

## Nanoindentation behavior and mechanical properties of active screen plasma-modified polypropylene

A. P. Kauling<sup>(1)\*</sup>, A. E. Crespi<sup>(1)</sup>, I.J.R. Baumvol<sup>(1,2)</sup>, G.V. Soares<sup>(1)</sup>, C.A. Figueroa<sup>(1)</sup>, M.E.H.M. Da Costa<sup>(3)</sup>, M.E.R. Dotto<sup>(3)</sup> and C. Giacomelli<sup>(1)</sup>.

(1) Universidade de Caxias do Sul, 95070-560 Caxias do Sul, RS, Brazil, email: apkaulin@ucs.br

(2) Universidade Federal do Rio Grande do Sul, 91501-970 Porto Alegre, RS, Brazil

(3) Pontifícia Universidade Católica do Rio de Janeiro, RJ, 22453-900 Brazil.

\* Corresponding author.

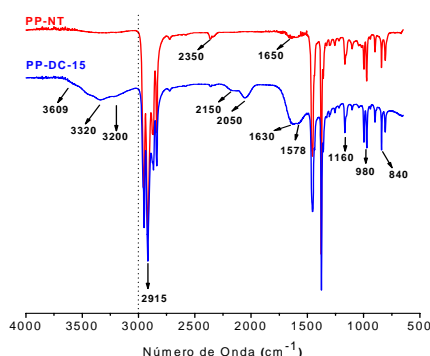
**Abstract** – In this work, we report the effect of active screen plasma nitriding on the nanohardness (H) of polypropylene (PP). The H-values obtained from indentation experiments depended strongly on the surface composition and structure, ranging from 0.14 GPa for pristine PP up to 1.01 GPa for PP submitted to 15-min N<sub>2</sub> pulsed plasma treatment (i.e.: a seven-fold increase). The surface chemical environment could be controlled by adequate selection of plasma processing parameters and experimental setup (cathodic cage material). The herein proposed method is an attractive tool for environment friendly, low cost, surface engineering of novel materials.

Plasma treatments offer diverse advantages over conventional approaches, since they are characteristically dry processes, which do not generate chemical waste, while allowing for facile control of superficial chemical composition of polymers simply by adjusting the stoichiometry of the gas inlet during the processes. Actually, this techniques aimed at control of biocompatibility, wettability, adhesion and tribological characteristics, have thus been controlled successfully in both laboratories and industries [1].

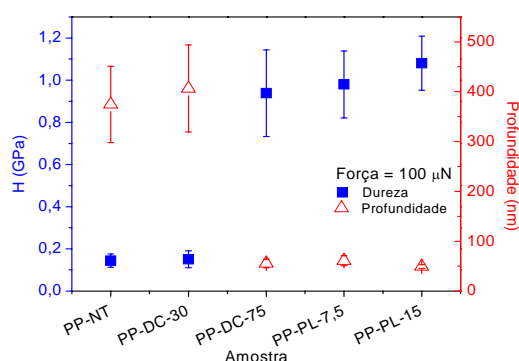
With the purpose of chemical functionalizing the surface of polypropylene (PP) in order to improve the hardness this polymer, specimens were submitted to different nitrogen plasma nitriding periods (1 – 75 min) under two plasma excitation methods (direct current (DC) and pulsed (PL) by using a cathodic cage supported system.

After plasma exposure, the attenuated total reflectance infrared (ATR-IR) spectra (Fig. 01) indicated the appearance of vibration bands typically assigned to –OH (hydroxyl), –NH<sub>2</sub> (primary amines) and –NRH (secondary amines) chemical moieties around 3600 – 3100 cm<sup>-1</sup>. The absorption at 1630 cm<sup>-1</sup> is attributed to C=O stretching, while the band at 1578 cm<sup>-1</sup> is presumably related to the presence of amine groups. The signals at 2150 and 2050 cm<sup>-1</sup> are ascribed to functional groups containing unsaturated bonds between C, N and O elements. These results were also confirmed by x-ray photoelectron spectroscopy (XPS).

Nanoindentation tests performed under different load regimes for samples submitted to plasma and treated under selected experimental conditions revealed a strong dependence of H-values on the plasma processing parameters. Figure 02 shows a significant increase in hardness after 75 min of processing when a DC power supply is used. In fact, the surface hardness could be augmented in a factor 7 from ~0.14 GPa in PP, before plasma treatments, to ~1.01 GPa after plasma treatments, confirming that this type of plasma treatment able to significantly improve the polypropylene surface mechanical properties [2]. Moreover, Rutherford backscattering measurements reveals that the nitrogen concentration on surface samples reaches a saturation level, stabilizing the surface hardness as a consequence. Finally, the use of low energy plasma immersion treatments leads to control surface properties of polymeric materials varying parameters and processes conditions.



**Figure 01.** ATR-IR spectra for PP before treatment (PP-NT) and after low energy plasma immersion treatment (PP-DC-15).



**Figure 02:** Hardness variation and indentation depth using constant load in PP-NT and PP using different plasma treatment time.

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[2] S.-H. Lee, S. Wang, G. M. Pharr, H. Xu, Composites Part 1 Appl. Scie. and Manufacturing 38, 1517 (2007).