Supplementary Information (SI)

for

Laser-Induced Graphene: From Precursor Chemistry to Process Control and Throughput-Resolution-Performance Tradeoffs

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Table S1. Summary of literature for laser-induced graphene (LIG) on different precursors.

Precursor	Laser type	Wavelength	Conductivity (Sheet resistance)	Ref
Kapton	Nd:YVO_4	355 nm		1
Kapton	Nd:YAG	355 nm	3.5 S/cm	2
Kapton	Nd:YVO_4	355 nm		3
Kapton	Diode laser	405 nm		4
Kapton	CO_2 pulsed laser	10.6 µm		5
Cellulose nanofiber	Yb-doped fiber laser	522 nm	6.9 S/cm	6
Kapton	Diode laser	405 nm	3000 Ω/sq	7
Kapton	Nd:YVO_4	1064 nm		8
Kapton	CO_2 infrared laser	10.6 µm		9
Kapton	Pulsed CO_2 laser	9.3 µm		10
Kapton	CW CO_2 laser	10.6 µm	0.4 kΩ/mm	11
Phenolic resin (PR)	CO_2 infrared laser	10.6 µm		12
PMDA-ODA & 6FDA-TFMB	CO_2 infrared laser	10.6 µm		13
PES-Cd^{2+}	CO_2 infrared laser	10.6 µm	23 Ω/sq	14
PEI	CO_2 infrared laser	10.6 µm	6.39 Ω/sq	15
PSU, PES, & PPSU	CO_2 pulsed laser	10.6 µm		16
6FDA-ODA & DSDA-ODA	CO_2 infrared laser	10.6 µm	13 Ω/sq	17
PBI	CO_2 infrared laser	10.6 µm		18
poly (Ph-ddm)	CO_2 pulsed laser	10.6 µm	35 Ω/sq	19
PI & PEI	CO_2 infrared laser	10.6 µm	19.75 Ω/sq	20
Kapton	Diode laser	405 nm	250 Ω/sq	21
Photo resist (Microposit S1818 positive resist)	CO_2 infrared laser	10.6 µm		22
Kapton	CO_2 infrared laser	10.6 µm		23
Kapton	CO_2 infrared laser	10.6 µm		24
Kapton	UV laser	357 nm	Resistivity: 1.065×10^{-3} Ω•m	25
Kapton	UV laser	355 nm		26
Kapton paper	CO_2 infrared laser	10.6 µm		27
Kapton	CO_2 pulsed laser	10.6 µm		28
Kapton	CO_2 infrared laser	9.3 µm	75.57 Ω/sq	29
PGE-a	CO_2 infrared laser	10.6 µm	1900 S/m	30
Kapton	CO_2 pulsed laser	10.6 µm		31
Kapton	CO_2 infrared laser	10.6 µm		32
Kapton	Diode laser	455 nm	1.35 kΩ/mm	33
Patterned PI using PAA	CO_2 infrared laser	10.6 µm		34
Kapton	UV laser	355 nm		35
Kapton	CO_2 pulsed laser	10.6 µm		36
Kapton	CO_2 infrared laser	10.6 µm	60 Ω/sq	37
PDMS	Visible light	522 nm		38
PI-$AgNO_3$	Visible light	800 nm		39

Kapton + Co_3O_4, MnO_x, $NiFeO_x$	CO_2 infrared laser	10.6 µm		40
Kapton + $CoCl_2$-H_2O	CO_2 infrared laser	10.6 µm	10 S/cm	41
Kapton + CoNiFe, MnNiFe	CO_2 infrared laser	10.6 µm		42
Kapton + PAA-H_3BO_3	CO_2 infrared laser	10.6 µm		43
Kapton + PAA-H_3PO_4	CO_2 infrared laser	10.6 µm		44
Kapton-lignin	CO_2 infrared laser	10.6 µm	11.05 Ω/sq	45
LIG on PEEK + MnO_2	Visible light	532 nm		46
NiFe-LIG (catalyst)	CO_2 infrared laser	10.6 µm		47
$FeCl_3$-doped phenolic resin coating	Visible light	405 nm		48
LIG-CNT	CO_2 infrared laser	10.6 µm	188.31 S/m	49
PES + PVA coating	CO_2 infrared laser	10.6 µm		50
PES + SLS coating	CO_2 infrared laser	10.6 µm		51
PI + blue chitosan coating	CO_2 infrared laser	10.6 µm		52
PI + electrochemical deposition	CO_2 infrared laser	10.6 µm		53
PI + KOH coating	CO_2 infrared laser	10.6 µm	22 Ω/sq	54
PI + MoS_2 coating	CO_2 infrared laser	10.6 µm		55
PI + MoS_2 coating	CO_2 infrared laser	10.6 µm		56
PI + Zn ZnO coating	CO_2 infrared laser	10.6 µm		57
PI +Au metal precursor-chitosan hydrogel coating	Diode laser	405 nm		58
BCP + R(resol)	CO_2 infrared laser	10.6 µm		59
BCP-CMG	Ytterbium pulsed fiber laser	1064 nm		60
BCP-Resol	CO_2 infrared laser	10.6 µm	28 Ω/sq	61
wood blocks and leaves	Yb-doped fiber laser	343 nm	10 Ω/sq	62
cedar wood-Cu, Co, Ni, Fe, NiFe	CO_2 infrared laser	10.6 µm		63
Cellulose paper with $NH_4H_2PO_4$	CO_2 infrared laser	10.6 um	300 Ω/ sq	64
Celullose, lignin	CO_2 infrared laser	10.6 µm		65
CMCS, COS, and CSHC	CO_2 infrared laser	10.6 µm	CMCS-LIG: 2.2 kΩ/sq COS-LIG: 33.9 Ω/sq CSHC-LIG: 12.7 Ω/sq	66
CMCS/SLS slurry on wood	CO_2 infrared laser	10.6 µm		67
cold-pressed 100% cotton fiber watercolor paper	CO_2 pulsed laser	10.6 µm	40 Ω/sq	68
Copy paper pretreated with Gelatin-mediated inks containing Mo^{5+}	CO_2 infrared laser	10.6 µm	51.3 Ω/sq	69

