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In-situ [illegible] for [illegible]

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ABSTRACT

C[illegible], [illegible] (3DG) [illegible] SLM [illegible] 3DG [illegible] *in-situ* [illegible] (CVD) [illegible] 3DG [illegible]. A [illegible] CVD [illegible] SLM [illegible] 3DG [illegible] 88% [illegible] 27% [illegible] (EMI) [illegible] EMI [illegible] 47.8 [illegible] 2.7 GH [illegible] *SE* [illegible] 32.3 [illegible] 2–18 GH. [illegible] SLM [illegible].

1. Introduction

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

* C[illegible]: G[illegible] I[illegible], C[illegible] U[illegible] G[illegible], W[illegible] 430074, PR C[illegible].
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[illegible]://[illegible]/10.1016/j.[illegible].2020.105904
R[illegible] 31 J[illegible] 2020; R[illegible] [illegible] 1 A[illegible] 2020; A[illegible] 13 A[illegible] 2020
Available online 18 April 2020

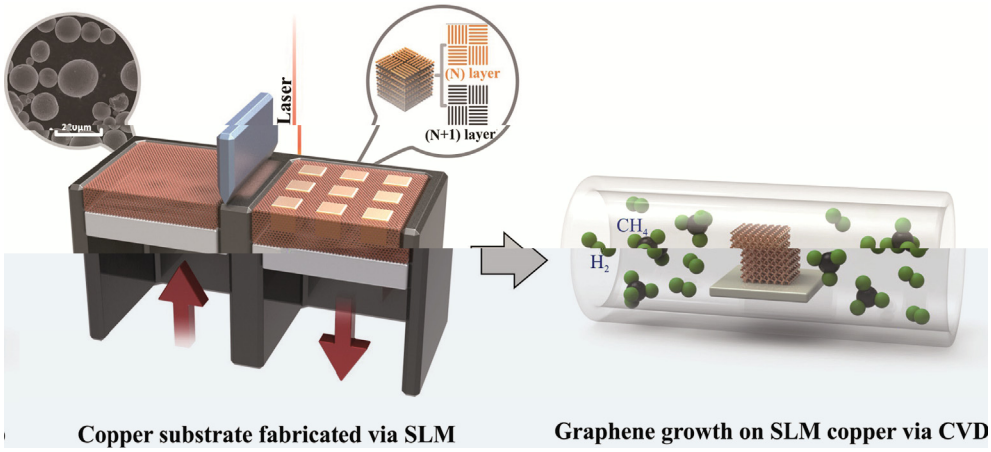

Fig. 1. [illegible] 3DG/C [illegible] SLM (J f) [illegible] *in-situ* [illegible] CVD ([illegible]). (F [illegible] [illegible] f [illegible] s [illegible] fi [illegible], [illegible] f [illegible] w [illegible] f [illegible].)

ASTMB193-2002 [illegible] s w [illegible] f 2 2 20 [illegible]³ f [illegible] [illegible] [illegible] [illegible]. T [illegible] iff [illegible] [illegible] (2 10 10 [illegible]³) [illegible] (5 10 10 [illegible]³) f [illegible] w ASTME1461-2013 [illegible] f [illegible] [illegible] w [illegible] LFA (L [illegible] fl [illegible], N LFA457, G [illegible]). R [illegible] (SENTERRA, B [illegible] x; G [illegible]) [illegible] 3DG/C [illegible] w [illegible] f 514 [illegible]. T *S* [illegible] (*S11* [illegible] *S21*) w [illegible] [illegible] (VNA, A [illegible] PNA-N5244A, US) [illegible] 2–18 GH . T [illegible] f *SE* [illegible], *SE* [illegible], [illegible] *SE* [illegible] fl [illegible] w [illegible] [illegible] E . 2–5 [illegible] S [illegible] In f [illegible].

