PROOF-OF-CONCEPT EXPERIMENT REPORT

LIGHT CONCENTRATOR PROTOTYPE FABRICATION BY DEEP X RAY LITHOGRAPHY

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Proof-of-Concept experiment details

The topic is the manufacture of an optical component capable of concentrating the light emitted by a small OLED source installed in a diagnostic instrumentation. The idea is to use the same principle as a bundle of optical fiber: we have chosen to fabricate an array of micro pillars on a thin slide of polymethiyl methacrylate (PMMA). We want to verify if Deep X-Ray lithography (DXRL) is a suitable option in the fabrication of this kind of optical elements. Figure 1 shows the geometry of the component to manufacture.

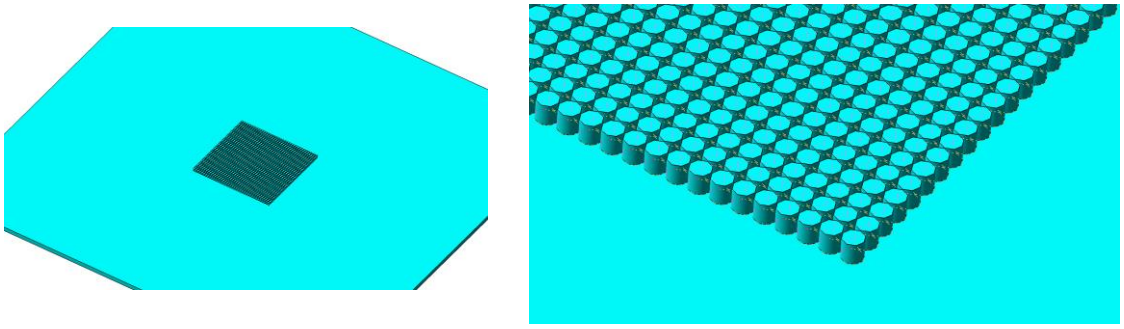


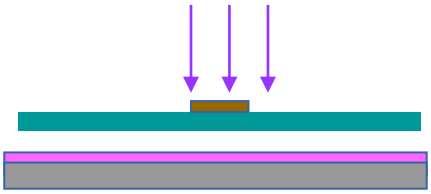
Figure 1

Planned Fabrication Process:

STEP 1: X RAY MASK FABRICATION

1) SPIN COATING SU8 ON SUBSTRATE

2) UV LITHOGRAPHY

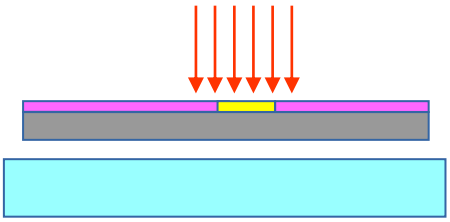


3) SU8 DEVELOPER BATH

4) GOLD ELECTRO DEPOSITION

STEP2 : COMPONENT FABRICATION

5) DEEP X RAY LITHOGRAPHY ON PMMA



6) PMMA DEVELOPER BATH

In the following we describe the details of fabrication process:

1st step: X-ray fabrication Mask

The optical device under study is composed of an array of pillars, a suitable pattern has been selected from those available among the UV masks in the DXRL laboratory, in order to reproduce such array.

In this array each pillar has a circular base with a diameter of 140um, the pitch is 150um, the array overall size is 3450 x3450 um. The used UV mask was a chrome-glass mask shown in the Figure 3: chrome is brown colored and the red circle shows the selected pattern.