Cork	CO_2 pulsed laser	10.6 µm	115 Ω/sq	70
Fallen Leaves	Ytterbium-doped fiber femtosecond laser	346 nm	10 Ω/sq	71
Filter paper pretreat with fire retardant	CO_2 infrared laser	10.6 µm	32 Ω/sq	72
Filter paper pretreat with fire retardant	Nd:YVO_4 pulsed lase	355 nm	125 Ω/sq	73
Lignin - coconut - potato - cork - paper	CO_2 pulsed laser, fiber laser	CO_2 pulsed laser: 10.6 µm, 9.3 µm; fiber laser: 1.06 µm		74
Coconut	CO_2 pulsed laser	10.6 µm		74
Potato	CO_2 pulsed laser	10.6 µm		74
Charred Bread	CO_2 pulsed laser	10.6 µm	5 Ω/sq	74
Boric Acid treated paper	CO_2 pulsed laser	10.6 µm		74
Charred Wood	CO_2 pulsed laser	10.6 µm	8 Ω/sq	74
PEI	CO_2 pulsed laser	10.6 µm	15 Ω/sq	74
Charred Whatman filter paper	CO_2 pulsed laser	10.6 µm		74
Lignin	CO_2 infrared laser	10.6 µm	3.8Ω/sq	75
Lignin(PVA,urea film)	CO_2 infrared laser	10.6 µm	2.8Ω/sq	76
Lignin	CO_2 infrared laser	10.6 µm		77
Ni and Sucrose	CO_2 infrared laser	10.6 µm	13.8 S/cm	78
Paper pretreated with wax	CO_2 infrared laser	10.6 µm	56 Ω/sq	79
Paperboard	CO_2 infrared laser	10.6 µm	Resistivity: 4.77 mΩ•m	80
PFA poly(furfurylalcohol)	CO_2 infrared laser	10.6 µm	13 Ω/sq	81
Pine Wood	CO_2 infrared laser	10.6 µm	10 Ω/sq	82
Silk fabric with thermal pretreatment	Fiber laser	1064 nm	40 Ω/sq	83
Silk fibroin with thermal pretreatment	CO_2 infrared laser	10.6 µm	5.5 Ω/sq	84
Kapton	UV- FS laser	355 nm	128.16 Ω/sq	85
Kapton	Yb:KGW	515 nm		86
Kapton	CO_2 infrared laser	10.6 µm		87
Kevlar	Yb-doped fiber laser	1030 nm		88
Kevlar	CO_2 infrared laser	10.6 µm	10.6 Ω/sq	89
PDMS	Diode laser	405 nm	5 kΩ/sq	90
PDMS-TEG	CO_2 infrared laser	10.6 µm	130 Ω/sq	91
PEEK	CO_2 infrared laser	10.6 µm	25 Ω/sq	92
Phenolic Paper	CO_2 infrared laser	10.6 µm	41 Ω/cm	93
Teflon	CO_2 pulsed laser	9.3 µm		94
Coal	CO_2 infrared laser	10.6 µm	30 Ω/sq	95
Graphite Oxide	Picosecond laser	1064nm		96
Graphite Oxide	Diode laser	532 nm		97
Bhitosan -borax	CO_2 infrared laser	10.6 µm	110 Ω/sq	98

