Polypropylene hybrid composites for the automotive industry

Marisa C. Rocha[1], Nancy I. Alvarez Acevedo[1], Jorge Futigami[1], Yesica Jiménez[2], and Ana L. N. da Silva[3]

[1] Polytechnic Institute, Rio de Janeiro State University, Nova Friburgo, Brazil; mrocha@iprj.uerj.br, nacevedo@iprj.uerj,br, jfutigami@iprj.uerj.br; www.iprj.uerj.br.

[2] Materials Science Engineering, Ohio State University, Columbus, USA; jimenez.225@buckeyemail.osu.edu, https://mse.osu.edu/.

[3] Institute of Macromolecules Professor Eloisa Mano, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil; ananazareth@ima.ufrj.br, www.ima.ufrj.br.

INTRODUCTION

Short fiber composites are increasingly used for applications in the automotive industry, which requires lightness, while maintaining the structural strength and safety characteristic of vehicles [1]. Polypropylene (PP) is the most used thermoplastic in the automotive industry. The growing demand for polypropylene composites reinforced with carbon fiber or glass fiber has increased the consumption of this material [2,3].

Hybrid composites are receiving a lot of attention, because the incorporation of nanoparticles not only strengthens the matrix, but also improves the polymeric matrix-SCF surface interactions [4-5]. Graphene, fullerene and carbon nanotubes have shown interesting properties for use in nanocomposites.

In this study, the effect of incorporation of short carbon fiber together with graphene nanoplatelets (GN) to polypropylene on the composites performance is explored, The response surface methodology was used to model the mechanical properties as a function of the composition of the hybrid composites.

This work is part of a research project aimed at developing low-density and low-cost products for the automotive industry, with satisfactory mechanical performance and dimensional stability, processed on a large scale by injection molding.

MATERIALS AND METHODS

Materials

Polypropylene (PP), Braskem H503 , melt flow, 3.5 g/10 min (230 °C/2.16 kg)., powder (maximum average size particle of 1 mm.). Short carbon fiber (SCF), Tenax^{TM}-A/J HT C804 (nominal diameter, 7µm; length/diameter, 100; an density of 450 g/l). Graphene nanoplatelets (GN), xGnP, Sigma Aldrich, surface area, 750 m^2/g; volumetric density, 0.2 - 0.4 g/cm^3. Antioxidant, Irganox 1010, BASF, 1% m/ m

Composites preparation

Table I shows the composition of the materials defined by Minitab 19 software (option-simplex lattice design for three components).

Sample	Polypropylene -PP (%)	Graphene - GN (%)	Short Carbon Fiber - SCF (%)
100 PP	100	0	0
95/5 PP/GN	90	5	0
80/20 PP/SCF	80	0	20
75/5/20 PP/GN/SCF	75	5	20
97.5/2.5 PP/GN	97.5	2.5	0
90/10 PP/SCF	90	0	10
77.5/2.5/20 PP/GN/SCF	77.5	2.5	20
85/5/10 PP/GN/SCF	85	5	10
87.5/2.5/10 PP/GN/SCF	87.5	2.5	10
93.75/1.25/5 PP/GN/SCF	93.75	1.25	5
91.25/3.75/5 PP/GN/SCF	91.25	3.75	5
83.75/1.25/15 PP/GN/SCF	83.75	1.25	15
81.25/3.75/15 PP/GN/SCF	81.5	3.5	15

Table 1. Formulation of the composites defined by mixture design methodology.

Co-rotating twin-screw extruder (Leistritz/ZSE 18 MAXX - 40 D) was used to prepare composites. Speed, 500 rpm; Temperature profile (feed to die), 200/210/190/90/190/190/200/220/220/230 °C. After extrusion, the composites were granulated and dried in an oven at 80 °C.

Composites characterization

Melt flow index (MFI) - ASTM D1238 determination; Thermogravimetric analysis (TGA/DTG); Impact test by Izod method - ASTM D256 and 3-point bending flexural test - ASTM D790

The specimens for mechanical tests were obtained by injection molding. The effect of incorporating GN and SCF into a PP matrix, on the mechanical and thermal stability of the polymer was evaluated using a response surface methodology.

