Innovations in nanotechnology propose applications integrating micro and nanometer structures fabricated as master geometries for final replication on polymer substrates. The possibility for polymer materials of being processed with technologies enabling large volume production introduces solutions to remove technology barrier between lab-scale proof-of-principle and high-volume low-cost production of nanotechnology based products.

The aim of the current study was to develop methods and approaches to process chain validation for final polymer micro and nano structures replication. Fidelity between different process chain steps and its dependency to process variation, process conditions, tool accuracy, material behavior and features geometries were considered and quantified. Nickel shims with different sub-µm topographies, for injection molding tooling purposes, were manufactured during the current project. Deterministic structures integrated in Lab-on-a-chip (LoC) devices were produced using the so-called DEEMO process (dry etching, electroplating and molding), enabling multilevel (from micro to sub-µm meter ranges) structures fabrication. Finger print test structures were introduced and fabricated aside of functional feature geometries consisting of different chip designs following same fabrication steps (DEEMO). Functional surface patterning method based on anodization of aluminium substrate to create alumina oxide connected membranes acting as template for later nickel electroplating were fabricated.

Replication fidelity of deterministic geometries over the entire process chain was quantified through traceable measurements on designed finger print test structures. Characteristic LoC critical geometries collected in different versions of the finger print test geometries allowed measurements relocation of calibrated AFM measurements of different replicated geometries. Degree of replication of produced pseudo hexagonal structures between nickel and polymer substrate was quantified through AFM height measurements and analysis of amplitude surface parameters. New approaches oriented to quantification of replication quality over large areas of surface topography based on areal detection technique and angular diffraction measurements were developed.

A series of injection molding and compression molding experiments aimed at process analysis and optimization showed the possibility to control features dimensional accuracy variation through the identification of relevant process parameters. Statistical design of experiment results, showed the influence of both process parameters (mold temperature, packing time, packing pressure) and design parameters (channel width and direction with respect to the polymer flow) on the final quality of replicated sub-µm features. For cross test structure with target design height dimension of 62 nm and width of 500 nm, the largest depth deviation was measured. For an average measured polymer channel depth corresponding to 94 % replication of the corresponding nickel tranches a standard deviation of 4 % around the calculated average value was assessed.

The work is concluded validating the deterministic test structures as a tool to predict, through relocation of measuring positions, replication quality of critical geometries of specific LoC devices. The study showed replication quality of the process monitoring geometries within the same dimensional variations of the functional structures fabricated in the same chip. Measurement results were evaluated in terms of process capability quantifying product accuracy to the target value (full replication) within a range of ±3 nm and process reproducibility within a range of ±8 nm. Therefore test structures provide a process calibration tool enabling definition of tolerance limits within micro and nano replication.