Epoxy-APP	CO_2 infrared laser	10.6 µm	9 Ω/sq	99
Epoxy-APP	CO_2 infrared laser	10.6 µm		100
PI + metal omplex	CO_2 infrared laser	10.6 µm		101
PBI-H_3PO_4	CO_2 infrared laser	10.6 µm		102
Phenolic resin(PR)-PVA	CO_2 infrared laser	10.6 µm	34.53 S/m	103
PI+activated carbon	CO_2 infrared laser	10.6 µm	30.12 Ω/sq	104
PI ion gel	CO_2 infrared laser	10.6 µm	30 Ω/sq	105
Pi with Pd nanoaprticle	CO_2 infrared laser	10.6 µm	24 S/cm	106
Pi with Pt nanoparticle	CO_2 infrared laser	10.6 µm		107
Pi with Pt nanoparticle	CO_2 infrared laser	10.6 µm		108
PI with Pt-Au nanpparticle	CO_2 infrared laser	10.6 µm		109
PI-APP(Ammonium polyphosphate)	CO_2 infrared laser	10.6 µm		110
PI-CMC-borax	CO_2 infrared laser	10.6 µm	5 Ω/sq	111
PI- H_3BO_3	Semiconductor diode laser	450 nm	25 Ω/sq	112
PI- H_3BO_3	CO_2 infrared laser	10.6 µm		113
PI-PDMS	CO_2 infrared laser	10.6 µm	100 Ω/sq	114
PMIA-$KMnO_4$	CO_2 infrared laser	10.6 µm		115
Polyolefin	CO_2 infrared laser	10.6 µm	76.2 Ω/sq	116
Transfer to different thermoplastics from PI	CO_2 infrared laser	10.6 µm		117
layer by layer PI - LIG - MXene - laccase enzyme -mis283	CO_2 infrared laser	10.6 µm		118
Stacked supercapacitor from PU	Femtosecond fiber laser	1030 nm	25 Ω/sq	119
Transfer to elastomer or sugar composites from PI	CO_2 infrared laser	10.6 µm	10.96 Ω/sq	120
Trasnfer to PDMS from PI	CO_2 nanosecond laser	10.6 µm		121
Trasnfer to PDMS from PI	CO_2 infrared laser	10.6 µm	170 Ω/sq	122
Transfer to PDMS with Ag coating	CO_2 infrared laser	10.6 µm		123
Transfer to PDMS with AgNW coating	CO_2 infrared laser	10.6 µm	21 Ω/sq	124
Transfer to PDMS	CO_2 infrared laser	10.6 µm		125
Transfer to PET with Pd Np	CO_2 infrared laser	10.6 µm		126
Transfer to PET	Picosecond laser	355 nm	12 Ω/sq	127
Transfer to polyeurathrene	CO_2 infrared laser	10.6 µm		128
Transfer to PU with sandwich structure	CO_2 infrared laser	10.6 µm		129

Table S2. Literature-derived dataset compiling resolution-performance benchmarks for LIG across different precursors. Reported parameters include printing speed (used as a throughput proxy), line width (printing resolution), sheet resistance, laser type, wavelength and power.

Precursor	Laser type	Line width (μm)	Speed (mm/s)	Power (W)	Wavelength (nm)	Sheet resistance (Ω/sq)	Reference
Wood blocks and leaves	Yb-doped fiber laser	40	35	0.1–0.8	343	400	[62]
Commercial PI	Nd:YVO4	50	60	0.3	355		[3]
Commercial PI	CO_2 laser	57	180	0.161	10600		[5]
Cellulose nanofiber	Yb-doped fiber laser	200	0.25	0.1 - 0.15	522		[6]
Commercial PI	CO_2 laser	130	500	11.7	10600	183.69	[11]
PMDA-ODA & 6FDA-TFMB	CO_2 laser	175	491	12.5	10600		[13]
PEI	CO_2 laser	140	25.4	27	10600	48.6	[15]
6FDA-ODA & DSDA-ODA	CO_2 laser	80	500	12.5 ~ 28.1	10600	170	[17]
Commercial PI	CO_2 laser	350	1200	2 ~ 40	10600		[20]
Phenolic resin (PR) or PR-Fe coated	Visible light	160	200	0.5	405	96.1	[48]
Commercial PI	CO_2 laser	200	220	6.2	10600		[23]
Commercial PI	UV laser	315	20	8	357	1081.9	[25]
Commercial PI	UV laser	18	11		355		[26]
Commercial PI	CO_2 laser	177	200		10600		[130]
Commercial PI	CO_2 laser	60	5	0.22	9300		[29]

PGE-a	CO_2 laser	88	190	3	10600		[30]
Commercial PI	CO_2 laser	177	1000	4	10600		[31]
Commercial PI	Diode laser	135	5	1.8	455	143.1	[33]
Commercial PI	UV laser	100	150		355		[35]
Commercial PI	CO_2 laser	116	50		10600		[36]
PDMS	Visible light	100	2	0.1	522		[38]
$AgNO_3$−PI	Visible light	6.5	2		800		[39]
Commercial PI	CO_2 laser	260	300	12	10600		[131]
Commercial PI	Fiber laser	38	1	0.2	1030	220	[119]
PI+activated carbon	CO_2 laser	150	375	5.7	10600	30.12	[104]
Commercial polyimide	Diode laser	13		0.161	405	1000	[7]

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