PRELIMINARY RESULTS

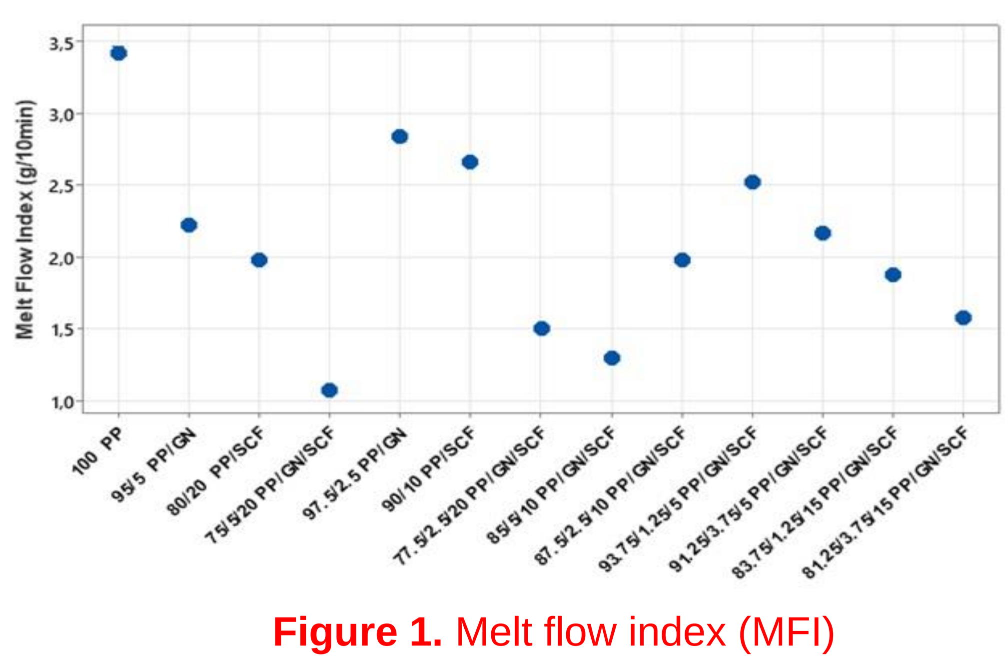


Figure 1. Melt flow index (MFI)

