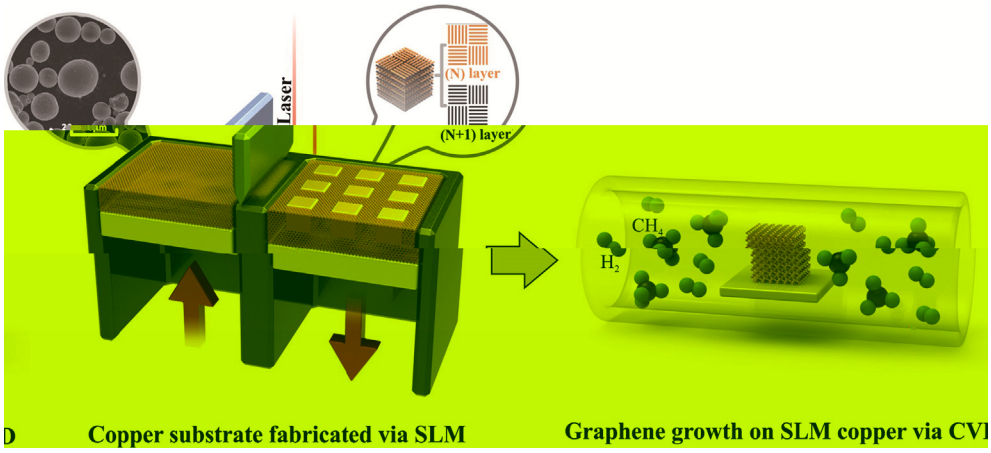

Fig. 1. I 3DG/C : ff SLM ( ) *in-situ* w ff CVD ( ). (F fi , w .)

ASTMB193-2002 w 2 2 20 $^{-3}$. T ff (2 10 10 $^{-3}$) (5 10 10 $^{-3}$) w ASTME1461-2013 w LFA (L fl , N LFA457, G). R (SENTERRA, B , G) w 3DG/C ff w - w 514 . T *S* (*S11* *S21*) w w w (VNA, A PNA-N5244A, US) 2–18 GH . T *SE* , *SE* , *SE* fl w E . 2–5 S I .

3. Results and discussion

3.1. Formation of SLM copper

3.1.1. SLM manufacturing of copper under different line energy densities

T ff (w) w . D ff w w (F . 2) , 30% w (A), 26.7% (B), 16.7% (C) 26.7% (D). D ff , LED (J/) 27 (E . 6, SI). T fl . T ffi w . I A, w ffi w . I B, w w w w fi . T fl w w ffi , w LED 400 J/ (C). W LED (> 800 J/) , 130 μ w - (D), w w - w w w w 28 .

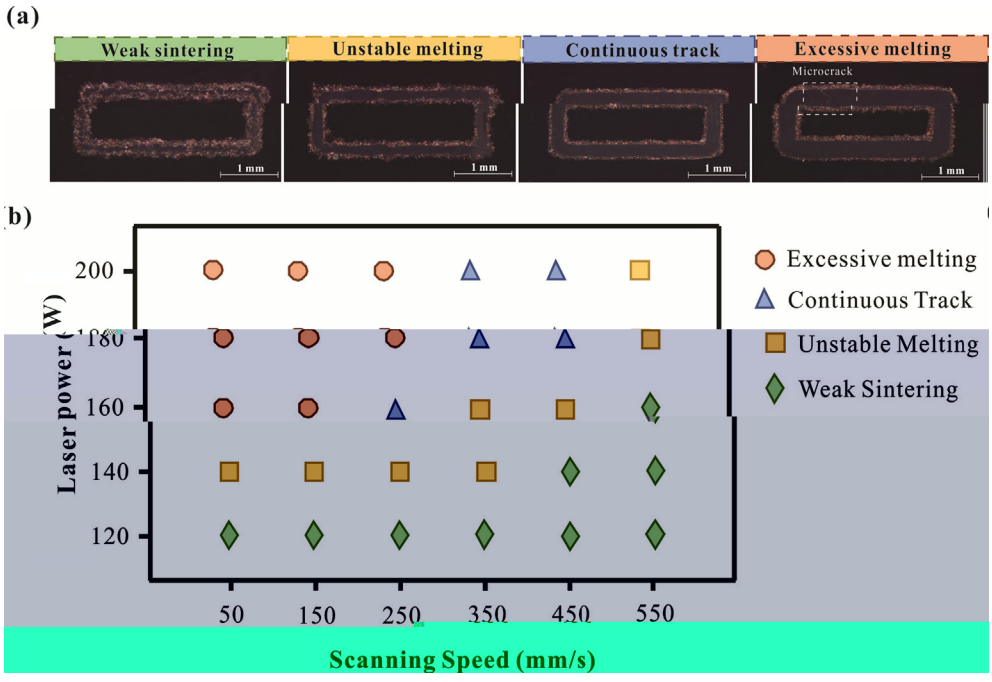

Fig. 2. ( ) T w , , , ; ( ) w w w . (F - fi , w .)

