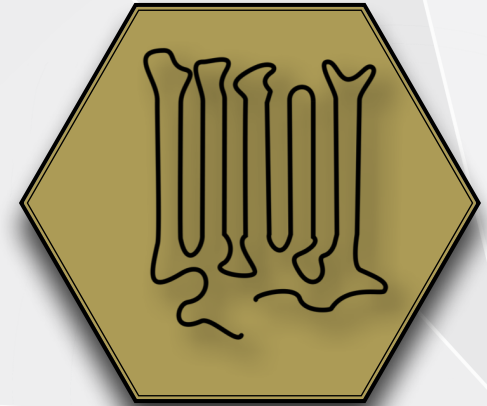
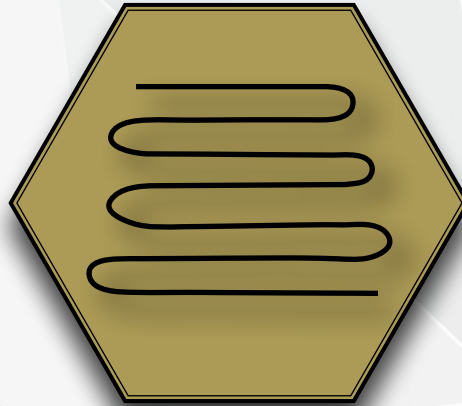


SEMI-CRYSTALLINE VS AMORPHOUS POLYMERS

PROPERTY & PROCESSING

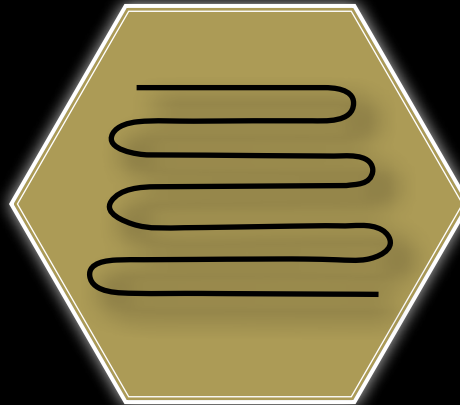


In recent technical overviews we have explored the differences in chemical and crystalline structures of polymers and how they affect various properties. In this document we will expand on a commonly overlooked processing detail between semi crystalline and amorphous materials.

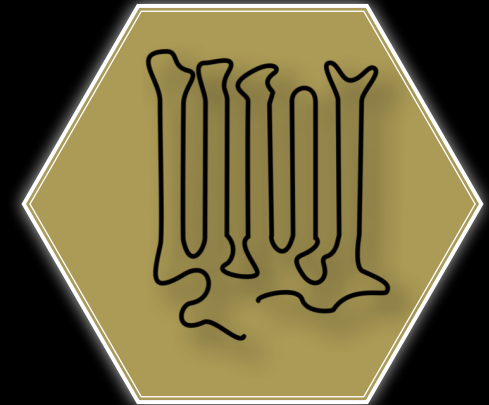
All polymers contain both amorphous (without structure) and crystalline (ordered) morphological structures within the solid state. The general thermodynamics for the formation energies of these amorphous and crystalline regions has been shown in previous documents. As a general rule, analogous amorphous polymers have higher viscosity (lower melt flow) in the molten state than crystalline polymers. In general this is due to the difficulty of amorphous polymers to form random coils in the molten phase and the associated energy required to rotate around the backbone. Below, we show three different systems of generic polymer families and the effect that backbone configuration has on viscosity.