3. Results and discussion

3.1. Formation of SLM copper

3.1.1. SLM manufacturing of copper under different line energy densities

T [illegible] ff [illegible] (J [illegible] w [illegible] x [illegible]) w [illegible] [illegible] . Diff [illegible] s f [illegible] w [illegible] s [illegible] [illegible] [illegible] (Fi . 2) [illegible] 30% w [illegible] (A), 26.7% x [illegible] (B), 16.7% [illegible] (C) [illegible] 26.7% [illegible] (D). Diff [illegible] LED (J/) 27 (E . 6, [illegible] SI). T [illegible] fl [illegible] f [illegible]. T [illegible] In A, [illegible] ffi [illegible] f [illegible] ffi [illegible]. In B, [illegible] f [illegible] f [illegible] . T [illegible] f [illegible] LED f 400 J/ (C). W [illegible] LED (> 800 J/) [illegible], 130 [illegible] (D), [illegible] [illegible] 28 .

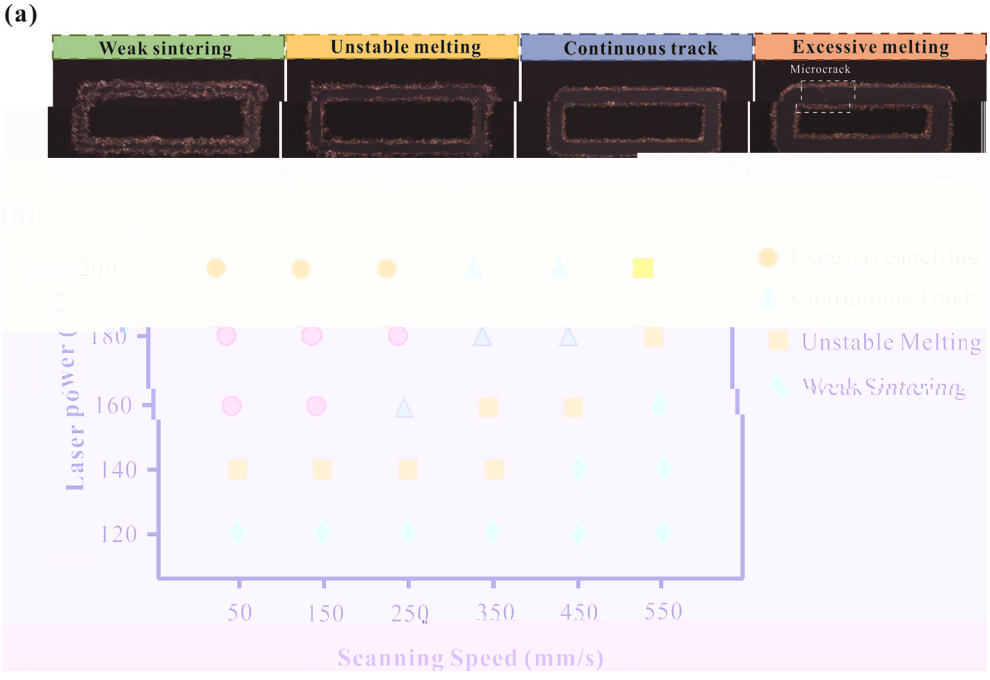

Fig. 2. ( ) T [illegible] f w [illegible], [illegible] x [illegible], [illegible] [illegible], [illegible] [illegible]; ( ) [illegible] w f [illegible] w [illegible] [illegible] s. (F [illegible] [illegible] f [illegible] [illegible], [illegible] f [illegible] w [illegible] f [illegible].)