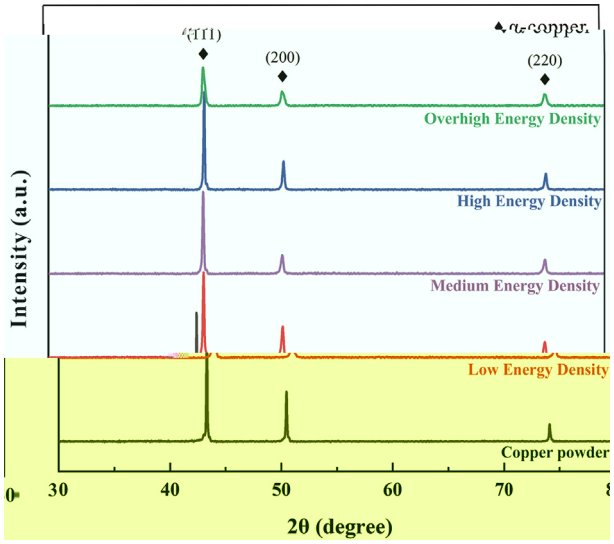

Fig. 3. RD w - . (F fi , w .)

3.1.2. Formation of anisotropic microstructure under different volumetric energy density

T α- RD (1 1 1) (2 0 0) fl ff 2θ = 43.32 2θ = 50.45 , (F . 3), (1 1 1) w . T - RD w ff w fi SLM . I , ff SLM ff , - 29 . T w - SLM w . T w : ( ) - , ( ) - w , ( ) . A 3000 J/ 3 (F . 4**a**), w w 180 μ , w w (F . 4**d**). T M 30 fl . T - w . W 857 J/ 3 , w w w w (F . 4**b**). U , fi- 96.2% w . H w , w , w- w fi - , 88.6% - (F . 4**d**). T SLM w w (F . 5). T - w w , w w . T _ w w w , w w - 32 . T fi fl w . S w W . 33 , , (398 W $^{-1}$ K $^{-1}$), ffi w w (F . 4**c**). G , w w M - . B , w SLM 31 . I , w 128 J/ 3 , - w w w fi - , (F . 4**d**). T SLM w w (F . 5). T - w , w w . T w w w , w - 32 . T fi fl w . S w W . 33 , , ,

