Assessment methods of injection moulded nano-patterned surfaces

S. Menotti[1], G. Bisacco[1], H.N. Hansen[1]
[1]*Dep. of Mechanical Engineering, Technical University of Denmark, Denmark*
steme@mek.dtu.dk

Abstract

Assessment of nano-patterned surfaces requires measurements with nano-metric resolution. In order to enable the optimization of the moulding process it is necessary to develop a robust method for quantitative characterization of the replication quality of random nano-patterned surfaces.

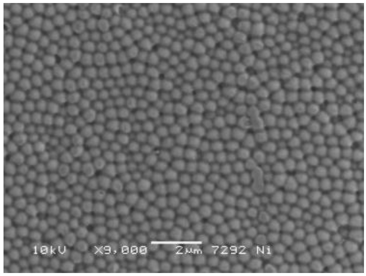
In this work two different methods for quantitative characterization of random nano-patterned surfaces were compared and assessed. One method is based on the estimation of the roughness amplitude parameters Sa and Sz (ISO 25178). The second method is based on pore and particle analysis using the watershed algorithm for feature recognition. To compare the methods, the mould insert and a number of replicated nano-patterned surfaces, injection moulded with an induction heating aid, were measured on nominally identical locations by means of an atomic force microscope mounted on a manual CMM.

1. Introduction

Deterministic and random nano-patterned surfaces have received increasing attention in the recent years due to their ability to enable different functionalities. Deterministic nano-patterned surfaces can for example be used for data storage, while random nano-patterned surfaces can be used for tissue engineering applications and tailoring of wettability. [1][2].

In applications where polymer substrates are suitable, components carrying such surface geometries can be mass produced by means of micro and nano injection moulding. A critical aspect is to ensure high quality of the nano pattern transfer from the mould to the polymer part during injection moulding.

2. Tool and process



The studied surface consisted of a random pattern of protrusions each having a spherical profile with lateral dimension in the range of 400-600 nm and a height in the range of 80-150 nm. The nano structures were injection molded in polycarbonate. To evaluate the filling and replication behavior during injection molding a general full factorial set of experiments was carried out. The two studied factors were injection speed and mould heating time.

3. Measurement procedure

Three measuring areas of 25 µm * 25 µm were scanned with an AFM on the nickel insert and on the polymer replicas, at different distances from the gate. Location recognition was obtained through reference marks embedded in the mould insert and replicated on the polymer parts.

4. Result and discussion

The pore and particle analysis gives a quantitative output consisting of the statistical distribution of the relevant measures of the surface features such as height, Figure 1.

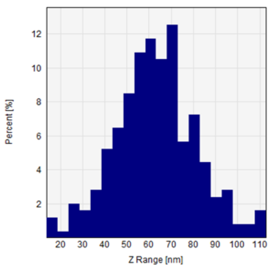


Figure 1: Example of the output of the pore and particle analysis method

For the optimization of the watersheld algorithm four different filter parameters were chosen. The maximum height value was chosen between 0 and 150 nm, the diameter between 300 and 900 nm, the elongation that is a measure indicating how elongated a shape it is (elongation=|length-width|/ length) was set from 0 to 0.8 and finally the form factor that is the aspect ratio defined as length over width between 0.8 and 1, these values were chosen to obtain the best feature recognition.

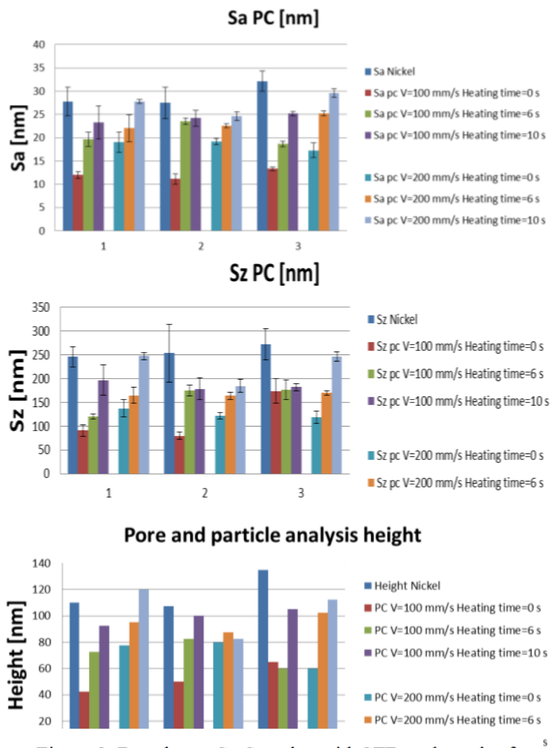


Figure 2: Roughness Sz-Sa value with STD and result of the pore and particle analysis height for PC and Nickel insert, number 1, 2, 3, refer to the distances from the gate.

In the plot of the height of the micro structures Figure 2 the reported value is the mode of the height's statistical distribution.

The simple approach based on the roughness amplitude parameters Sa and Sz builds on the consideration that higher values of roughness amplitude parameters correspond to a better replication quality, while at the same time their maximum values are defined by those of the nickel mould surface.

In the Sa and Sz plot Figure 2 the average values of 12 measurement for the three different measurement areas, and different process conditions, is reported.

From Figure 2, it is possible to observe that the two measurement methods are capable to detect the trend of the replication quality of the surface changing the process condition. However the roughness analysis was performed by manually selecting smaller evaluation areas over scanned areas in order to avoid defects of the replica surface. The pore and particle analysis instead, after a first optimization of the watersheld algorithm could proceed in an automatic way due its ability to recognize the specific features of interest and avoid the defects. Furthermore, while the output of the roughness estimation based method only allows comparative evaluation of replication quality, the pore and particle analysis method gives a real distribution of the dimensions of the measured features allowing full quantitative characterization of the replication quality. If we compare the Sz value and the height of the particle it is possible to notice that the values are not matching, this is due to the fact that the Sz value is a local parameter, while the pore and particle analysis gives the value of height which is detected with the maximum frequency. The Sz value should instead correlate with the maximum value detected from the pore analysis.

In this work the injection molding process was used like an instrument for characterizing the surface and in both the analysis it is possible to notice that the increase of the heating time is the most important parameter for improvement of the surface quality [3].

5. Conclusion

The results of the comparison show that the first method is strongly affected by local variations of the surface and therefore requires the ability to locate exactly the areas for comparison on each replica and on the mould surface. In contrast the second method is implicitly more robust and the output is more directly correlated with the dimensional characteristics of the features to be replicated and therefore allows a more explicit assessment of the quality of replication.

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