Supplementary material

Review

Recent Progress on Graphene/Polyaniline Composites for High-performance Supercapacitors

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Abbreviations

polyaniline (PANI)
two dimensional (2D)
three dimensional (3D)
ammonium persulfate (APS)
graphene oxide (GO)
vanadium pentoxide hydrate ($V_2O_5 \cdot nH_2O$)
p-toluenesulfonic acid (PTSA)
polystyrene (PS)
polymethyl methacrylate (PMMA)
reduced graphene oxide (rGO)
mesoporous silica ($mSiO_2$)
PANI hollow fibers (PANI-HF)
polyacrylonitrile (PAN)
multidimensional (MD)
polyvinyl alcohol (PVA)
polyethylene glycol (PEG)
N-methylpyrrolidinone (NMP)
polycarbonate (PC)
dodecyl benzene sulfonic acid (DBSA)
porous tubular carbon (PTC)
glassy carbon electrode (GCE)
stainless steel fabric (SSF)
chloroform ($CHCl_3$)
$CHCl_3$-treated PANI (HSSA-PANI)
pristine graphene (PG)
graphene quantum dots (GQDs)
graphene microspheres (GMS)
sulfonated graphene (GS)
aminated graphene (GN)
amino-functionalized graphene sheets (AFG)
graphene (G)
p-phenylenediamine (PPD)
PANI nanofiber/N-doped graphene hydrogels (PNGH)
graphene aerogel (GA)
m-phenylenediamine (mPD)
graphene hydrogel (PGH)
phytic acid (PA)
amino-triazine (AT) functionalized rGO (ATrGO)
2, 4, 6-Trichloro-[1, 3, 5] triazine (TCTA)
ST functionalized graphene sheets (STGNS)
tannic acid (TA)
pyrenebutyric acid (PBA)
oriented graphene hydrogel (OGH)
cellulose nanofibers (CNF)
graphite nanoplatelets (GNP)
carbon black (CB)
carbon nanofiber (CNF)
PS/reduced graphene (PS/rGN)
silver nanoparticles (AgNPs)
exfoliated graphite (ExG)
graphene woven fabric (GWF)
graphite sheet (FGS)
carbon woven fabric (CWF)
chemical vapor deposition (CVD)
nickel foam (NF)
rGO foam (rGO-F)
multi-growth site graphene (MSG)
nitrogen-doped graphene/PANI (N-GE/PANI)
nitrogen-doped 3D interconnected graphene (N-3D-rGO)
unidirectional graphene aerogel (UGA)
self-suspended polyaniline (S-PANI)
graphene paper (GP)
graphene/sulfonated PANI (rG/SP)

Table S1. The performance of graphene and PANI composites for supercapacitors.

Electrode materials	C_m (F g^{-1})	C_A (mF cm^{-2})	C_V (F cm^{-3})	Cycle life	Refer
graphene/PANI electrode	480 (0.1 A g^{-1}) 3-electrode				38
rGO-PANI electrode	286 (5 mV s^{-1}) 3-electrode			94% capacitance after 2000 cycles (50 mV s^{-1})	39
GO/PG/PANI ternary composite	793.7 (1 A g^{-1}) 3-electrode			80% capacitance after 1000 cycles (100 mV s^{-1})	40
GQDs-PANI composites	1044 (1 A g^{-1}) 3-electrode			80.1% capacitance after 3000 cycles (1A g^{-1})	42
Microspherical polyaniline/graphene (PANI/GMS)	338 (20 mV s^{-1}) 2-electrode			87.4% capacitance after 10000 cycles (3A g^{-1})	43
PANI/G-MS	596.2 (0.5 A g^{-1}) 447.5 (20 A g^{-1}) 3-electrode			83.7% capacitance after 1500 cycles (2A g^{-1})	44
PANI/GO composite	475 (5 A g^{-1}) 3-electrode			90% capacitance after 2000 cycles (10A g^{-1})	45
PANI-GS composite	863.2 (0.2 A g^{-1}) 3-electrode			85.6% capacitance after 1000 cycles (1A g^{-1})	46
GMPH7 electrode	514.3 (1 A g^{-1}) 3-electrode	584.7 2-electrode		12.9% capacitance loss after 1000 cycles (10A g^{-1})	47
DN-PGH/PANIPA		3488.3 (0.5 mA cm^{-2}) 2-electrode	872	82.1% capacitance after 10000 cycles (20 mA cm^{-2})	48
Polyaniline-graphene composites	1295 (1 A g^{-1}) 3-electrode			98% capacitance after 1500 cycles(100 mV s^{-1})	51
PANI/GO	442 (1 A g^{-1}) 3-electrode			83% capacitance after 2000 cycles (2A g^{-1})	52
Chemically grafted graphene-polyaniline composite (a-G-PANI200)	422 (1 A g^{-1}) 3-electrode			68.7% capacitance after 1000 cycles (1A g^{-1})	53
PANI nanofiber/N-doped graphene hydrogels (PNGH)	610 (1 A g^{-1}) 3-electrode			94.3% capacitance after 1000 cycles (20A g^{-1})	54
GA/PANI composite	108 (1 A g^{-1}) 3-electrode			83.2% capacitance after 10000 cycles (10A g^{-1})	55
PANI-ATRGO	1510 (1 A g^{-1}) 3-electrode			89% capacitance after 1500 cycles(100 mV s^{-1})	59

