Development of Highly Conductive Hybrid Composites

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macromolecules adsorbed at the wall. In this work, the effect of LIPSS on the filling flow resistance in thin-wall injection molding of polypropylene was investigated. The use of ultrafast laser processing of the mold surface allowed the generation of different surface topographies, which are characterized by nano-scale ripples of different orientation and morphology.

The results of the injection molding experiments showed that the different LIPSS topographies affect the filling resistance by modifying the critical shear stress in regards to the onset of the wall slip effect. In particular, nano- structuring was observed to reduce the density of adsorbed macromolecules at the polymer/mold interface. The highest reduction of the injection pressure (i.e. 13%) was obtained when molding PP over the intersecting ripples. In fact, considering the reduced dimensions of the LIPSS troughs, the polymer is not able to replicate the nano-scale topographies and adsorption is limited near ripples intersections. Moreover, it was observed that the ripples parallel to the flow favors the bending of the adsorbed chain loops, and thus promoting the disentanglement from those adsorbed in the bulk in comparison with those normal to the flow.

The effect of laser treatment on wall slip was further investigated using a numerical model that was calibrated by determining the slip velocity value that minimizes the difference between the simulated and experimental values. In fact, the higher the drag reduction the higher the slip velocity, due to the smaller interaction at the polymer/mold interface. The good linear correlation between the calibrated slip velocity values and the shear stress at wall, obtained from the simulations, shows that the flow conditions are characterized by a strong slip regime.

The effect of increasing the mold surface temperature was investigated both experimentally and numerically. The results show that the LIPSS treatment affects the filling flow by shifting the onset of the strong slip phenomenon to higher shear stress values. Indeed, the higher adsorption density at a higher temperature results in lower deformability of the macromolecules attached to cavity walls and thus in a higher resistance to their bending when under strong flow conditions.

T3 Development of Highly Conductive Hybrid Composites

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Electrically conductive plastic composites are developed to overcome the major short comings of naturally conductive polymers. Conductive plastic composites combine the properties of metals with the polymers. But the state of-the-art conductive plastics available in the market are also characterized by the short comings for example, the low electrical conductivity compared with the standard metallic conductors. This low conductivity of the materials is the bottleneck for many fascinating applications of the composites where they can provide lot of process and design related advantages. The work presented here attempts to overcome this short coming of the conductive composites by developing hybrid composites to enhance the conductivity network inside the polymer matrix. It discusses the on-going work on the development of the composite based on metal-graphene hybrid system. The production and properties of novel composites based on Polyamide 6, Graphene nano-platelets (GNPs) and Cu fibers are discussed. The mechanical, electrical, and thermal properties of the produced hybrid composites are studied. The influences of the factors like filler contents, filler characteristics, annealing etc. on the electrical, thermal, and mechanical properties of the composites are presented. The presentation discusses the underlying mechanisms responsible for the modulation in the properties of the hybrid composites. Experimental work shows that the combination of GNPs and metallic micro fillers leads to significant improvements in thermal and electrical conductivities. To some extent GNPs acts as conductive bridges in minuscule gaps of the Cu fibers to increase the number of contacts in the constructed network. The combination of the two different fillers increased the mechanical properties up to 133 % compared to the metal reinforced composites indicating stronger interfaces between the fillers and polymer matrix. Rheological investigations also confirm the effectiveness of

hybridization. Furthermore, the influences of annealing on the conductivities of the specimens are studied. Adding an annealing step following the nanofiller inclusion within the metal filled composite resulted in 250 and 151 % enhancement in the thermal and electrical conductivities respectively.

Key words: *Injection moulding, Polymeric composites, Nanofillers, Electrical conductivity*

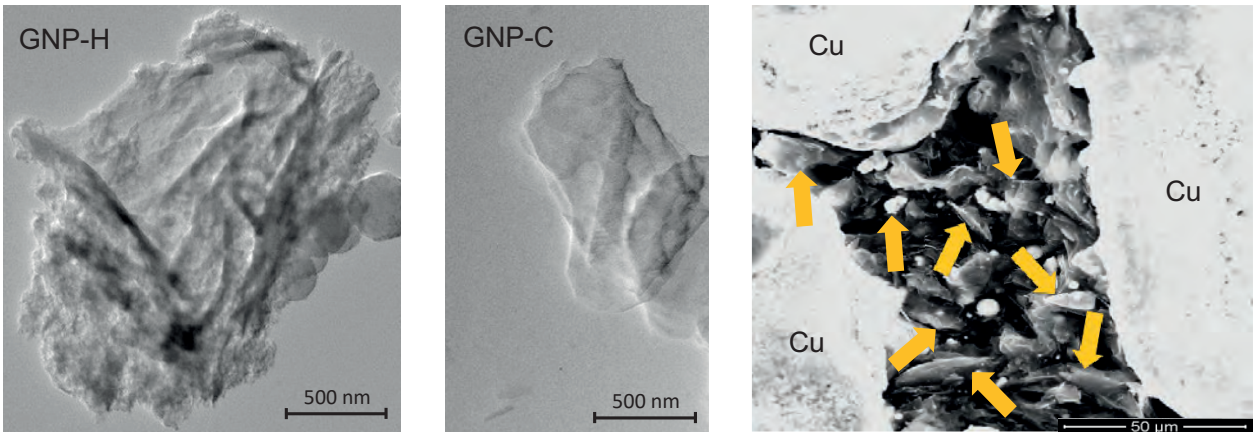

Fig: Left: Picture of graphene platelet (CNP-H), middle: picture of graphene platelet (GNP-C), right: presence of graphene in the space among the copper fibers.

T4 Extrusion melt flow characterized in real time using in-line rheo-optical techniques

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The polymer melt flow can be studied in-line using simultaneous rheo-optical techniques. The rheological behavior is obtained recording the pressure drop along the slit-die. Optical effects like light scattering and structure anisotropy are measured as turbidity, birefringence and low angle laser light scattering (LALLS). For this purpose we have designed and constructed an instrumented slit-die with three ports to measure pressure drop along the slit and two transparent windows for the optical measurements. It includes measuring turbidity and birefringence in the first window and LALLS at the second. The morphology of flowing polymer blends and composites are evaluated in the molten flowing field using, i) a known flowing field produced by a Cambridge Shearing System and ii) during extrusion in a Werner & Pfleiderer ZSK 30. Using different polymer blends and processing conditions the rheo-optical variables can be obtained and the morphological characteristic of the polymer flow be studied. The results can be compared with any conventional off-line measurement like, thermal (DSC), spectroscopic (FTIR) and morphology (POM, SEM, TEM), taken from samples collected during extrusion. Examples of various set of data will be presented during the conference, including diluted polymer blends and composites.

Keywords: process monitoring; extrusion; low angle laser light scattering; turbidity; flow birefringence.