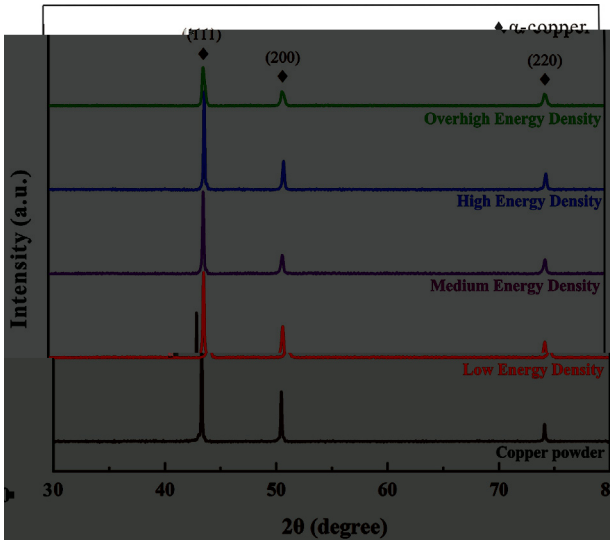

Fig. 3. RD [illegible] (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

3.1.2. Formation of anisotropic microstructure under different volumetric energy density

[illegible] α- [illegible] RD [illegible] (1 1 1) [illegible] (2 0 0) [illegible] 2θ = 43.32 [illegible] 2θ = 50.45 , [illegible] (Fig. 3), [illegible] (1 1 1) [illegible] RD [illegible] SLM [illegible]. In [illegible] SLM [illegible] 29 .

[illegible] SLM [illegible] : (i) [illegible], (ii) [illegible], (iii) [illegible]. A [illegible] 3000 J/mm³ (Fig. 4a), [illegible] 180 μm, [illegible] (Fig. 4d). [illegible] 30 [illegible]. [illegible] 857 J/mm³, [illegible] (Fig. 4b). [illegible] 96.2% [illegible]. [illegible] (398 W m⁻¹ K⁻¹), [illegible] (Fig. 4c). [illegible] 128 J/mm³, [illegible] 88.6% [illegible] (Fig. 4d).

[illegible] SLM [illegible] (Fig. 5). [illegible] 32 . [illegible] 33 , [illegible]

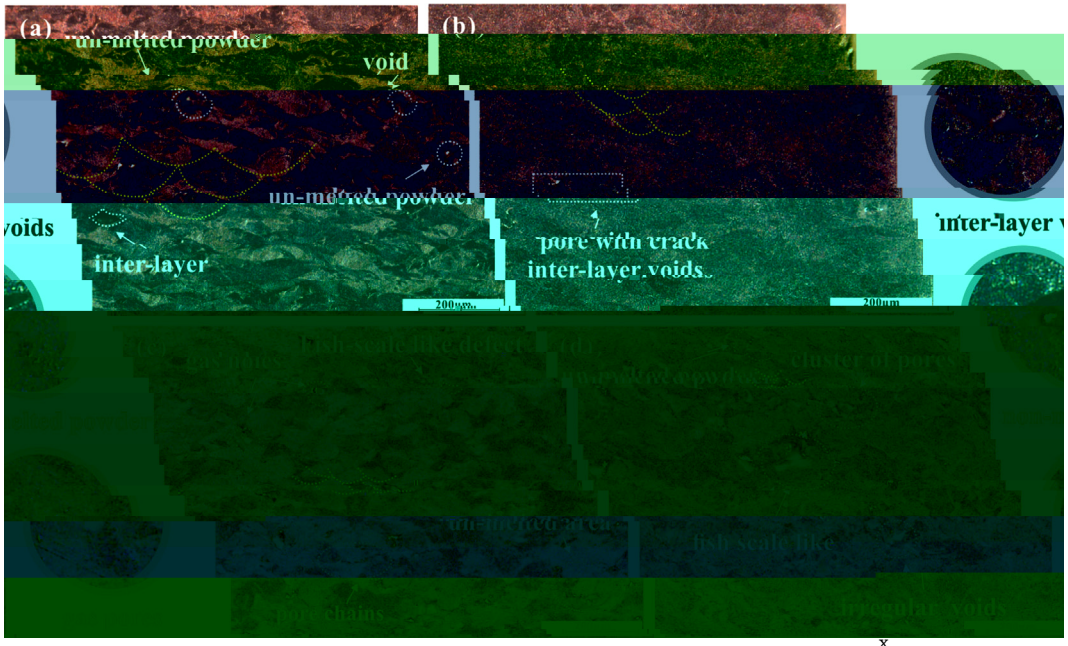

Fig. 4. [illegible] (3000 J/mm³), ( ) [illegible] (857 J/mm³), ( ) [illegible] (285 J/mm³), ( ) [illegible] (128 J/mm³), [illegible]. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

