Dimensional verification of high aspect ratio micro structures using FIB-SEM

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Abstract

Micro-structured surfaces are increasingly used for advanced functionality. In particular, micro-structured polymer parts are interesting due to the manufacturing via injection moulding. A micro-structured nickel surface was characterized by focussed ion beam-scanning electron microscope (FIB-SEM) and then analysed by Spip®. The micro features are circular holes 10μm in diameter and 20 μm deep, with a 20 μm pitch. Various inspection methods were attempted to obtain dimensional information. Due to the dimension, neither optical instrument nor atomic force microscope (AFM) was capable to perform the measurement. Via FIB-SEM, the process was recorded by images when slicing the sample layer by layer by ion-beam. In this way, the dimension and the geometry of the holes are characterized.

1 Introduction

Micro polymer pillars arrays modify the wetting properties of the surface, for instance previous research suggests that micro-structured surface can favour cells growth when the pillars are patterned in certain ways [1], therefore it has a wide application in bio-medical fields. Biocompatible polymers are used for this type of application.

The micro pillars array is a surface geometry; the dimension of the feature is typically orders of magnitude smaller than the structured surface area [2]. A master geometry is required for the replication of the micro pillars array. Lithographical methods are often used to produce the master, i.e. the pattern of the pillars is introduced by lithography and metal deposition (such as physical vapour deposition) with a mask. Subsequently electroplating is used to create an insert for the moulding process.

In order to analyse the replication degree, it is necessary to characterize the mould structure accurately. The nominate dimensions of the circular holes studied in this paper are 10 μm in diameter and 20 μm deep, with a 20 μm pitch. For most types of AFM it is beyond the measurement ability, unless a customized cantilever is used.

An optical microscope with Focus-Variation (Alicona®) was applied to measure the depth of the holes, however, the bottom of the holes cannot be "observed" by the microscope simply because the reflected light from the bottom was insufficient. Figure 1 is the top view of the investigated surface, obtained by scanning electron microscope (SEM). Similar to the result of an optical instrument, conventional SEM has the difficulty to get sufficient information from inside the holes. When the sample was tilted up to 30 degree, the surface of the inner wall was shown (Figure 2). But the depth of the hole was still not illustrated.

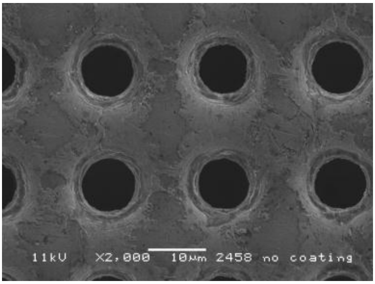

Figure 1 A SEM image of the top of the surface with micro holes.

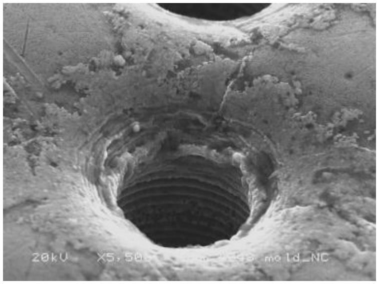

Figure 2 The sample was tilted in SEM.

2 Conventional cross section measurement

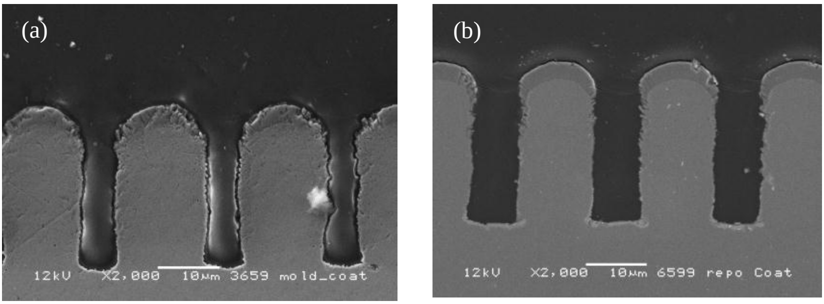

Figure 3 epoxy-moulded of cross sections of the mould.

The result is influenced significantly by the alignment and cutting process. The same scale is applied in these two images. Sample (b) was polished further based on sample (a).