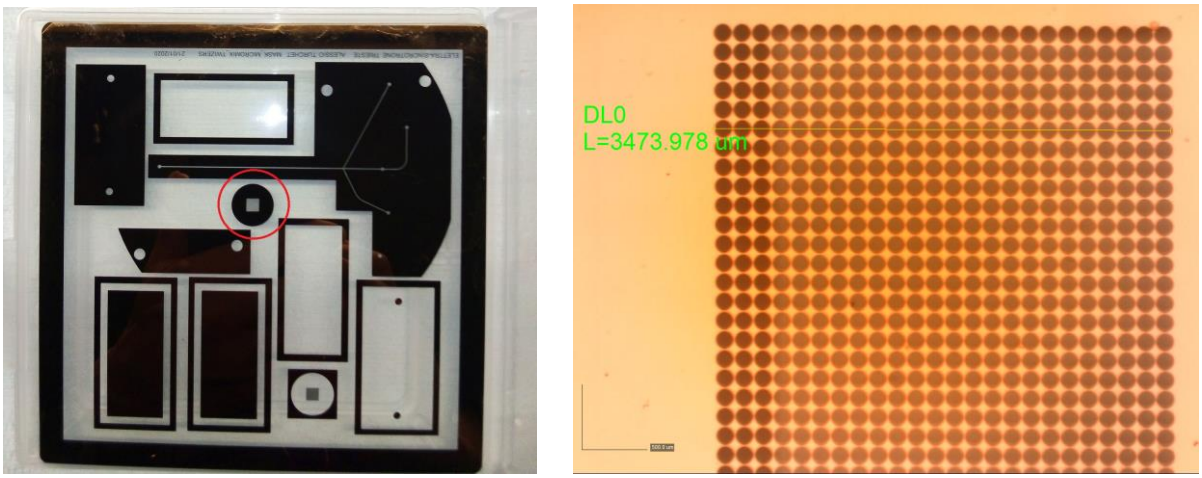


Figure 3

Mask substrate preparation

A 250 um thick graphite slide has been polished to obtain a low value of roughness (0.25 um), then the resist SU8 (a negative resist) has been spin coated on this layer, with requested thickness 20 um.

UV Lithography

The UV litography has been performed on a UV station, the exposure parameters were :

Power: 17.5 mW/cm^2

Exposure Time : 12 sec

After the exposure the sample has been immersed in the SU8 developer bath in order to remove the not exposed area.

Gold Electro deposition

This is the final step to obtain the x ray mask; the graphite layer with the SU8 litographed pattern has been immersed in an electrochemical gold bath (TechniBond RM). After some tests these parameters have been selected :

Current I = 10 mA

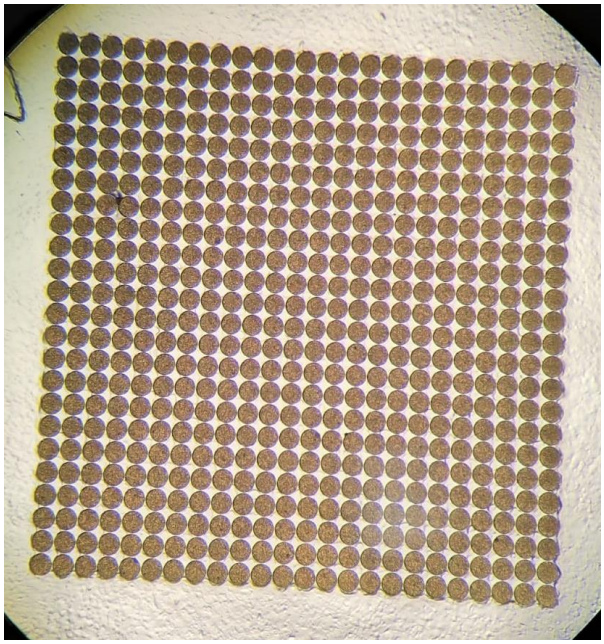
Impulse Delay time : 2 msec

Bath Temperature 64 °C

Deposition Time : 7 h

The finished x ray mask and a magnificaton view are shown respectively in Figure 4a and 4b

Figure 4(a)



4(b)

X-ray Mask Dimensional Verification

The finished x ray mask was subjected to dimensional verification. The used instrumentation was a Profilm 3D optical profilometer. In the following picture the inner volumes appear empty because the reflectivity of graphite and gold is very different and at low magnification and this prevents to see the gold upper surface. Anyway this allow us to verify and measure the geometry of the patterned area.