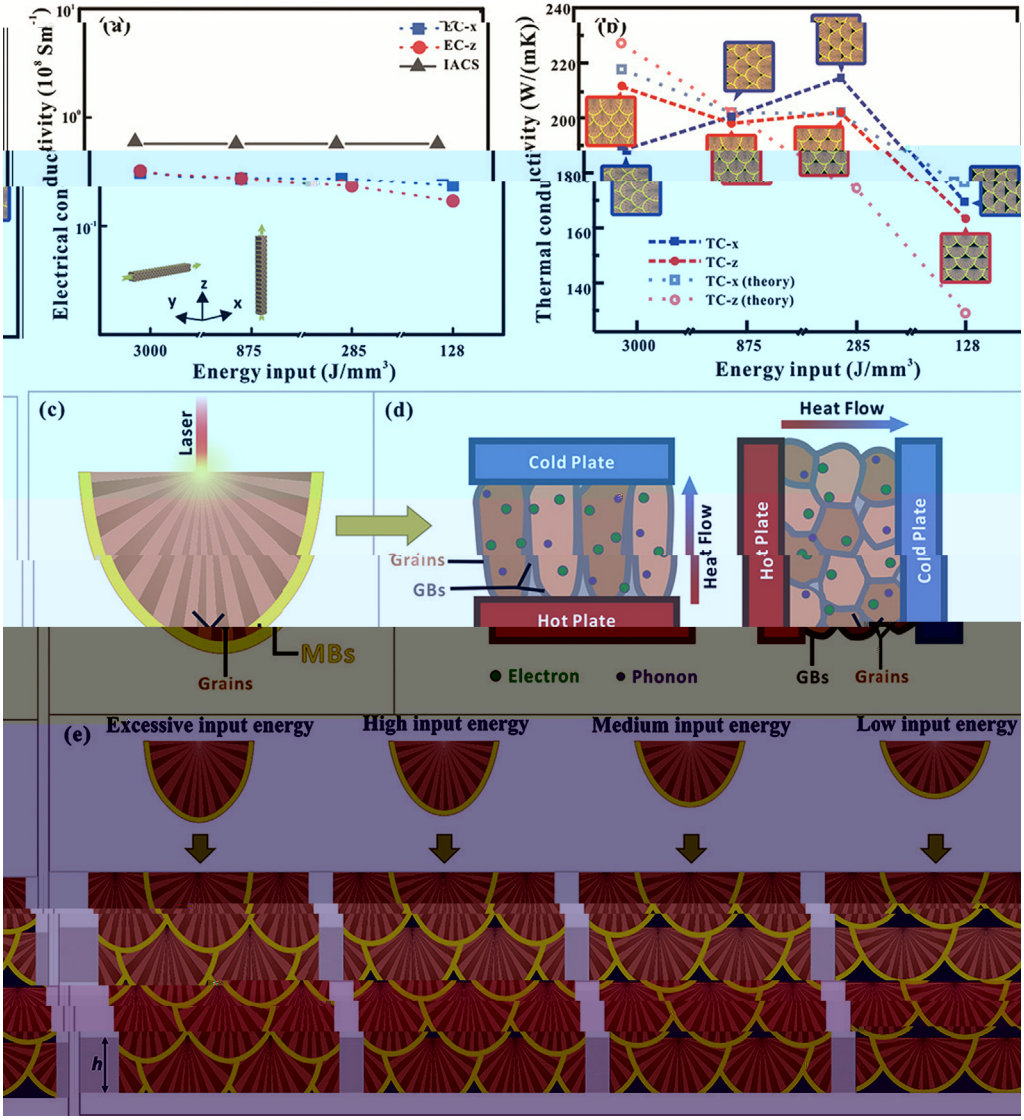

Fig. 7. ( ) El l ( ) l f ; ( ) s f l ; ( ) s f l ; ( ) s f . (E r). (F f s l fi l , f .)

s l f s l s l .