sulfur functionalized PANI/FrGO composite films	692 (1 A g^{-1}) 3-electrode 324.4 (1 A g^{-1}) 2-electrode			83.3% capacitance after 1000 cycles (10A g^{-1})	60
PANI-STGNS10	1225 (1 A g^{-1}) 3-electrode			85.7% capacitance after 1500 cycles (100 mV s^{-1})	61
Flexible rGO/PANI nanocomposite film		920 2-electrode	1314.3	80% capacitance after 2000 cycles (7 mA/cm^2)	62
Porous PANI-RGO composite	630 (0.5 A g^{-1}) 3-electrode			81% capacitance after 5000 cycles	63
Flexible paper-like film of PANI nanofibers (PANI-NFs) and chemically converted graphene (CCG)	210 (0.3 A g^{-1}) 2-electrode			21% loss after 800 cycles (3A g^{-1})	64
OGH-PANI composite film	530 (0.5A g^{-1}) 2-electrode			80% capacitance after 10000 cycles (10A g^{-1})	65
Core-shell structured CB@CNF/PANI membrane	501.6 (0.5 A g^{-1}) 3-electrode			91% capacitance after 5000 cycles	66
PANI nanorods on the peeled reduced GO paper	763 (1 A g^{-1}) 3-electrode			82% capacitance after 1000 cycles (5A g^{-1})	67
GWF+PANI composite electrode		23 2-electrode		~100% capacitance after 2000 cycles	68
CNF/GNP substrate generated with worm-like PANI nanorods	421.5 (1 A g^{-1}) 2-electrode			78.3% capacitance after 1000 cycles (8A g^{-1})	69
Porous rGN/PANI composite film	740 (0.5 A g^{-1}) 3-electrode		510	87% capacitance after 1000 cycles (10A g^{-1})	70
PANI/ExG/cellulose/AgNPs	240.10	3840 at 5 mA			71
flexible FGS-SSG/PANI composite electrodes	491.3 (50 mV s^{-1}) 3-electrode			86% capacitance after 3000 cycles (50 mV s^{-1})	72
PANI/rGO fabric composite		790 F cm^{-2} (1 A cm^{-2}) 3-electrode		88.9% capacitance after 5000 cycles (10A g^{-1})	73
3D graphene framework grew vertically aligned PANI nanocones	751.3 (1 A g^{-1}) 3-electrode	3.0		93.2% capacitance after 1000 cycles (10A g^{-1})	75
3D graphene network growing PANI nanofibers	1002 (1 mA cm^{-2}) 3-electrode			86.5% capacitance after 5000 cycles (4 mA/cm^2)	76
3D hierarchical porous PANI-NFS/GF composite	1474 (0.47 A g^{-1}) 3-electrode		86	83% after 15,000 cycles	77

