A Brief Review: Study on Mechanical Properties of Polycarbonate with Different Nanofiller Materials

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Abstract Recently, the use of polycarbonate has been studied intensively and many researchers started producing polycarbonate-based composites by introducing different carbon-based nanofillers. Significant improvement in mechanical properties of polycarbonate has been reported due to the inclusion of even small amount of nanofillers. Enhancement of properties through the inclusion of nanofillers into polycarbonate matrix will be useful for both application-based investigations and scientific studies. Current study provides some insights of different research papers based on polycarbonate composites. Present literature shows that inclusion of small quantity of nanofiller in to polycarbonates can significantly enhance various mechanical properties.

Keywords Polycarbonate · Composites · Nanofiller · Mechanical properties

Abbreviations

PC	Polycarbonate
ABS	Acrylonitrile-butadiene-styrene
PEI	Polyetherimide
EMA	Ethylene-methyl acrylate
PBT	Polybutylene terephthalate
EPC	Ethylene-propylene copolymer
MWCNT	Multiwalled carbon nanotube
SWCNT	Single wall carbon nanotube
GO	Graphene oxide
RGO	Reduced graphene oxide

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1 Introduction

1.1 Polycarbonate

Polycarbonate is a thermoplastic material which is strong and unbreakable. Polycarbonate contains polymers with carbonate groups and it is produced by reacting bisphenol A with phosgene. Polycarbonate possesses good mechanical, thermal, and electrical properties. Due to these properties, polycarbonates are used for industrial applications like window shades, CD's and DVD's, eye glasses, roof sheets, aeronautical, and military applications [1]. Polycarbonate has high impact strength, but it is less scratch resistance, scratches can be formed easily on applications like eye wears, automotive parts, so they are coated with scratch resistance coatings. The demand for production of polycarbonate is increasing all over the world due to its properties and applications [2]. Polycarbonate is transparent and lightweight compared to other thermoplastics. The properties of the polycarbonate can be further more increased by introduction of different nanoparticles in to polymer matrix [3]. The mechanical properties, e.g. tensile strength, impact resistance, and ultimate tensile strength can be enhanced by introducing nanofillers like graphene, graphene oxide, reduced graphene oxide, carbon nanotubes, and many other nanofillers. The improved properties can be useful for different applications [4].

2 Literature Review

Polycarbonate has good mechanical, electrical, and thermal properties. We can further more increase the properties of polycarbonate by incorporating polycarbonate matrix with different nanofillers. Nanofillers like CNT, graphene, carbon nanofillers, and other fillers can be reinforced with polymer matrix to improve mechanical properties [5]. Nanofiller like graphene can be used to improve mechanical properties of polycarbonate. Graphene is thinnest material available in the world. Graphene alone has good mechanical, electrical, and thermal properties. Incorporating of very small amount of graphene into polymer matrix increases mechanical, electrical, and thermal properties. Graphene is reinforced with polycarbonate matrix by using solution blending technique to prepare PC/G composite and its properties are investigated. By introducing graphene in to polymer matrix, the mechanical and electrical properties of the composites are boosted [6]. Carbon nanotubes are allotropes of carbon. Carbon nanotubes are of two types (1) SWCNT and (2) MWCNT. Single walled nanotubes have diameter less than 1 nanometer (nm), where as multiwalled nanotubes have diameters reaching up to 100 nm (nm). Both single walled and multiwalled nanotubes have high mechanical strength and electrical conductivity. Introducing small amount of single walled or multiwalled nanotubes in to polymer matrix increases the properties of that composite. Different types of MWCNT are reinforced with polycarbonate and investigated on mechanical, electrical, and glass

