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Bringing Injection Moulding of Plastics to the SAXS Beamline at ALBA

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Injection moulding is the most common fabrication technology used to shape plastics including recycled plastics. In this technique, molten plastic is injected into a metallic mould under high pressure where it rapidly cools to a solid, thereby preserving the shape and it is then ejected from the mould. The high throughput of this technology has led to its widespread use. The properties of the part critically depend on both the polymer used and the complex processes of flow and cooling within the mould. Analysis using SAXS techniques after moulding reveal complex behaviour which would be easier to understand, optimize and develop, if the data were obtained in real time. This would enable the different processes to be observed separately rather than superimposed as in the final product. This is the objective of the current work. For an amorphous polymer the material solidifies by cooling below the glass transition but for a semi-crystalline polymer, solidification involves crystallization which is strongly affected by the coupled flow and cooling processes within the mould. To develop an understanding of these processes we have set out to design a realistic replica of an industrial injection moulding system, but which would fit on the ALBA NCD-SWEET beam line to allow us to use in situ time-resolved small-angle X-ray scattering techniques to follow the development of structure and morphology of the polymer following the injection stage. There are many challenges in preparing a successful design. Foremost is the restricted space available on the beam line and the need to protect sensitive parts of the beamline equipment from the high temperatures of the mould during the cycle. A second restriction is the weight of the system. The sample translation stage of the NCD-SWEET beamline has a maximum load of 100 kg. The third challenge is the need to design a mould to withstand the pressures within the mould which may reach 200Bar and which provides adequate x-ray transmission without artifacts to enable highly quality time resolving small-angle X-Ray scattering patterns. This presentation will detail the design philosophy we have followed to remain true to industrial practice and which has yield a successful design and we will present the results from experiments performed at the end of last year and discuss the prospects for the future focusing on biopolymers and recycled plastics.

Injection moulding is the most common fabrication technology used to shape plastics including recycled plastics. In this technique, molten plastic is injected into a metallic mould under high pressure where it rapidly cools to a solid, thereby preserving the shape and it is then ejected from the mould. Industrial scale injection moulding can be automated to produce several parts per minute. This high throughput has led to its widespread use. The properties of the part critically depend on both the polymer used and the complex processes of flow and cooling within the mould. Analysis using X-ray scattering technique after moulding reveal complex behaviour which would be easier to understand, optimize and develop, if the data were obtained in real time. This would enable the different processes to be observed separately rather than superimposed as in the final product. This is the objective of the current work. For an amorphous polymer the material solidifies by cooling below the glass transition but for a semi-crystalline polymer, solidification involves crystallization which is strongly affected by the coupled flow and cooling processes within the mould. To develop an understanding of these processes we have set out to design a realistic replica of an industrial injection moulding system, but which would fit on the ALBA NCD-SWEET beam line to allow us to use in situ time-resolved small-angle X-ray scattering techniques to follow the development of structure and morphology of the polymer following the injection stage. There are many challenges in preparing a successful design. Foremost is the restricted space available on the beam line and the need to protect sensitive parts of the beamline equipment from the high temperatures of the mould during the cycle. A second restriction is the weight of

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