3D AND 4D PRINTING OF POLYPROPYLENE HAVING DIFFERENT CONTENT OF COPOLYMER

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Polypropylene (PP) is one of the most used thermoplastics in the world due to its versatility and relatively low cost. It has been demonstrated that PP can be shaped via additive manufacturing (AM) techniques like material extrusion (MEX) and powder bed fusion (PBF). The most common AM technique is MEX; however, problems of build-platform detachment and warpage are observed. One way to solve these issues is to use copolymers of propylene-ethylene. In addition, it has been observed that PP and its copolymers show a thermos-responsive shape memory response; hence, if a 3D printed specimen is exposed to thermal fluctuations, it can change shape, giving rise to 4D printing. This investigation studies the effect ethylene content has on the MEX processability and the shape memory response of propylene-ethylene copolymers.

Three polypropylene copolymers with an ethylene content of 4, 9 and 11 wt.% were extruded as filaments. Tensile tests and rheometry were performed on the three materials. The printability of the three copolymers was tested in two filament-based MEX printers, one with a direct extrusion head and another with a Bowden extrusion head. It was observed that copolymers with 4 and 9 wt.% of ethylene could be printed in both printers, but the copolymer with 11 wt.% was not printable in any of the tested printers due to buckling at the feeding mechanism. Even though the copolymer with the highest ethylene content showed a slightly lower viscosity (Figure 1a), it also had the lowest tensile modulus (Figure 1b) and thus becoming not AM-processable as a filament; demonstrating, once again, that during filament-based MEX, having the correct filament stiffness is crucial to achieving printability.

Bar specimens were fabricated using the Bowden MEX printer using the two copolymers that were printable. The bar specimens were tested in a rotational rheometer fitted with solid clamps. Their shape memory response was evaluated by calculating their fixing and recovery ratios. It was observed that the copolymer with the 9 wt.% had the highest fixing (R_f) and recovery (R_r) ratios (Figure 2).

The study demonstrates the versatility of propylene-ethylene copolymers as materials for 3D and 4D printing.

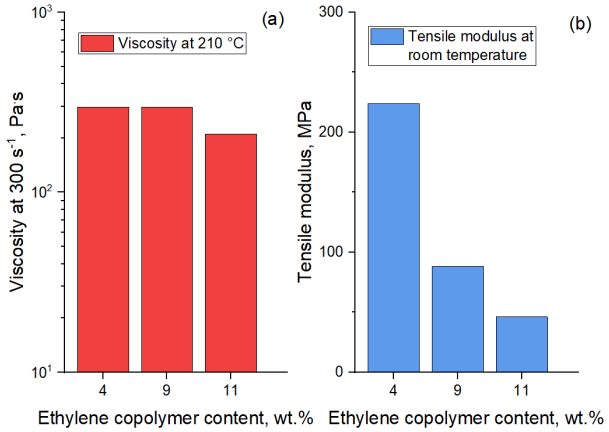

Figure 1 – (a) Viscosity and (b) tensile modulus

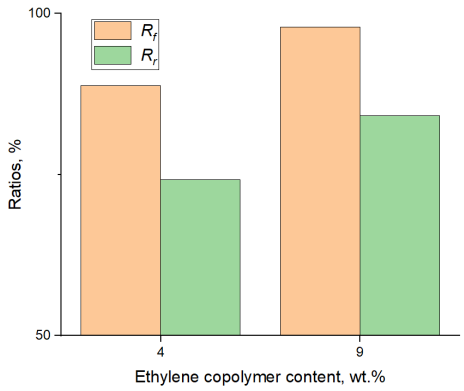

Figure 2 – Shape memory response