



## Review

## Evolution from graphite to graphene elastomer composites



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## ABSTRACT

Elastomer composites have established a unique position among technologically important materials because of their extensive and potential applications. Considerable interest has been devoted to graphite derived elastomer composites, known as new generation materials, due to their exceptional electrical, mechanical and permeability properties. The discovery of graphene opened a promising aspect towards the synthesis of elastomer nanocomposites. A thorough investigation of the properties of various graphitic fillers, such as natural graphite flakes, expanded graphite (EG), graphite nanoplatelets (GNP) and graphene is undertaken in this review. The dependence of these fillers on the rheological, electrical (sensing), mechanical, thermal, dielectric and barrier properties of elastomer composites is discussed, giving special emphasis to particle size and mode of interactions with the matrix. A systematic evolution from microcomposites to nanocomposites is shown to give definitive evidence of the importance of graphene nanocomposites. Most preparation methods of these composites are covered, including, solution blending, latex compounding, in situ polymerization, and melt intercalation. Graphene exhibits very good dispersion in most elastomers and substantially improves the mechanical and electrical properties of the matrix compared to all other graphite derivative composites. A review of the potential applications of these composites and current challenges is provided in order to guide future progress on the development of more promising materials.

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### Nomenclature

A/C	acid–graphite and coupling agent
$A_f$	aspect ratio
AGs	acid graphite platelets
AGT	acid graphite with thermal shock
AFM	atomic force microscopy
AGS	acid graphite with sonication
AGTS	acid graphite with thermal shock and sonication
BYK-9076	alkylammonium salt of high molecular weight copolymer
CNF	carbon nano fibers
CB	carbon black
CNT	carbon nanotube
CVD	chemical vapor deposition
CRG or GE	chemically reduced graphene
CTAB	cetyltrimethyl ammonium bromide
CuPc	copper phthalocyanine
DMF	dimethyl formamide
EG	expanded graphite
FGS	functionalized graphene sheet
GNP or GN	graphite nano platelets
GIC	graphite intercalation compounds
GO	graphene oxide
GONP	graphite oxide nanoplatelets
HR-TEM	high resolution-transmission electron microscopy
HAF	high abrasion furnace black
HXNBR	hydrogenated carboxylated nitrile–butadiene rubber
HTAB	hexadecyl trimethyl ammonium bromide
iGO	isocyanate treated graphene oxide
IIR	poly(isobutylene–isoprene) rubber
LCM	latex compound method
MMT	montmorillonite

MLGS	multilayer graphene sheets
MG	modified graphene
MM	melt mixing
NR	natural rubber (poly isoprene)
NGs	natural graphite
NMR	nuclear magnetic resonance
NGT	natural graphite with thermal shock
NGS	natural graphite with sonication
NGTS	natural graphite with thermal shock and sonication
NFG	natural flake graphite
NBR	nitrile–butadiene rubber
XNBR	carboxylated nitrile–butadiene rubber
NBR-PVC	nitrile butadiene rubber with poly(vinyl chloride)
PMN-PT	lead magnesium niobate–lead titanate
PDMS	polydimethylsiloxane
PAC	polyaluminium chloride
PHT	poly(3-hexylthiophene)
Ph-iGO	phenyl isocyanate treated graphene oxide
RTVSR	room temperature vulcanising silicone rubber
RGO	reduced graphene oxide
SWCNT	single wall carbon nanotube
SEM	scanning electron microscopy
SDS	sodium dodecyl sulfate
SR	silicone rubber
SBR	styrene–butadiene rubber
TEGO	thermally expanded graphene oxide
TEM	transmission electron microscopy
TRG	thermally reduced graphene
TPU	thermoplastic polyurethane
ULMR	ultrasonically assisted latex mixing and in situ reduction

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