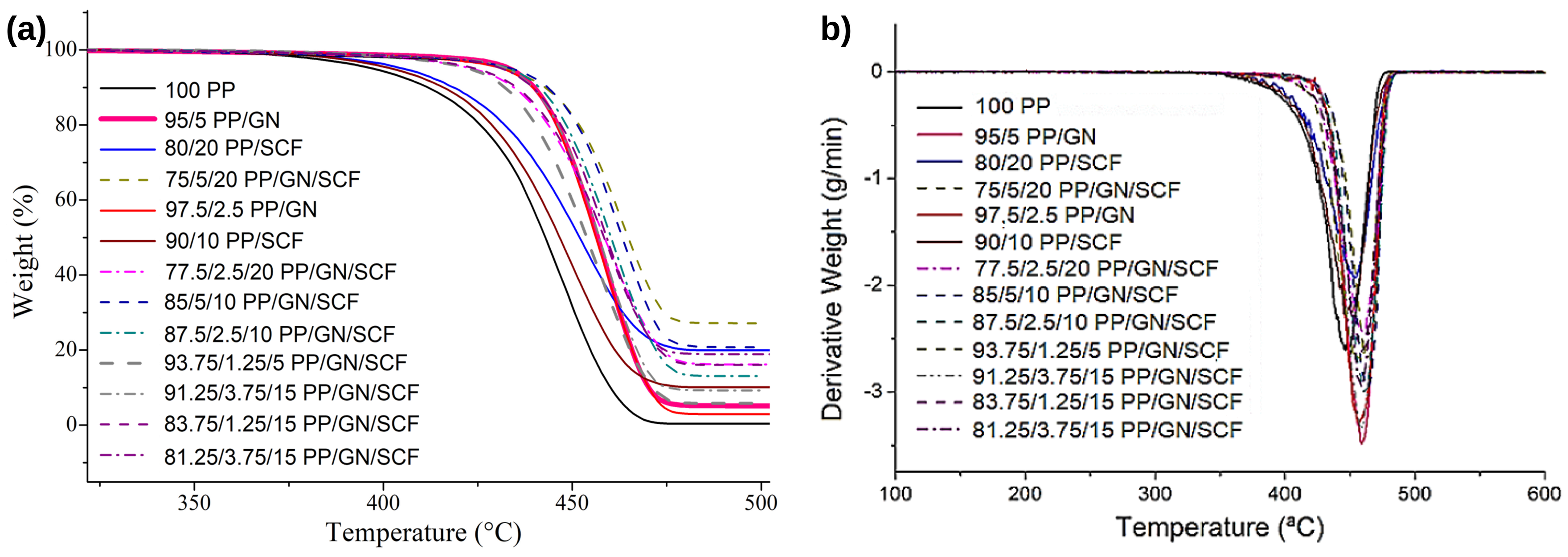
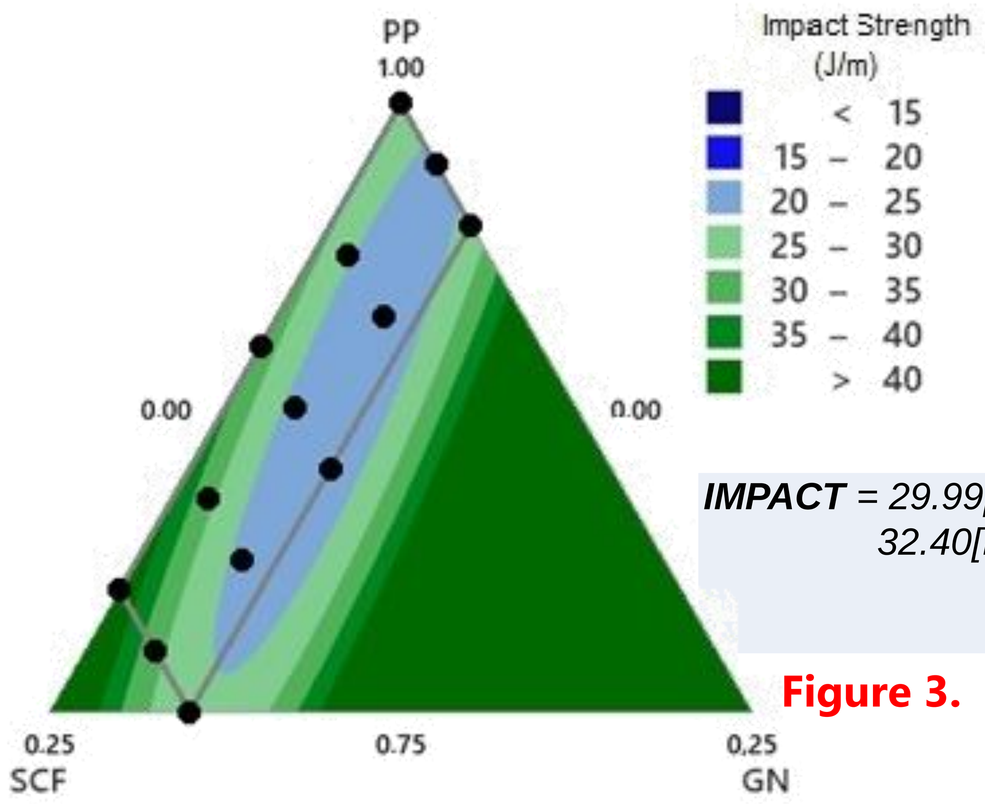


