Polyolefin material properties, designed for 3D printing applications

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Introduction

Production methodologies are changing and with it material diversity and requirements are increasing. 3D-printing is an uprising technique which is, perfect for rapid prototyping and small series.

Concerning the Fused Filament Fabrication process (FFF, also known as FDM-printing), the most commonly used filament materials used are primarily acrylonitrile-butadiene-styrene (ABS) and polylactic-acid (PLA).

One advantage of Polyolefins is that their properties can be varied over a broad range and designed for a specific application. The applicability of Polyolefin based materials is likely to enrich the 3D-printing sector.

Scope of work

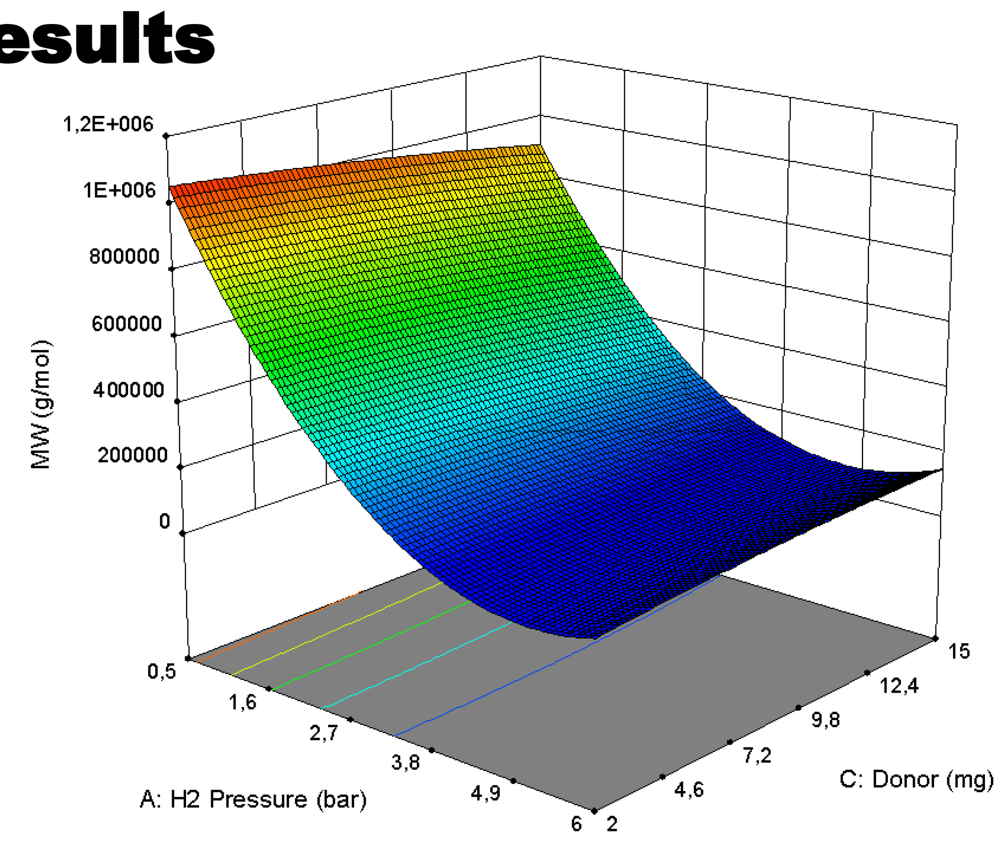
The task was to estimate the main influencing factors on printability. Therefore a multitude of commercially available filaments based on diverse materials have been reviewed and were tested for their printing behavior.

Furthermore the filaments were investigated via differential scanning calorimetry (DSC), size exclusion chromatography (SEC) and rheology measurements. After determination of influencing factors and defining a range for these material properties, the next step was to polymerize polypropylene based polymers using an in-house 0.5 L reactor system.

