The Route of 3D Printed Functional Parts

The effect of hard/soft ratio and end-groups on the layer to layer adhesion of 3D printed polyurethanes

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Introduction

3D printing of three different polyurethanes with different end-groups and different hard/soft ratios, shown in Figure 1. These materials can be used for orthopaedic applications, such as the meniscus. The problem is the layer to layer adhesion when 3D printed, this could result in different mechanical properties.

Bionate I® $PCU - n/a$

Bionate II® $PCU - C_{18}$

Carbosil® $PCU - PDMS$

Figure 1: Polyurethanes with different end-groups

Materials & Methods

Pre processing
To remove the moisture the material is dried in the vacuum oven for 24 hours at 70°C.

DSC
DSC curves are used for the determination of T_g and the T_M. The Tg is for the post-processing step and the melting point for optimization of the printer settings. Temperature are from $-80°C$ to 215°C.

3D printing
Optimization of the polyurethanes with the Arburg Freeformer. This is important to assure the samples are of good quality. Printing a hollow square is to make sure the time between the layers are the same. The hollow square is displayed in Figure 2.
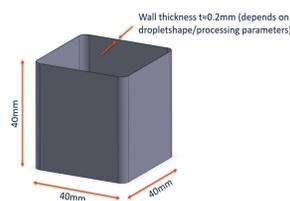

Wall thickness t=0.2mm (depends on dropletshape/processing parameters)

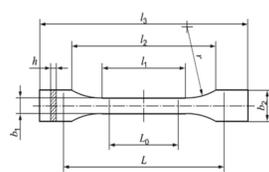*Figure 2: Measurements hollow square*

Figure 3: Measurements tensile bars

Tensile test
Determination of the E-modulus for wet and dry samples. ISO-527-1BB is being used for the measurements of the tensile bars, Figure 3, that are going to be cut out of the hollow squares.

Post- processing
To strengthen the bonds between the printed layers. The materials are annealed in a vacuum oven for 24 hours at 80°C.
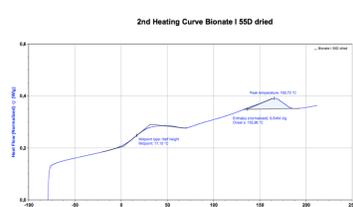
Results

DSC

2nd Heating Curve Bionate I 55D dried

2nd Heating Curve Bionate I 55D nd
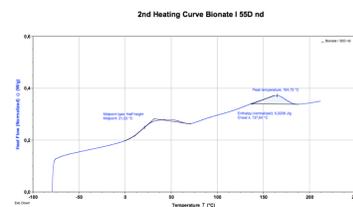
Figure 4: Dried material

Figure 5: Not dried material

The DSC graphs are being used to characterize the different materials and to testify if the material is processable. Figure 4 and 5 are examples of curves where the T_g and T_m are obtained. The different end-groups, ratios and moisture content can have an influence in these characteristic temperatures.
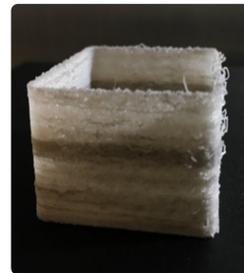
Results

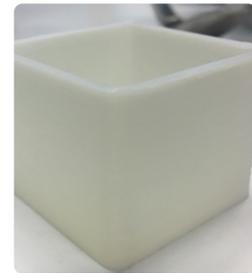### 3D printing

Figure 6: Inadequate hollow square

Figure 7: Adequate hollow square

The presence of a darker colour in the printed samples are not recommended because it represents the occurrence of an undesirable reaction. This is established in Figure 6. Therefore, the printing target is a hollow square with a light and uniform coloration, demonstrated in the Figure 7.
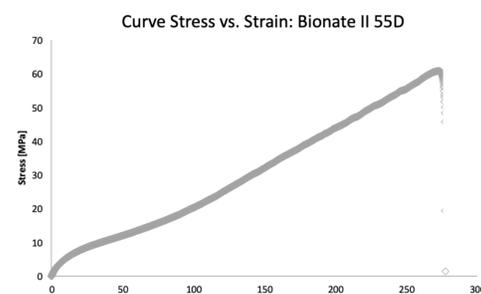
Tensile test

Curve Stress vs. Strain: Bionate II 55D

Figure 8: Stress plotted against strain for tensile test

From the Stress versus Strain curve, obtained with the Tensile Test, it is possible to determine some relevant information about the mechanical behaviour of the specimens, such as the E-modulus and yield point. This kind of curve for polyurethanes does not show a distinct yield point, as demonstrated in the Figure 8, characteristic of an uniform deformation.

Discussion

DSC

The effect of an end-group can result in a different Tg. The different ratios, 80A and 55D, in the material cause different melting temperatures. This is an effect of the different hard and soft blocks in the materials. There is no significant difference for T_g and T_m between the dried material and the not dried material.

3D Printing

It could be observed that the optimum printing conditions vary significantly for different materials. The main printing features changed were the discharge, temperatures, printing speed and the droplet aspect ratio.

Tensile

The printed samples are going to be compared to compression moulded samples and both will be tested. A discovered already made was that 3d printed samples break more easily than the ones that were compression moulded because of the layer wise build up.