The measurements are shown in Figure 5

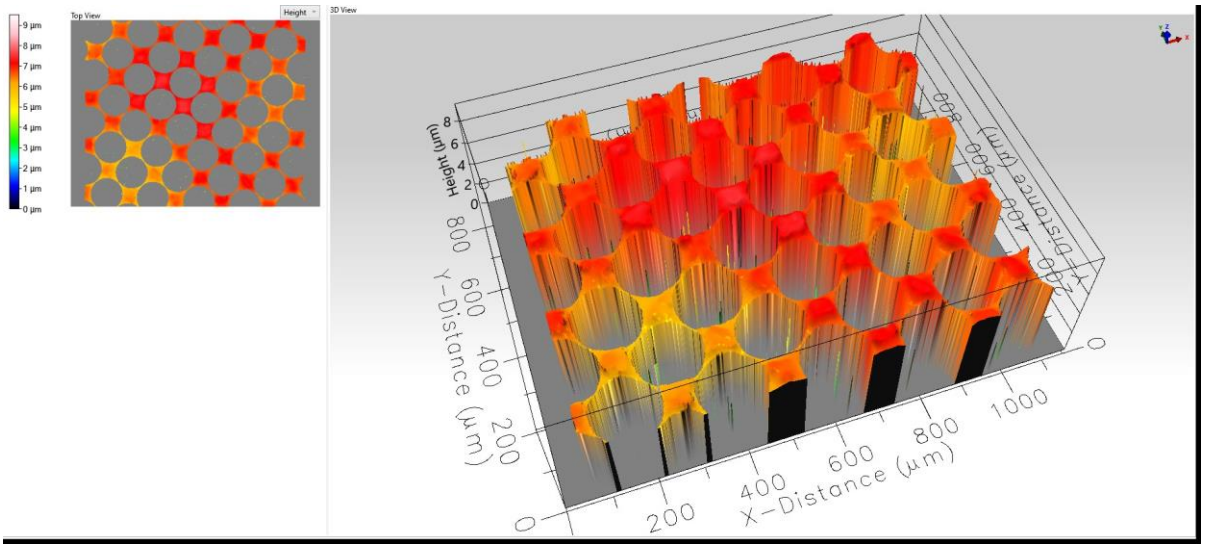


Figure 5

The measurement of the pitch distance is 149.7 um : Figure 5(a)

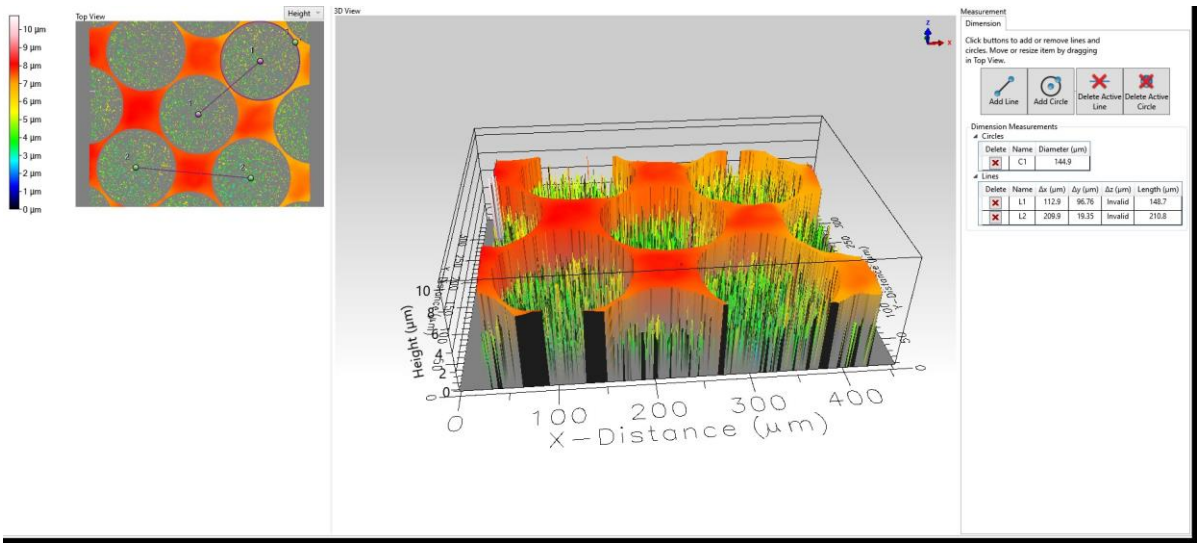


Figure 5(a)

The measurement of the pillar's diameter is 140.7 um Figure 5(b)

