Dimensional verification of high aspect micro structures using FIB-SEM

Zhang, Yang; Hansen, Hans Nørgaard

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Dimensional verification of high aspect micro structures using FIB-SEM

Y. Zhang[1], H.N. Hansen[1]
[1] *Department of Mechanical Engineering, Technical University of Denmark, Denmark (DTU)*
yazh@mek.dtu.dk

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) assisted by Spip®. The micro features are circular holes 10µm in diameter and 20µm deep, with a 20µm 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. A cross sectioned sample was prepared for conventional SEM in order to inspect the geometry of the holes, but the cutting angle used when making the cross section had a significant influence on the obtained results. 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 favor cells growth when the pillars are patterned in certain ways[1], therefore it has a wide application in bio-medical fields. Biocompatible polymer is 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 10µm in diameter and 20µm 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 an optical instrument's result, 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.

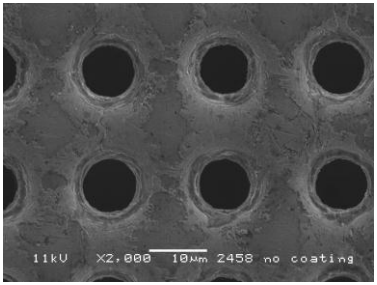


Figure 1 A SEM image of the top of the surface with micro holes.

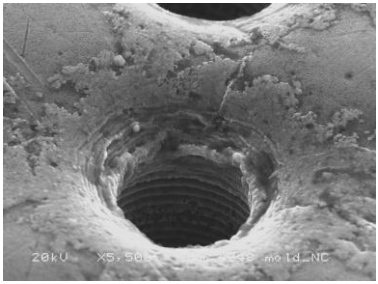
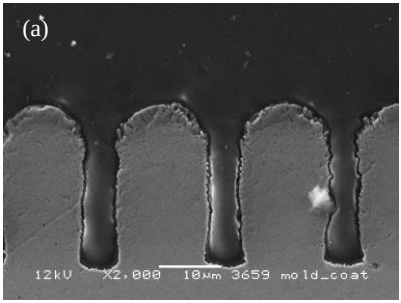


Figure 2 The sample was tilted in SEM.

2 Conventional cross section measurement



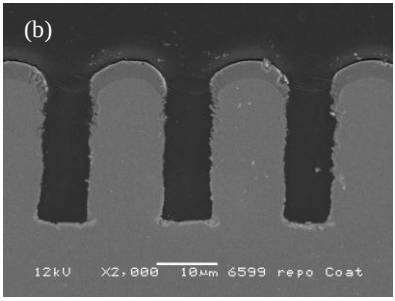


Figure 3 epoxy-moulded of cross sections of the mould. The result is influenced significantly by the alignment and cutting process. The same scale is applied in these two images. Sample (b) was polished further based on sample (a).

Another often used method to investigate the geometry is to make cross section of the holes. For this 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) 1mm further down. Image (a) shows that the hole's diameter is approximately 6.5µm, while image (b) shows the hole's diameter is 8.5µm. Neither of them confirm to the nominate value 10µm. Theoretically it is possible to make such a cross section sample for every few micrometres of the sample, presuming it's 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.

3 Quanta 200 3D SEM FIB

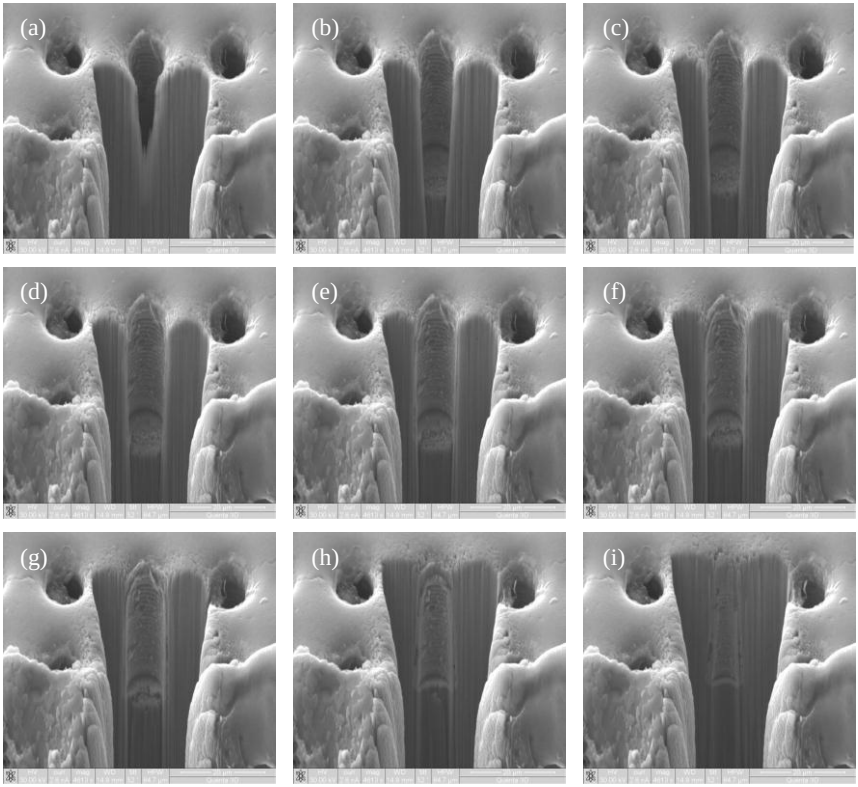


Figure 4 FIB SEM milling process. From (a) to (h) the distance between two image is 1µm, from (h) to (i) the distance is 2 µm.

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 30KV, using imaging detector Everhart-Thornley in high vacuum. The current was 7nA in the milling process.

A random hole was chosen to be observed. The side of the sample was placed 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 200nm, i.e. 200nm thick material was 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 2.8degree tilted. From image (c) the contour of the hole is visible, as well as the structure on the inner wall.

The dimension was analyzed 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±0.06μm, the depth is 24.8±0.06μm considering the tilted angle.

4 Conclusion

A structured surface 10μm in diameter and approximately 20μm 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.

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