Another often used method to investigate the geometry is to make cross section of the holes. The sample needs cutting from the side, then epoxy moulding in order to be ground and polished. Due to the micro dimension of the structure, the obtained cross section is influenced significantly by the sample preparation process, such as the alignment, the cutting step and the grinding step. Pictures (a) and (b) in Figure 3 show two different cross sections from the same sample; (b) was obtained by polishing the sample in (a) 1 mm further down. Image (a) shows that the diameter of the hole is approximately 6.5 µm, while image (b) shows the diameter of the hole is 8.5 µm. Neither of them confirm to the nominate value 10 µm. theoretically it is possible to make such a cross section sample for every few micrometres of the sample, presuming it is allowed by the cutting technique. However, it is not only time consuming but also completely destructive, as a result this is not the first choice when the sample material is expensive and the time schedule is tight.

2 Quanta 200 3D SEM FIB

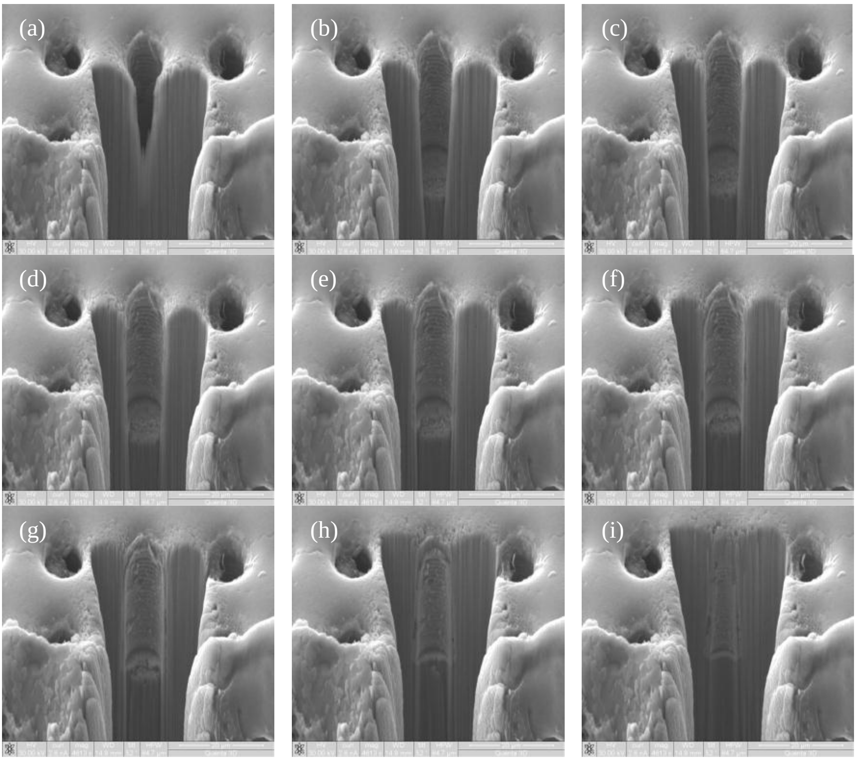

Figure 4 FIB SEM milling process. From (a) to (h) the distance between two image is 1 µm, from (h) to (i) the distance is 2 µm.

The Quanta 200 3D was used in this study. It is a dual-beam scanning electron microscope which combines normal SEM mode functionality. It uses a focussed ion beam (FIB) for removing material by milling. In this study, the accelerating voltage was 30 KV, using imaging detector Everhart-Thornley in high vacuum. The current was 7 nA in the milling process.

A random hole was chosen to be observed. The side of the sample was positioned to be vertical to the ion beam. A block of material was removed by ion beam until the investigated hole was exposed. The sample was sliced from the side instead of from the top, to avoid debris falling into holes. The hole was sliced with a step of 200 nm, i.e. 200 nm thick materials were removed in each layer during the milling.

As the images in Figure 4 illustrate the hole was milled from the front to the back. (a) and (b) show that the side wall of the hole was not perfectly perpendicular to the milling beam direction; it was approximately 2.8 degree tilted. From image (c) the contour of the hole is visible, as well as the structure on the inner wall.

The dimension was analysed by SPIP® using x-y scaling tool. Picture (e) in Figure 4 was used for this analysis, since it illustrates the central position of a hole. The diameter is 9.7 ± 0.06 µm, the depth is 24.8 ± 0.06 µm considering the tilted angle.

3 Conclusion

A structured surface 10 µm in diameter and approximately 20 µm deep was measured by conventional SEM and a FIB SEM. Due to the relatively high aspect ratio, only FIB SEM can measure the depth of the hole by milling the hole from side. Compared to conventional epoxy-moulded cross section method, FIB-SEM is relatively faster and less destructive; meanwhile it requires much less preparation work.

References:

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