transition behaviour of the composites. It is found that by reinforcing polycarbonate with MWCNT improves the mechanical properties but there is a slight decrease in the glass transition temperature of composites [7]. SWCNT are reinforced with polycarbonate to investigate on mechanical and electrical conductivity of the composite. The mechanical properties of the composites increased by addition of very less amount of SWCNT in polycarbonate matrix [8]. Nanofiller particles like ZnO, sic, TiO_2, ZrO_2, Al_2O_3 can be reinforced with polymer matrix to obtain better mechanical properties. These nanofillers are called nanooxides, and these fillers can be used as reinforcing agents in polymer matrix. Nanofiller like nanoclay can also use as reinforcing agent in polymer matrix, but nanoclay in some cases reduces the tensile strength of polymer composites and improves Young's modulus. Polycarbonate reinforced with TiO_2 and investigated on mechanical properties of composite. The mechanical properties like tensile strength and hardness of the nanocomposite can be increased by increasing TiO_2 content in the polymer matrix [9]. Polycarbonate is reinforced with glass fibre and its mechanical properties are investigated. Glass fibre with 10% and 20% taken as compositions in polycarbonate matrix and mechanical properties like tensile strength, flexural strength, and hardness is investigated. The results revealed that glass fibre with 10 wt.% has shown increase in tensile strength up to 253 N/m^2 compared to 247 N/m^2 of 20% glass fibre. Flexural strength has also increased to 160 N/m^2 compared to 130 N/m^2 of 20% glass fibre. From the results, it has been observed that increase in glass fibre content decreases the strength of the composite [10]. Polycarbonate reinforced with 3 wt.% CNT and the effect of recycling on the structure and properties of the composites are investigated. Polycarbonate with 3 wt.% CNT has Young's modulus of 6000 Mpa compared to neat PC of 2600 Mpa. Recycling of the composite up to 20 times is carried and the results were compared between neat PC and CNT/PC composites. After 20 recycles, it was found that the Young's modulus of CNT/PC is 5000 Mpa which is still higher than neat PC, and it is still suitable for many applications, whereas the tensile strength of the composite is decreased to 18 Mpa with less than neat PC of 51 Mpa., and the impact strength of the CNT/PC reduced to 60 J/m. From the results, it has been observed that recycling the composites affect the strength of the composites [11]. Polycarbonate was grafted on to functionalized graphene nanosheets, and properties are compared with polycarbonate graphene nanosheets of simple mixing. It has been observed that PC-g-MGNS of 3 wt.% has increased tensile strength up to 81 MPa and Young's modulus up to 2270 MPa which is 20.5 and 22.7% higher than that of conventional PC-s-GNS [12]. Polycarbonate reinforced TiO_2 nanocomposite films are prepared and its mechanical properties like tensile strength, hardness, and elastic modulus are investigated. The tensile strength of the composite increased up to 18% by addition of only 2 wt.% of TiO_2. The elastic modulus also increased by addition of only 0.8 wt.% of TiO_2 [13]. Polycarbonate is reinforced with multiwalled carbon nanotubes and its mechanical, and thermal properties are investigated and it was found that by addition of only 10 wt.% of multiwalled carbon nanotube in to polycarbonate matrix shows decrease up to 35% in tensile strength and 47% decrease in tensile strength of the composite.

Addition of 1–5 wt.% of MWCNT in polycarbonate shows good mechanical properties, but addition of 10 wt.% shows decrease in mechanical properties like tensile strength and bending strength (Table 1).

It has been observed from the above discussion that introducing small amount of nanofiller in polycarbonate matrix has improved mechanical properties like tensile strength, Young's modulus, impact resistance, and flexural strength of the composite.

3 Discussion and Conclusion

The present literature depicts study on improving mechanical properties of polycarbonate using different nanofillers. The nanofillers mainly used in this literature works are graphene, carbon nanotubes, clays, and nanooxides. By introduction of nanofillers in to polycarbonate matrix improved the properties like tensile strength, Young's modulus, and impact strength. Above study shows maximum tensile strength of 253 GPa when polycarbonate reinforced with glass fibre. Also, it depicts maximum Young's modulus of 6000 Mpa when polycarbonate reinforced with 3 wt.% CNT. Since PC shows different characteristics for different applications, there is a substantial room for improvement in various mechanical, optical as well as electrical properties.

Table 1 Mechanical properties of polycarbonate reinforced with different nanofillers

Matrix	Reinforcement	Tensile strength (MPa)	Young's modulus (MPa)	Impact (J/m)	References
PC/ABS	4 wt.% T-RGO	+135	–	–	[14]
PC	2 wt.% WO_3	+53.6	+1527	–	[15]
PC	3 wt.% ZrO_2	+59	–	+1240	[16]
PC	30 wt.% SGF	+107.4	+2966	−31.5	[17]
PC	2 wt.% Al_2O_3	+73	+3000	–	[18]
PC	7 wt.% GNP	+70	–	−20	[19]
PC	0.5 wt.% ZNO	+61.0	+1957	–	[20]
PC	Glass fibre	+138	+11.0	+218	[21]
PP/PC	1 wt.% GO	–	+2516	+40	[22]
PC/PLA	30 wt.% carbon fibre	+114.6	–	–	[23]
PC/PEI	Glass fibre	190.82	+ 6.25	−153.61	[24]
PC/EMA	10 phr Ir-GO	70	+90	–	[25]
PC/PBT	4 wt.% c-MWCNT	+65.9	+2116	–	[26]

(continued)

Table 1 (continued)

Matrix	Reinforcement	Tensile strength (MPa)	Young's modulus (MPa)	Impact (J/m)	References
PC/EPC	1 wt.% MWCNT	57.39	+1320	–	[27]
PC/ABS	10 phr MICA	−54.8	+1162	−582	[28]
PC	15 vol% SCF	+95	+2500	–	[29]
PC/ABS	3 wt.% GNP	+58.37	+2820		[30]
PC	0.5 phr organ clay	+65	+1600		[31]
PC	0.1 wt.% SWCNT	+26		+0.05	[32]
PC	5 vol% CNT/CU	467	111		[33]
PBT/PC	0.3 wt.% MWCNT	+85	+4.0	+72	[34]

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