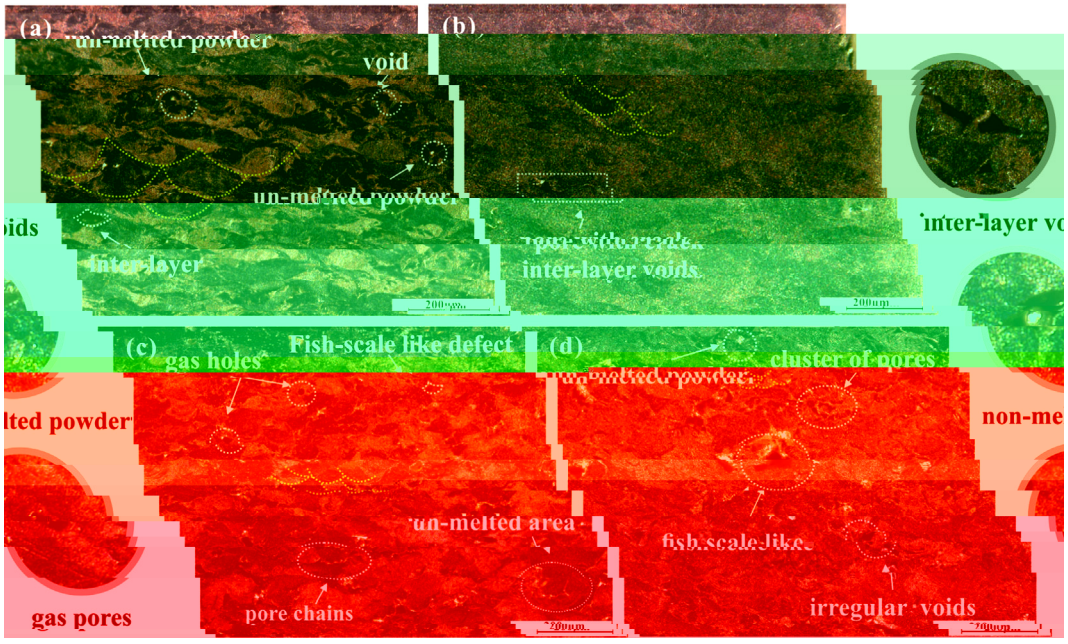

Fig. 4. O : ( ) (3000 J/ 3), ( ) (857 J/ 3), ( ) (285 J/ 3), ( ) w (128 J/ 3), . (F fi , w .)

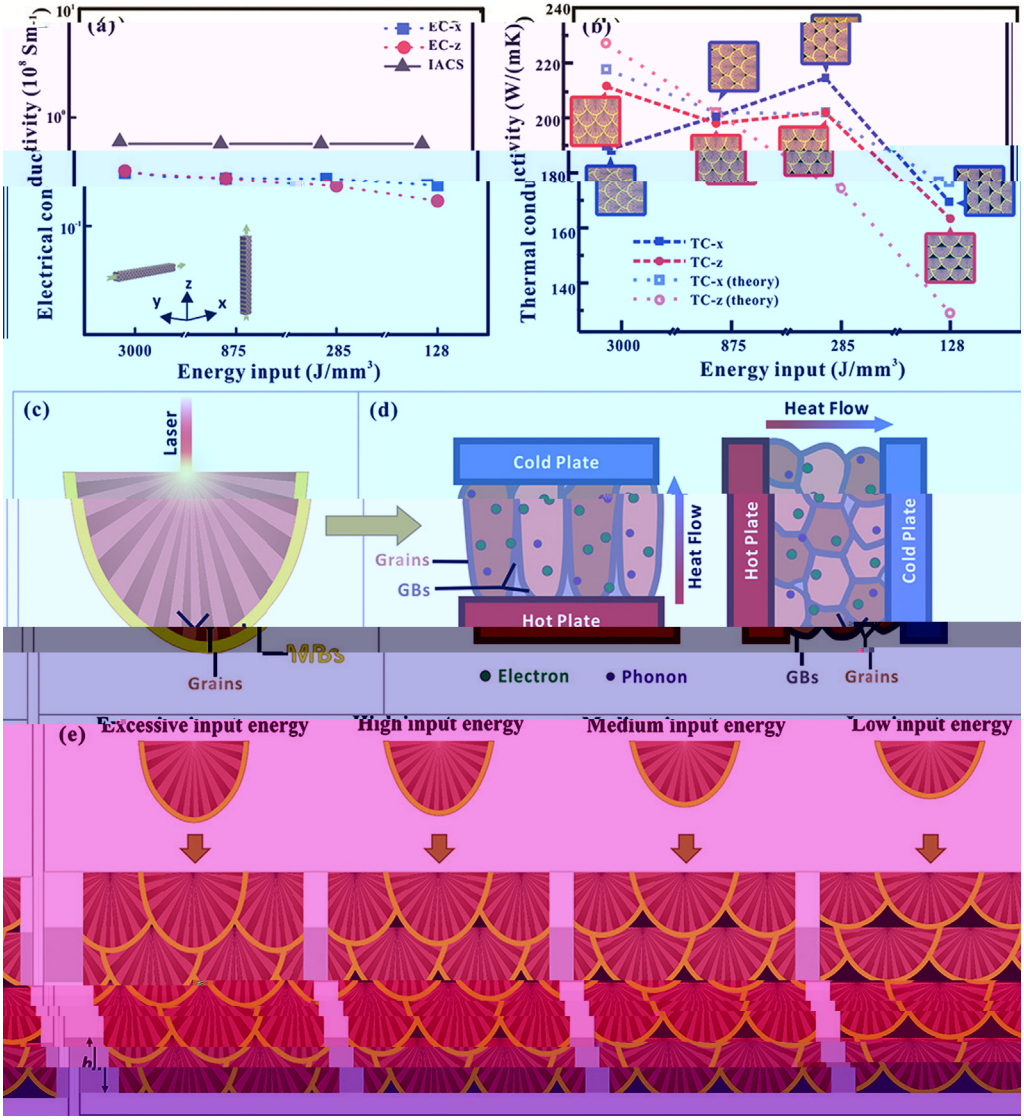

Fig. 7. ( ) E ( ) ; ( ) ; ( ) ; ( ) ff . (E). (F fi , w .)