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

F l ss ff s w iff s w f s ss f s , s f s i i f s, s f s i i , i w s f fil i f 39 . A s w s s w i f 33 V (25 V) 39 . U s i C i Ni, Li . 40 s i f w ss. H w , s i s (. i f 23 , f i f s 41) CVD- w f s s , fl s w s i w

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

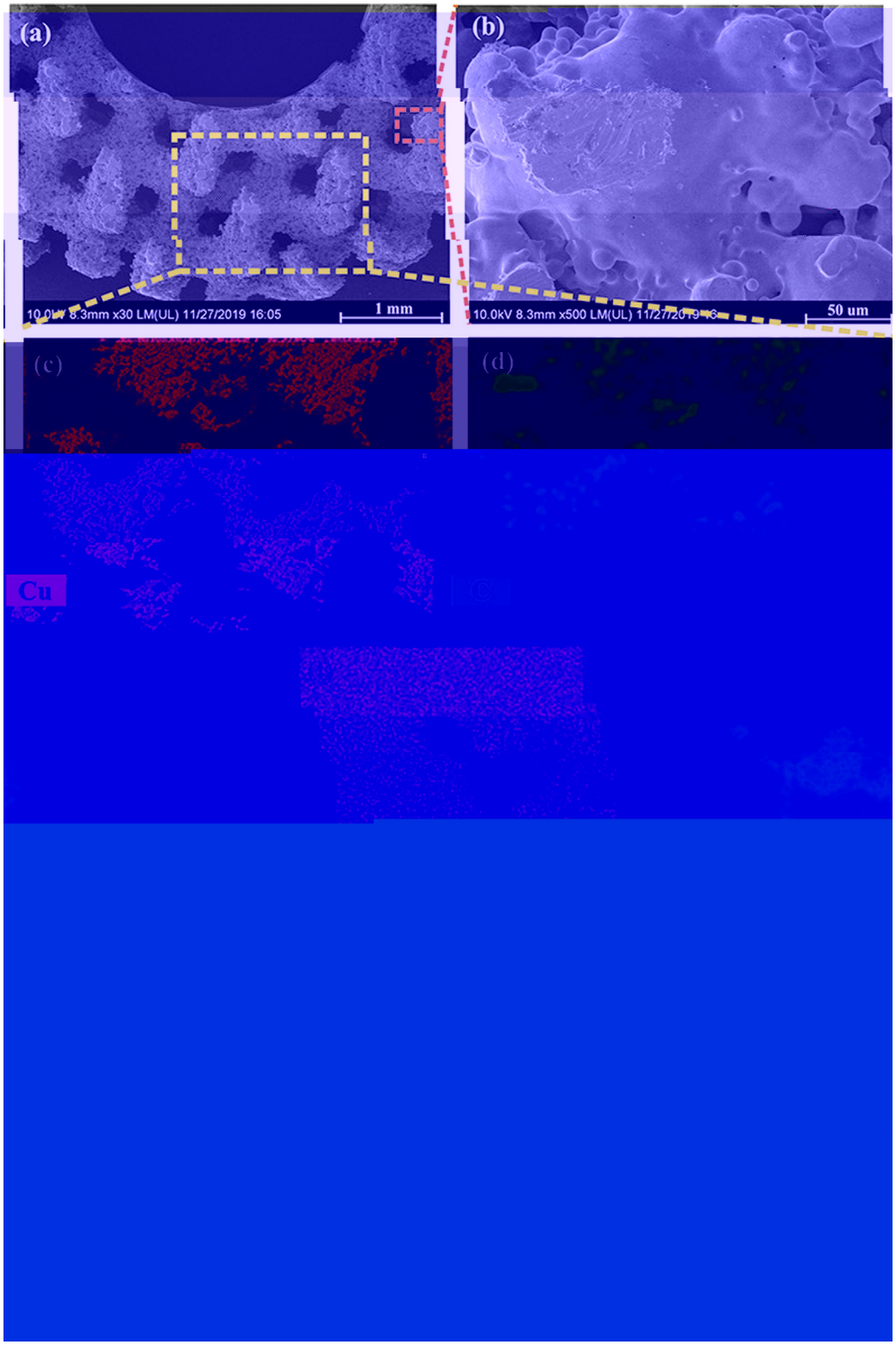

Fig. 8. (-) SEM i s f 3DG/C ss ff l i iff i i s; EDS i u i f ( ) C i ( ) C; ( ) l i f SEM i , i s i u EDS i u i f ( ) C i ( ) C; ( ) i f i f i w f OM; (i) R i s i f i i s ff l i iff i w i i s. (F i i f i s l i i fi l i , i f i w s f i .)

l i s f f s. W s i w i s l w fl w i s, l f I_D/I_G i s f 0.71 0.93, i i i u- i s f f s i u l i f s i s. A s i s i w i i (i w i f 1000 C, fl w f CH_4 i 30 s , i w i f 20 i u) w s s f i 3DG/C ss i .

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

T l iff s i f i s s i l i s i i f i C ss ff l , 26.8% i s i i i f i s l i i 14.8% i s