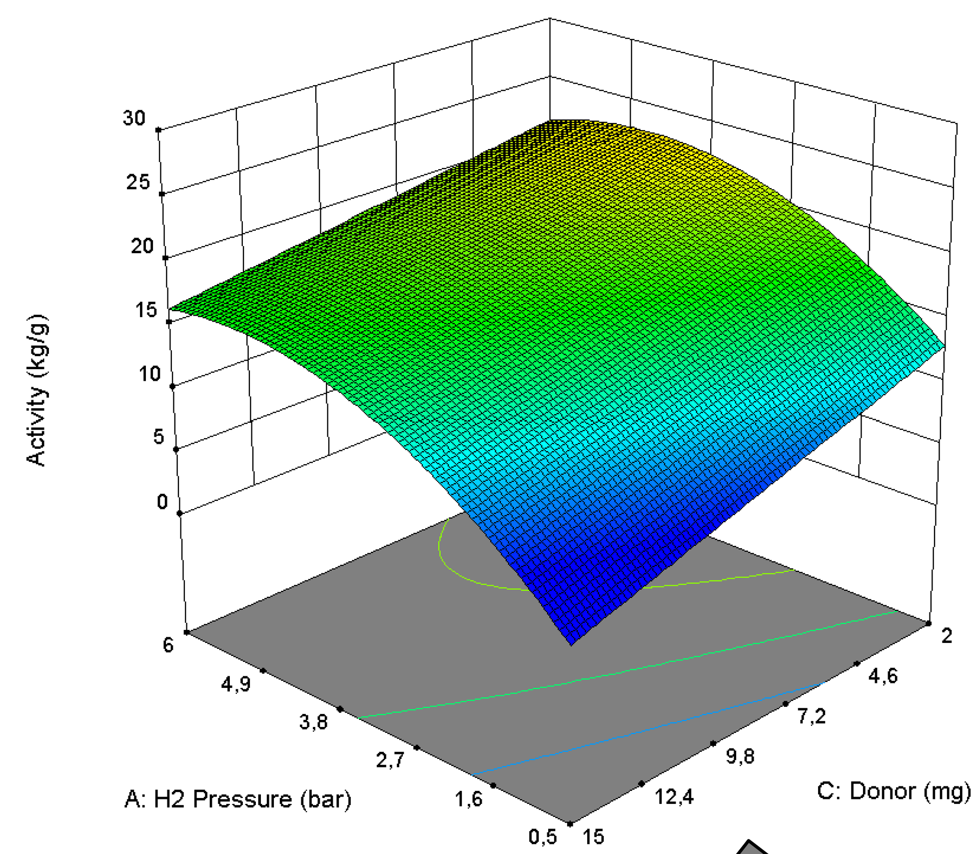
Therefore a commercial Ziegler-Natta catalyst was screened for effects of e.g.: external donors, hydrogen partial pressure.

Preliminary experiments were conducted via the one-factor-at-a-time (OFAT) approach by altering single parameters only. From these experiments a promising set of factors was then augmented by a design oriented approach (DoE), so the optimal conditions for the favored criteria could be isolated.