Figure 2. (a) TGA thermograms and (b) DTG curves



$$IMPACT = 29.99[PP] + 456.78[SCF] + 6682.91[GN] - 432.40[PP][SCF] - 7068.75[PP][GN] - 9166.32 [SCF][GN] \quad (1)$$

$$R^2 = 0.91$$

Figure 3. Response surface plot - Impact strength

$$FLEXMOD = 1557.1 \{PP] + 19483.3 [SCF] + 40789.1 [GN] -909.8 [PP] [SCF] - 29461.5 [PP][GN] + 61375.3 [SCF] [GN] \quad (2)$$

$$R^2 = 0.98$$

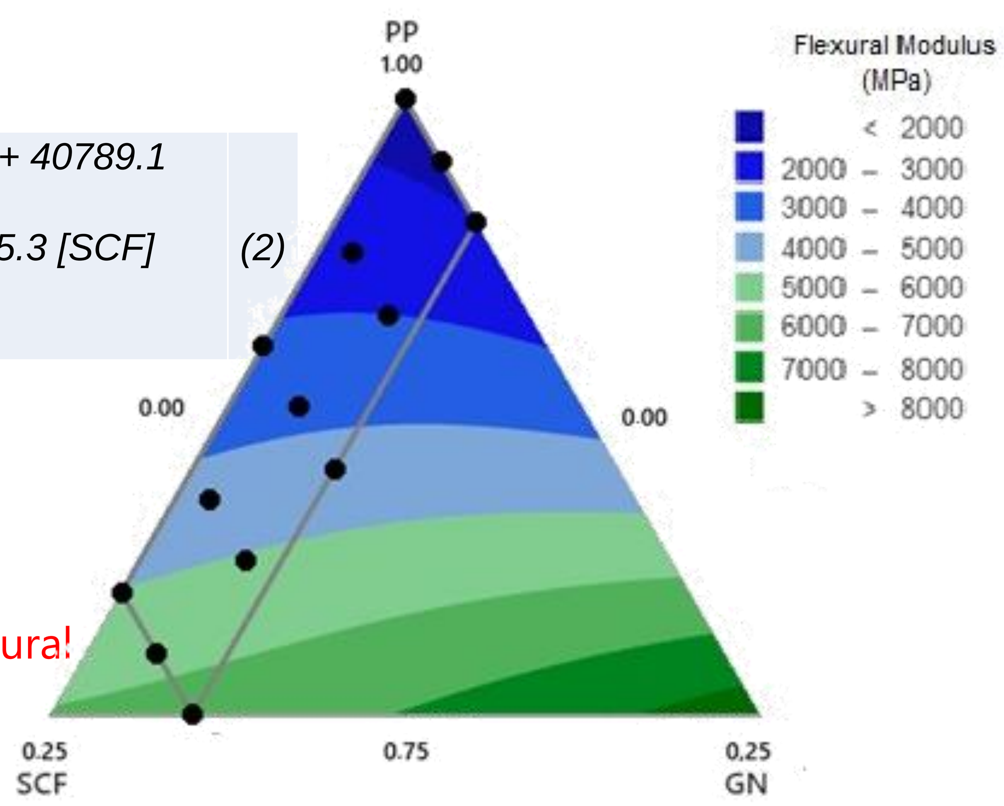
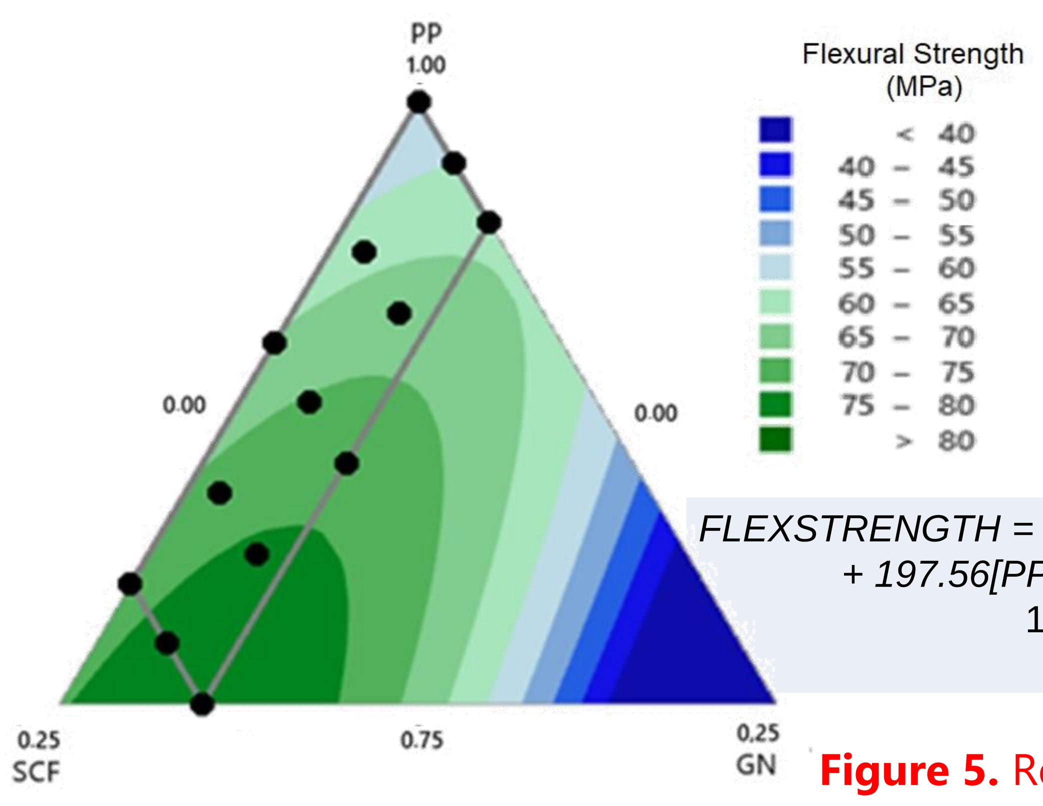


Figure 4. Response surface plot- Flexural modulus



$$FLEXSTRENGTH = 54.37[PP] -12.57[SCF] -1530.99[GN] + 197.56[PP][SCF] + 1856.41[PP][GN] + 1822.97[SCF][GN] \quad (3)$$

$$R^2 = 0.97$$

Figure 5. Response surface plot - Flexural strength

CONCLUSIONS

The effect of incorporating graphene platelets and short carbon fibers into a polypropylene matrix, on the mechanical and thermal stability of the polymer was evaluated using a response surface methodology. Flexural properties and thermal stability of polypropylene were improved by incorporating both reinforcement elements. The 75/5/20 PP/GN/SCF hybrid composites showed the best flexural properties. Superior impact properties were obtained when the polymer was reinforced with short carbon fibers.

References

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