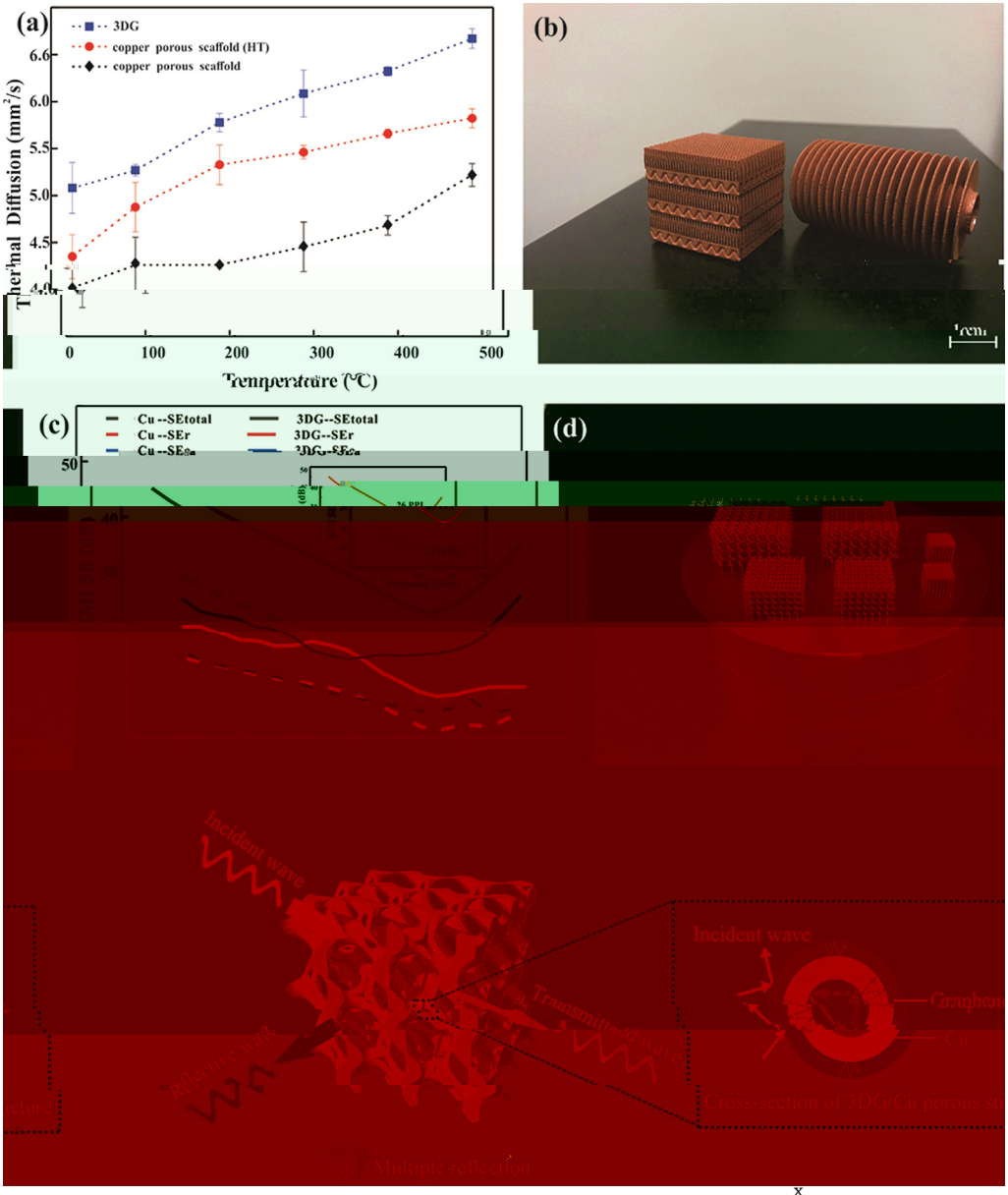

Fig. 9. P f l f 3DG/C s ff : ( ) l iff s ; ( ) SLM l il- ss fl (l - s l f l l ; ( ) EMI SE; ( ) C s ff l iff l s ; ( ) S f 3DG/C EMI. (F l f l s l fi l , l s f l .)

Table 1
C l s f f l - s s l l s W s l EMI s l f l l f l - l l f l .

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

Note: l (l l)-PPMA, l s l -PS.

HT
in-situ
(Fig. 9a). Su
3DG/C
. I
HT
1–2
f
SLM
500 μm)
x(Fig. 9b),
(T 1). I
T
EMI, EMI *SE,*
(EM)
2–18 GH (Fig. 9c),
in-situ
SE
15.9 32.3 B,
47.8 B (88.2% in
20 B. T
3DG/C
. J K 44
EMI
EMI *SE*
133% in
(i., s
20 110 PPI (in).
R j K 45
EMI
. W
17 26 PPI (Fig. 9c insert)
105%
EMI *SE*. In
EMI
SLM. T
3DG/C
26 PPI
EMI *SE*
32.3 B,
99.9%
EMI
. T
60
(30
) 46 . T EMI
3DG/C
T 1. I
EMI *SE*
3DG/C
3D
T
EMI
(SE_r),
(SE_a)
(EM)
47 ,
48 . R 49
T
EMI
50 . R EMI
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51 . F
52
SiO_2 53 . W
3DG/C

SE_r
SE_a,
Fig. 9e. W
3DG/C
3DG/C
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EM
SE_r. O
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54 . I
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44 . T
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CVD
R
S 3.3
55 . I
EM
3DG/C
3DG/C
EMI
EMI

4. Conclusions

A 3DG/C
in-situ
CVD
3DG/C
EMI *SE*
15.9 ( )
32.3 B,
47.8 B (88.2% in
26.8%
3DG/C
EMI
3DG/C
EMI

Credit authorship contribution statement

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

Declaration of Competing Interest

T . . [illegible]

Acknowledgement

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

Appendix A. Supplementary data

S [illegible] ://[illegible]/10.1016/j.[illegible].2020.105904.

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