Graphene/PANI electrodes	261.24 (0.38 A g^{-1}) 2-electrode			89% capacitance after 1000 cycles (1mA/cm^2)	78
RGO-F/PANI	790 (1 A g^{-1}) 2-electrode		205.4	80% capacitance after 5000 cycles (1 A g^{-1})	79
Carbon foam@reduced graphene oxide scaffold grown with PANI nanofibers	868.5 (1 A g^{-1}) 2-electrode			94.1% capacitance after 2000 cycles (10A g^{-1})	81
Flexible fRGO-F/PANI composites	939 (1 A g^{-1}) 2-electrode			88.7% capacitance after 5000 cycles (1 A g^{-1})	82
GH/PANI electrode	710 (2 A g^{-1}) 2-electrode			86% capacitance after 1000 cycles (2A g^{-1})	84
3-D graphene/PANI	352 (10 mV s^{-1}). 2-electrode				85
3D hierarchical porous rGO-PANI aerogels		453		90% capacitance after 3000 cycles 100 mV s^{-1}	86
rGO/PANI (50%)	1182 (1 A g^{-1}) 3-electrode 808 (1A g^{-1}) 2-electrode			108% capacitance after 10000 cycles (10 A g^{-1})	87
3D graphene/PANI hydrogels	648 (0.5 A g^{-1}) 3-electrode			88% capacitance after 1000 cycles (1 A g^{-1})	88
3D RGO-g-PANI	1600 (12 A g^{-1}) 3-electrode			91.3% capacitance after 3000 cycles (4 A g^{-1})	89
Sheet-like graphene/PANI composite	532.3 (2 mV s^{-1}) 3-electrode			99.6% capacitance after 1000 cycles (50 mV s^{-1})	90
GH/PANI composite	323.9 (2 mV s^{-1}) 2-electrode			99% capacitance after 1000 cycles	91
3D MSG/PANI composite	912 (1 A g^{-1}) 3-electrode			86.4% capacitance after 10000 cycles (20A g^{-1})	92
(N-GE/PANI)	528 (0.1 A g^{-1}) 3-electrode			95.9% capacitance after 5000 cycles (5 A g^{-1})	93
3D-rGO/PANI composite electrode	243 (1 A g^{-1}) 3-electrode			86% capacitance after 1000 cycles (1 A g^{-1})	94
3D porous PANI/RGO composite	808 (53.33 A g^{-1}) 3-electrode	5.717 (377.4 mA cm^{-2})	.		95
rGO/PANI composite	438.8 (0.5A g^{-1}) 2-electrode			76.5% capacitance after 2000 cycles (4 A g^{-1})	96
N-3D-rGO/PANI-B	282 (1 A g^{-1}.) 3-electrode			69% capacitance after 1000 cycles (2 A g^{-1})	97

UGA/PANI composites	538 (1 A g^{-1}) 3-electrode			74% capacitance after 1000 cycles (3 A g^{-1})	98
3D-G/PANI composite	567 (1 A g^{-1}) 3-electrode (77.8 Wh Kg^{-1}) 2-electrode		720 3-electrode	100% after 10000 cycles 5 A g^{-1}, 3-electrode 95.6% for 10,000 cycles 2-electrode	99
Graphene/PANI composite nanosheets	665 (1 A g^{-1}). 2-electrode		847	86% capacitance after 1000 cycles (20 A g^{-1})	100
3D RGO/S-PANI aerogel	480 (1 A g^{-1}) 2-electrode			96.14% after 10,000 cycles (10 A g^{-1})	101
RGO/PANI/RGO hybrid paper	581 (1 A g^{-1})			85% capacitance after 10000 cycles (10A g^{-1})	107
GH-PANI/GP	864 (1 A g^{-1}) 2-electrode	190.6 (0.5 mA cm^{-2})		85.6% capacitance after 5000 cycles (8 A g^{-1})	108
PANI/rGO electrodes		1329 2-electrode		75% capacitance after 1000 cycles 50 mA cm^{-2}	109
Graphene/sulfonated PANI (rG/SP)		3.31	16.55 2-electrode	85.4% capacitance after 10000 cycles	110

From Table S1, among 59 papers about composite electrode, 22% of works (13 papers) had a specific capacitance of more than 800 F g^{-1}, and only 6.78% works (four papers) achieved the higher capacitance (≥800 F g^{-1}) in two-electrode systems. From the long-term cycling performance, 16.95% works (10 papers) list the capacitance retention over 10,000 cycles, and only 10.17% works (six papers) have a high capacitance retention (≥85%). Therefore, there is still a long way to further enhance the electrochemical performance of graphene/PANI composite electrodes.

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