. .

3.3. Morphology and structure of CVD 3DG/Cu porous scaffolds

F ff w ff w w ff . G w *in-situ* w CVD . A w ff , w fi 39 . A , w w w 33 V , (25 V) 39 . U w C N ;L . 40 w . H w , (. . 23 , - 41) w CVD- w , - fl w w w .

. A , w SEM, w - . T SEM - 3DG/C ff - w w 450 μ (F . 8**a**). A fi (F . 8**b**), fl w ff , . T - ff , EDS w w (F . 8**c-d**), w fi . A fl w fi (F . 8**e-g**). T 3DG/C ff w - w w (F . 8**h**). R w 3DG/C - . T G- (~ 1590 $^{-1}$) w 2D- (2699 $^{-1}$) w w 42 (F . 8). S D- (~ 1350 $^{-1}$) fl - 43 , D G (I_D/I_G) w

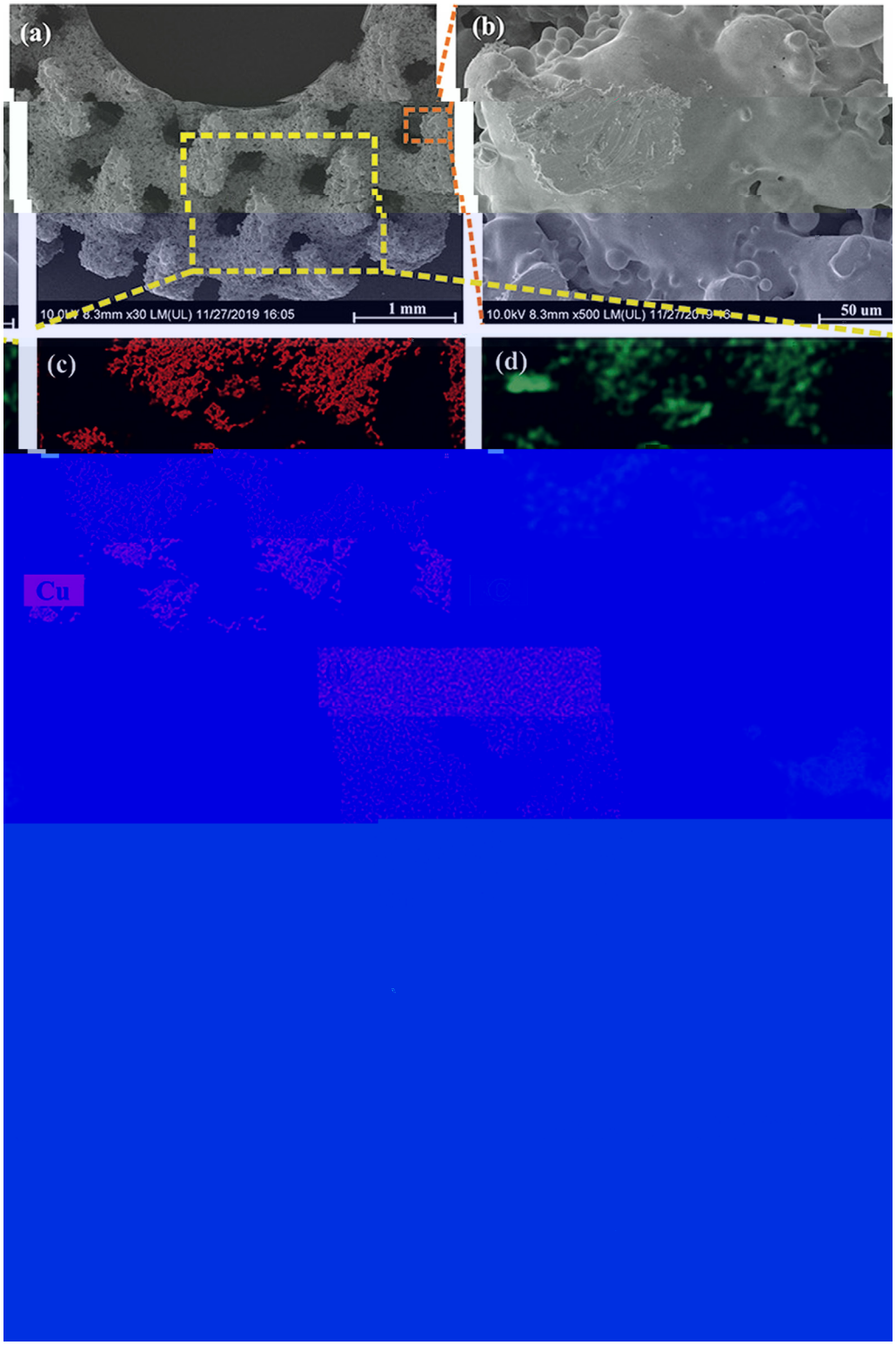

Fig. 8. (-) SEM 3DG/C ff ff fi ; EDS ( ) C ( ) C; ( ) fi SEM , EDS ( ) C ( ) C; ( ) w OM; ( ) R ff ff w . (F fi , w .)

. W w w fl w , I_D/I_G 0.71 0.93, - . A , w (w 1000 C, fl w CH_4 30 , w 20) w 3DG/C .