Design Results

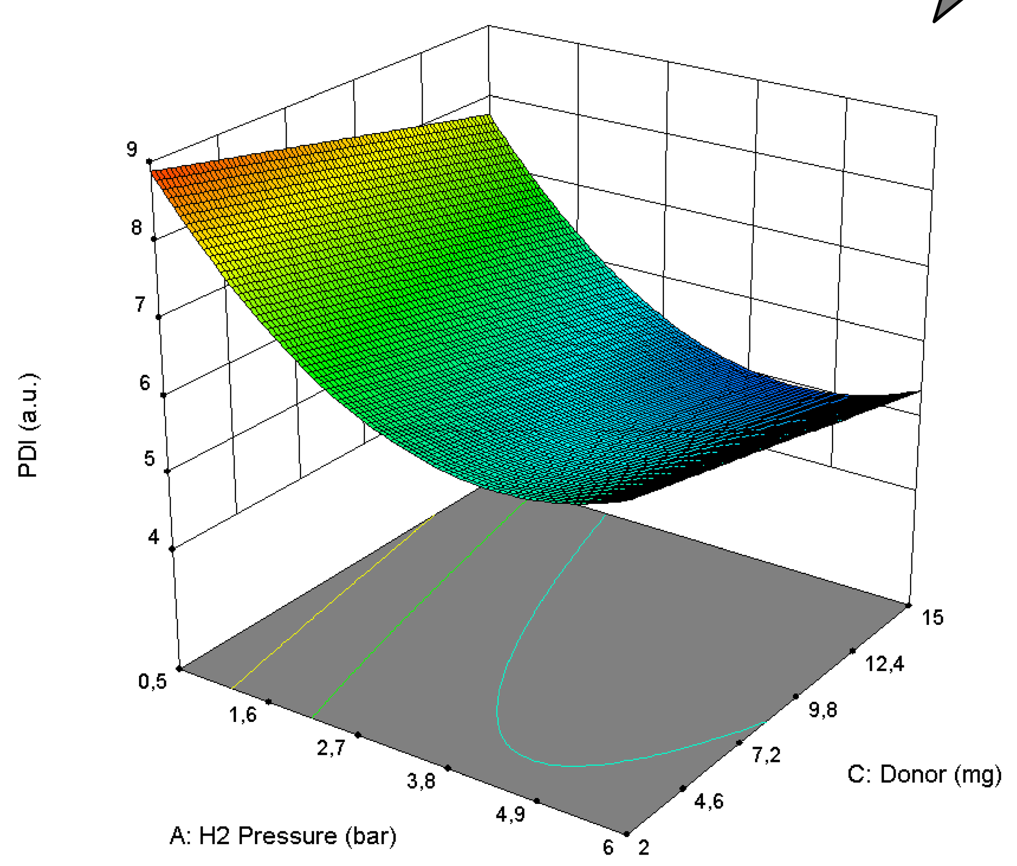


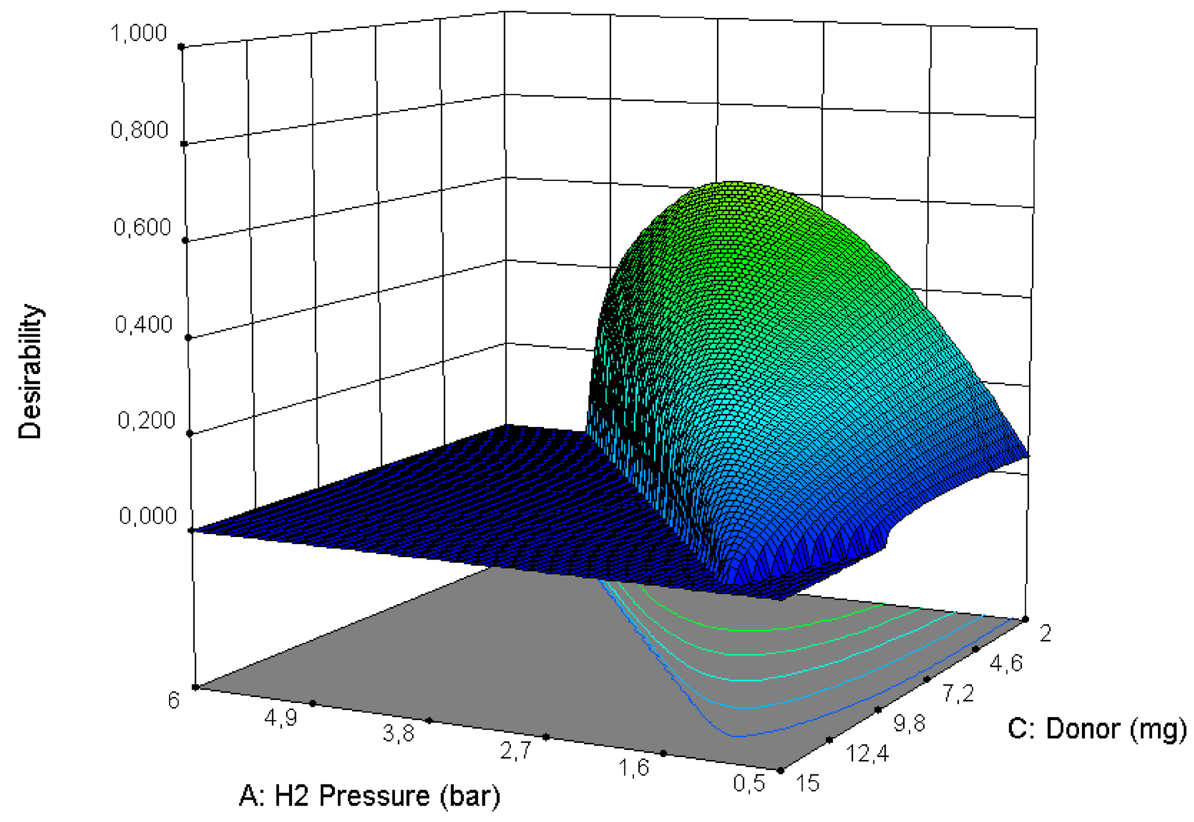
Molecular Weight



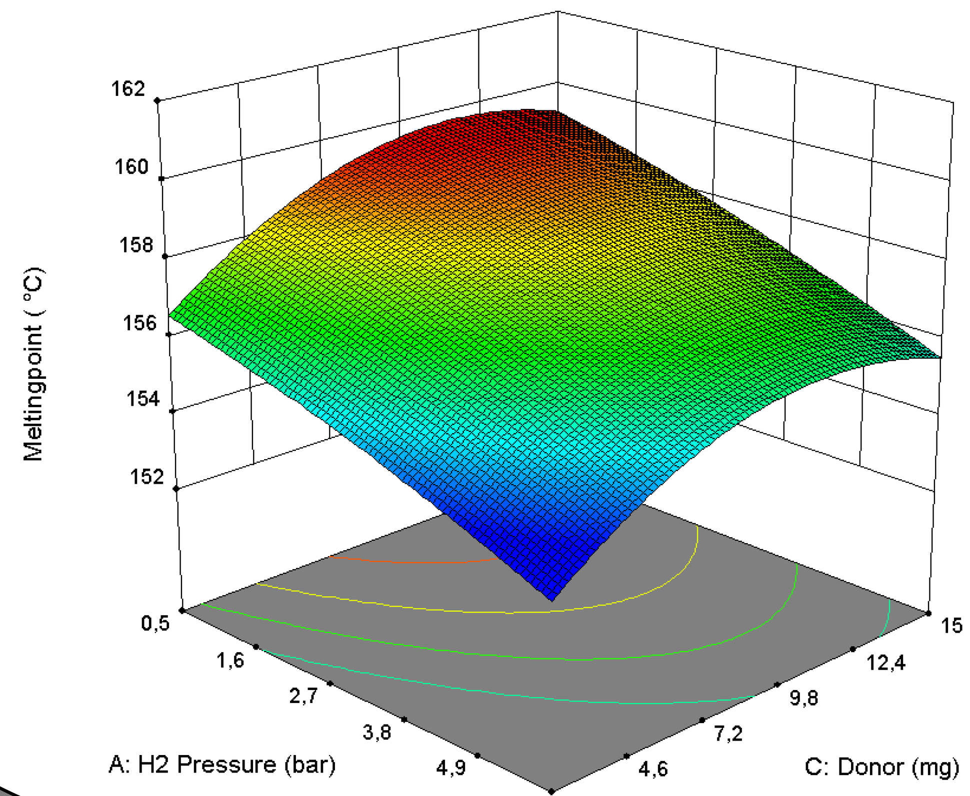
Activity

Polydispersity Index



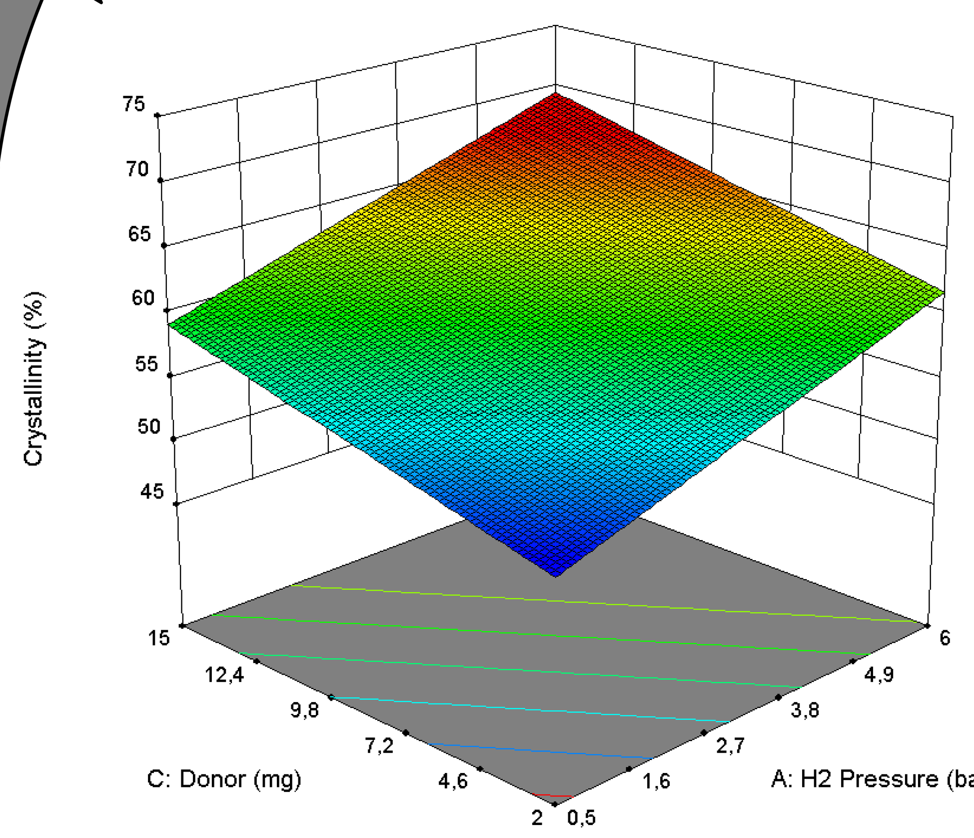


Desirability



Meltingpoint

Crystallinity



DoE Parameters

For this design the Box-Behnken model was used. It was selected due to the reduced amount of experiments, saving resources and time. This model permitted higher reproducibility, concerning fouling, at the cost of an lower precision model.

The design rests upon three numerical factors, with an evaluation of five response factors. The results were achieved using 15 experiments, 12 design points with three additional center points.

By adjusting the desired range and importance of the factors, one can narrow down polymerization conditions in order to obtain the favored properties; resulting in the desirability plot (center graph).

Conclusion

Some fundamental understanding of the investigated process presumed, a design oriented approach is very helpful regarding optimization of favored material properties.

The desirability plot displays the direction on where to expand the design space in order to achieve desired properties. For this setup donor concentrations below 4 mg with hydrogen partial pressures of around 3 bar resulted in properties that are located inside the targeted range.

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