

# A capability study of micro moulding for nano fluidic system manufacture

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# A capability study of micro moulding for nano fluidic system manufacture

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**Abstract**

With the present paper the authors analysed process capability of ultra-precision moulding used for producing nano crosses with the same critical channels dimensions of a nano fluidic system for optical mapping of genomic length DNA. The process variation focused on product tolerances is quantified through AFM measurements. Uncertainty assessment of measurements on polymer objects is described and quality control results of sub-micro injection moulded crosses are shown in respect of the tolerance range specified by the end user as limit value for functional design.

## 1 Introduction

The possibility of miniaturizing methods for diagnosing, screening and treatment procedures of minuscule sample amounts could dramatically contribute to the advancement of biomedicine and healthcare applications. Moreover the potential of polymer-based nano fluidic systems fabricated through replication technologies used for faster parallel analysis and low costs chip production is enormous. Ultra-precision manufacturing of sub-micrometer features presents challenges in terms of quality control due to the increased measurement uncertainty in respect to the tolerance interval leaving therefore a smaller conformance zone for process variation. For this reasons, the present paper investigates the capability of the injection moulding process by means of optimized parameters to replicate the produced sub-micrometre test geometries in the thermoplastic Cyclic Olefin Copolymer (COC) Topas 6013.

## 2 Nano manufacturing and injection moulding

Quality control of replicated geometries introduces complication related to measurement relocation. Therefore the process quality control was carried out on

fabricated key test geometries representing critical geometries in the real application of the nano fluidic design. The master geometries were manufactured on an oxidized silicon wafer. The sub-µm features represented by three crosses having constant thickness (nominal value on the silicon master equal to 65 nm) with horizontal and vertical wings width of 10 µm, 2 µm and 500 nm respectively, were defined by 100 keV e-beam lithography. The e-beam defined channels were etched by selective reactive ion etching. After the writing process on the silicon master a first seed layer composed of Ti/Au (thickness of 10 nm/100 nm respectively) was deposited by physical vapour deposition (PVD) in order to enhance the corrosion resistance of the obtained nano structures and to promote the deposition of a thick electroplated nickel layer. The crosses, positioned in the centre of a 22 × 22 $mm^2$ nickel shim, were replicated by injection moulding on the commercially available thermoplastic COC 6013 (see Figure 1). Optimized injection moulding process parameters [1] were employed. Mould temperature of 130°C, packing pressure of 600 bar, packing time of 4,5 s, high injection speed of 130 mm/sec and mould temperature of 270°C were selected to enhance replication.

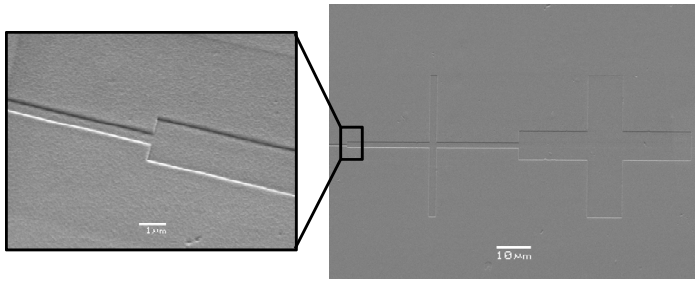

Figure 1: Scanning electron microscopy images of the µm/sub-µm grooves in the COC injection moulded part. From the right hand side, cross number 1 with vertical and horizontal wings width of 10µm, cross number 2 with vertical and horizontal wings width of 2µm, finally a close view picture of cross number 3 with vertical and horizontal wings width of 500 nm.

## 3 AFM measurements and tolerance verification

A calibrated atomic force microscope (AFM) was employed to verify the quality of injection moulded crosses transferred over 9 polymer samples (see Figure 2) produced under the same moulding conditions. Polymer channels depth and nickel trenches height were measured implementing the definition described in ISO 5436-1

[2]. Profile analysis of the different sub-microchannels (corresponding to the critical height on which single molecule of denatured DNA sequence are gathered for later analysis) were chosen as measurands for process validation. The measuring campaign was carried out using a ScanAsyst-Air probe with triangular cantilever with low spring constant and high sensitivity. The step height standard reference represented by a quartz block with precisely etched uniform bar of 46 nm height was calibrated by metrology AFM developed by NIM with laser interferometers integrated on the X, Y and Z axis allowing to trace measured values to the SI unit. The calibrated standard artefact was also used to calibrate the piezoelectric ceramic of the employed AFM. The uncertainty of the performed vertical measurements was calculated following the GUM [3]. A number of errors contributors related to AFM instruments were considered in the uncertainty budget calculation see Table 1.

Table1: Results of uncertainty contributors and combined expanded standard uncertainty.

| | | |
|---|---|---|
| $u_{res,z}$ (vertical resolution) | **0,05 nm** | |
| $u_{c,z}$ (calibration factor) | **0,58 nm** | |
| $u_{cal,z}$ (calibration artefact) | **0,75 nm** | |
| *$u_{afm,z}$ (instrument repeatability)* | *0,36 nm* | **$u_{rep}$ = max ($u_{afm}$, $u_{sample}$)** |
| *$u_{sample}$ (sample variation)* | *0,69 nm* | **0,69 nm** |
| $u_{noise}$ (background noise) | **0,43 nm** | |
| U (exp. comb. uncertainty) | **2,5 nm** | |

The standard uncertainties are treated as independent (i.e. no correlation) and are combined following the law of propagation of uncertainty (1) with $u_{rep}$ = max ($u_{afm}$, $u_{sample}$) [4] and confidence level of 95% (k=2):

$$U = k * \sqrt{{u_{res}}^2 + {u_c}^2 + {u_{cal}}^2 + {u_{rep}}^2 + {u_{noise}}^2} \qquad (1)$$

## 3 Conclusion

This paper addressed product compliance with specifications of micro injection moulding test geometries for nanofluidic systems through high accuracy AFM measurements. Although data analysis have shown a considerable product variation

within the conformance zone, micro injection moulding shows to be a promising process for the purpose of mass fabrication. The study proposes an effective, robust and systematic evaluation of product quality control at nanometre dimensional scale introducing reference values for master making quality assessment polymer replication process capability and final fluidic systems bonding processes.

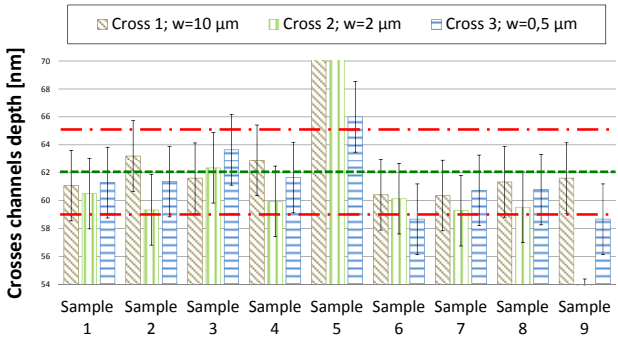


Figure 2: Quality control results of micro injection moulded components. Green square dot line=absolute value of the crosses height measured on the nickel insert (U = 2,3 nm); red dash dot lines= tolerance range (as ± 5% of the crosses height on the nickel insert); error bars indicate expanded combined uncertainty (k = 2, conf. level 95%).

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