3.4. Thermal property and EMI shielding effectiveness of 3DG/Cu porous scaffolds

T ff C ff , 26.8% 14.8%

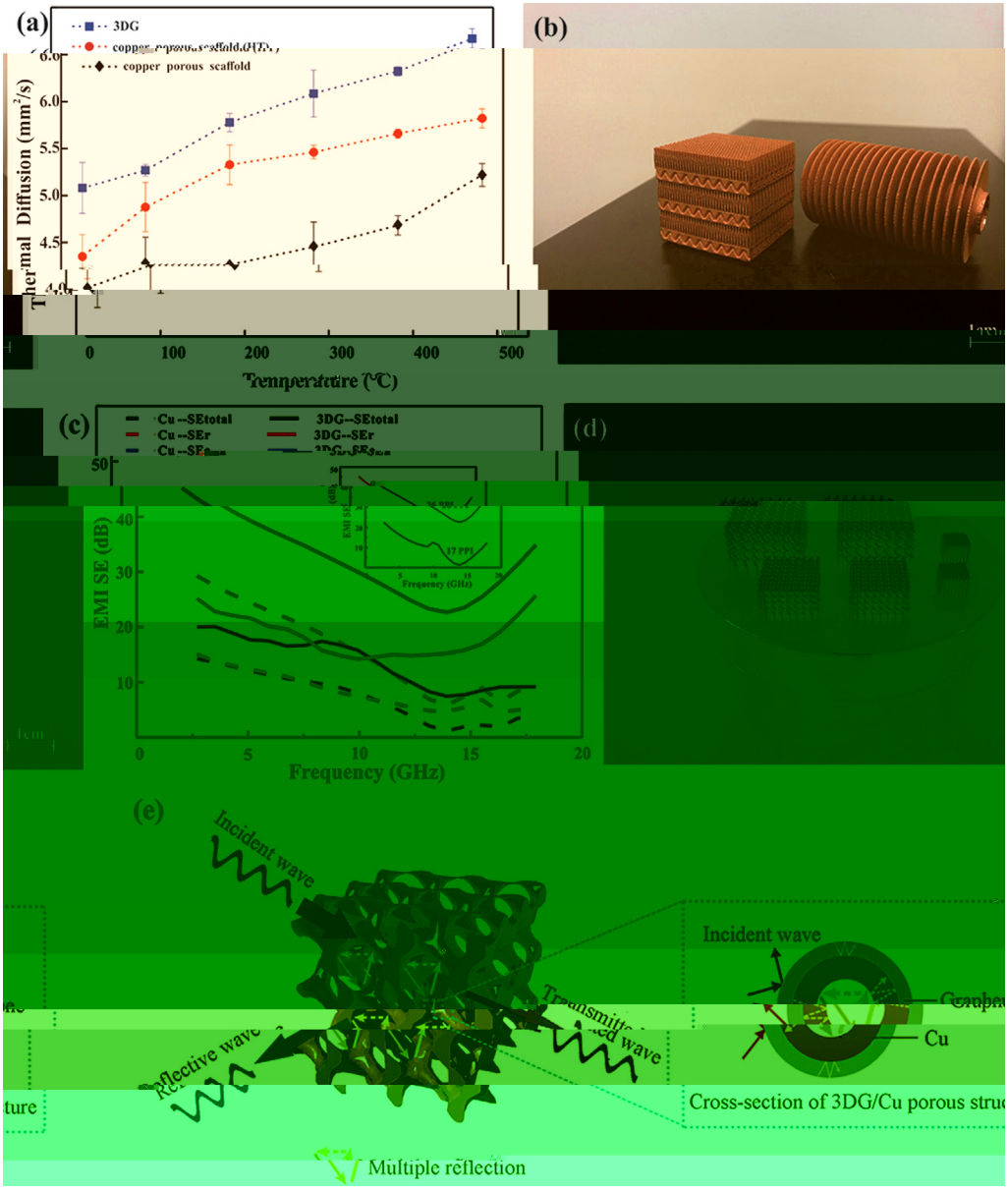

Fig. 9. P 3DG/C ff : ( ) ff ; ( ) SLM fl w (w fl) - ; ( ) EMI SE; ( ) C ff w ff ; ( ) S 3DG/C EMI. (F fi , w .)

Table 1
C - w EMI -

Coating materials	Substrate	Method	Maximum shielding efficiency (dB)	Improvement of thermal property (%)	Ref
G	G	I + + +	37	–	50
G	PS	H - + + -	29.3	–	56
G	PMMA	S + + +	19	–	57
C /G /C	A	S fi +	–	8.5	58
G	N	F + CVD	–	554	59
G	C -N	E +	20	–	60
G	C	P w + CVD	–	2.4	61
G	C	F - +	47	6.3	62
G	C	CVD + SLM	47.8	27	T w

Note: ( )-PPMA, -PS.

HT
in-situ w (F . 9**a**). S - - -
, -
3DG/C ff - .
I w HT
w
1–2 . I , -
w
w , . W
, SLM
– fl w (w fl
500 μ) -
w
(F . 9**b**), -
w - . G - ,
, , ,
w -
(T 1). I w
w . O -
w
, N .
T 3DG/C ff
EMI, EMI *SE,* w
(EM) , w
2–18 GH (F . 9**c**), -
. W *in-situ* w
ff , *SE* 15.9 32.3 B, w
47.8 B (88.2%),
20 B. T
3DG/C fi w
. J K . 44 EMI
w T EMI *SE*
133% w
(.,) 20 110 PPI ( ).
R K 45 w EMI
. W
17 26 PPI (F . 9**c** insert) 105%
EMI *SE*. I w , EMI
ff w w SLM. T
3DG/C 26 PPI EMI *SE*
32.3 B, 99.9% EMI w . T
w 60
(30 ff) 46 . T EMI
3DG/C w - -
T 1. I EMI *SE*
3DG/C w
3D - , -
.
T EMI fl (*SE*$_r$),
(*SE*$_a$) fl (EM) w 47 ,
w w , ,