AMORPHOUS

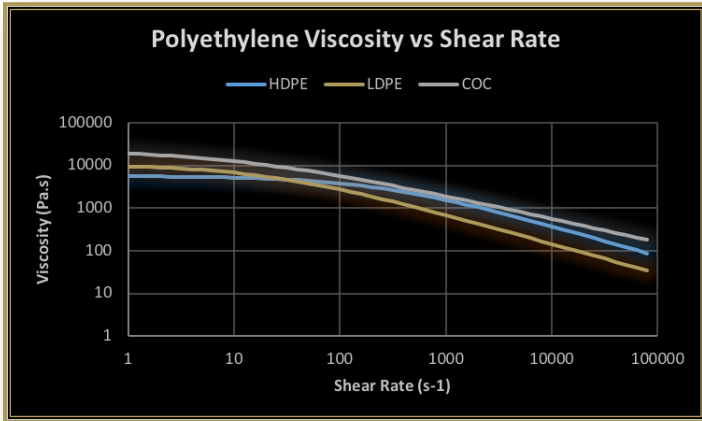
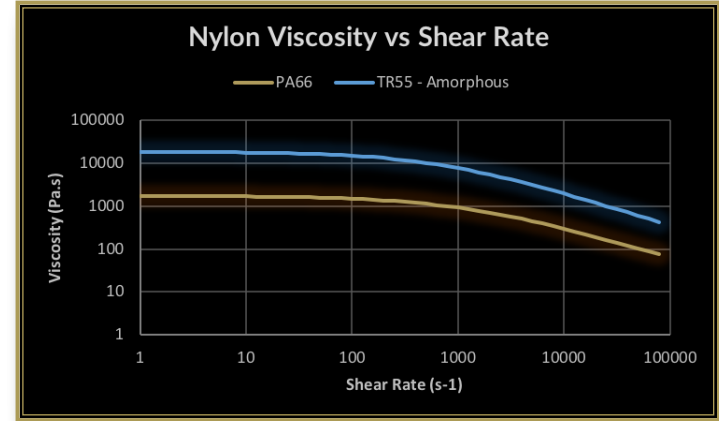


CRYSTALLINE



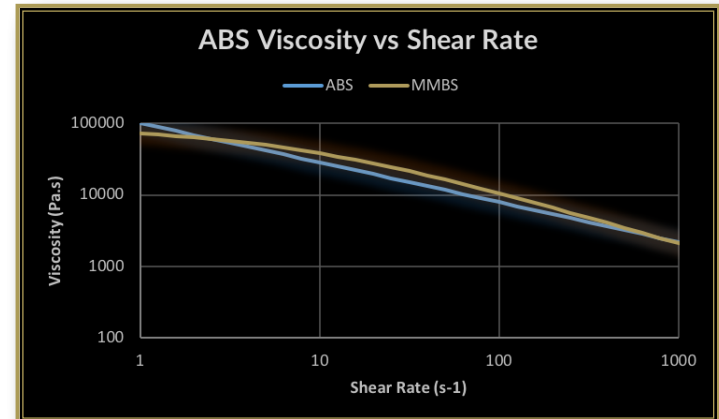
SEMI-CRYSTALLINE

The first chart is amorphous nylon and nylon 66. Nylon 66 is readily crystallized from the molten state. While in the molten state and beyond its melting point, the molecular chains begin to readily slide past each other with very little energy requirements. In contrast, the amorphous nylon with large aromatic structures requires higher temperatures in order to overcome steric interactions.



This trend is also found with HDPE/LDPE vs cyclic olefin copolymers. The norbornene structure which causes the disruption in re-crystallization (creating an amorphous solid state) considerably increases the viscosity in the molten state.

Similar to the previous two examples, the methyl methacrylate copolymer family within the ter-polymer family ABS reduces crystallinity and increases molten viscosity over a wide range of shear rates.



MECHANICAL PROPERTIES / PROCESSING

Due to the differences in molten viscosity and recrystallization rates a few key comments can be made regarding the processing of semi-crystalline vs amorphous materials:

- During the metering phase, it is important to ensure that semi-crystalline material has reached the T_m (melting point) prior to reaching the metering zone. Transitioning from solid to the molten phase requires an extra enthalpy of formation for semi-crystalline materials and increases the heat load on the molding machine. Generally, this heat can be supplied by shear heating in the transition zone, but if the barrel is not sized adequately, it is possible to have un-melted pellets in the final product.
- During the pack phase it is important for the screw to continue moving forward for semi-crystalline materials in order to ensure proper molecular orientation at the end of fill. Hold pressure should be adequate to prevent screw bounce back when transitioning and holding the cushion.
- In general, both amorphous and semi crystalline materials are prone to pressure induced warp (molded in stress) if over packed or if a large pressure gradient exists from the gate to the end of fill. Adjusting mold and melt temperatures allows processors to reduce pressure drop and flow into the cavity with less molded in stress.

MECHANICAL PROPERTIES

The chart to the right shows a general overview of the mechanical differences between amorphous and semi-crystalline materials. The biggest difference is the retention of properties between the glass transition and melting point of the polymer. Crystalline materials will have very little reduction in strength from T_g to T_m while amorphous materials will exhibit a significant reduction in mechanical properties linearly with temperature. This goes into one of the core principles of material selection: semi-crystalline materials are more preferentially selected for applications requiring retention of properties over time and heat aging; whereas amorphous materials are commonly used either above their T_g to offer elastomeric properties or below their T_g or optical clarity.