, , ,
48 . R 49 w
, fl
w , w w .
T w EM w
fi
50 . R EMI
. T - -
w w w -
w fi , C 51 . F ,
- w
52 S O_2 53 . W
3DG/C ff w

SE$_r$ *SE*$_a$, w F . 9**e**. W w
w 3DG/C ff ,
w w fl , w -
w ff . S -
, 3DG/C -
fl
w w w . T
EM w fi w
w EM w , *SE*$_r$. O
, w ff , w w fi EM
w ff , , EM -
. T
ff w
w J 54 . I w
fi w
fl ff . M ,
w
, fl
EM w ,
EM w . T
w 44 . T
w 3D EM w w
. I , CVD
R -
S 3.3 ,
55 . I
EM w w , w
. O w ,
3DG/C
fl , , w fi
. T
w ff

4. Conclusions

A 3DG/C ff w w
in-situ CVD .
T w
ff . W
, 3DG/C
EMI *SE*
15.9 ( ) 32.3 B,
47.8 B (88.2%), w 26.8%
ff . T 3DG/C
ff fl , fl -
. T EMI
3DG/C ff
EMI .

Credit authorship contribution statement

Kaka Cheng: C , M , F ,
W - . **Wei Xiong:** V , I , W -
. **Yan Li:** W - w & , F ,
R , S . **Liang Hao:** F . **Chunze Yan:**
R , F . **Zhaoqing Li:** V . **Zhufeng Liu:**
F . **Yushen Wang:** I , S w . **Khamis Essa:**
W - w & . **Li Lee:** D . **Xin Gong:** S w .
Ton Peijs: W - w & , S .

Declaration of Competing Interest

T fl

Acknowledgement

T w fi N N S F C (N . 51671091, N . 51902295, N . 51675496). T F R F C U , C U G (W) (N . (N . CUG170677) H P N S F (N . 2019 CFB264).

Appendix A. Supplementary data

S :// /10.1016/ . .2020.105904.

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