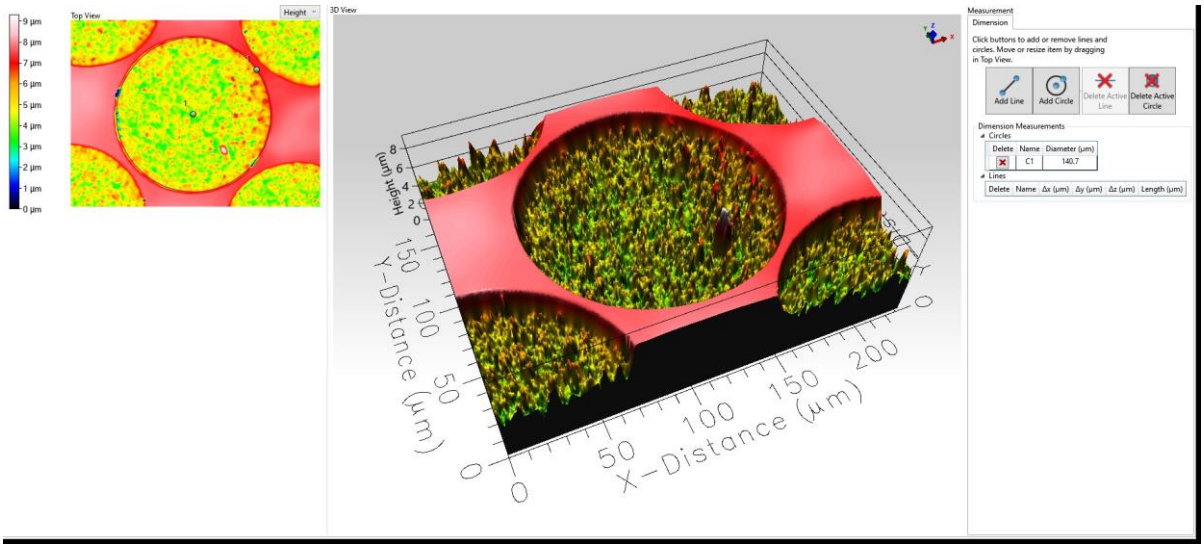


Figure 5(b)

The last measurement was the step height between the deposite gold and the upper surface of the graphite substrate, Figure 5 (c) shows that this gap was 3um. Figure 5(c)

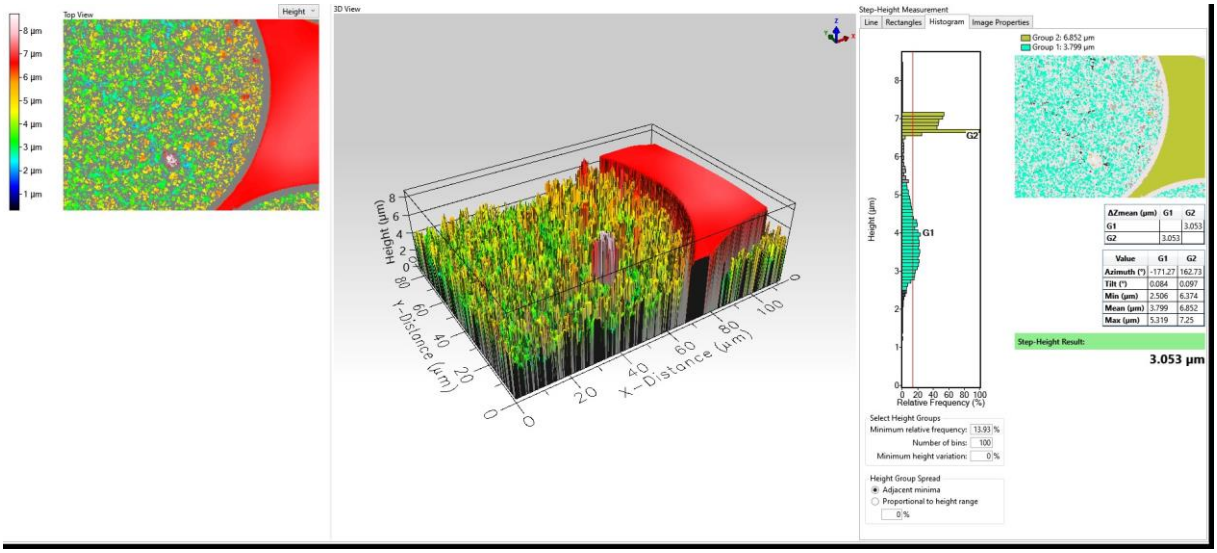


Figure 5(c)

This measure allow us to calculate the thickness of the gold layer : Thk = 17 um

Step 2 : Deep X-ray Litography

This is the final step in which the optical component is manufactured with x ray lithography. The material used to fabricate the component was PMMA, a polymer with good optical properties.

The X-ray mask and a PMMA layer 1mm thick were placed in the DXRL beamline Scanner DEX02.

The exposure parameters were:

Beam Energy E= 2.4 GeV; Machine Current I= 159 mA

Dose contrast = 3.3; Resist Bottom Dose =3000 J/cm^3; Scanner Dose = 954 mA min /cm

To obtain the array of pillars on a solid support, the exposure parameters take into account that the thickness to be lithographed is less than the thickness of the PMMA slide (1mm). In this case we have chosen a lithography depth equal to 0.5 mm

After the exposure step the PMMA slide was immersed in the developer bath to remove the exposed zones. The finished component and a magnification view are shown in Figure 6

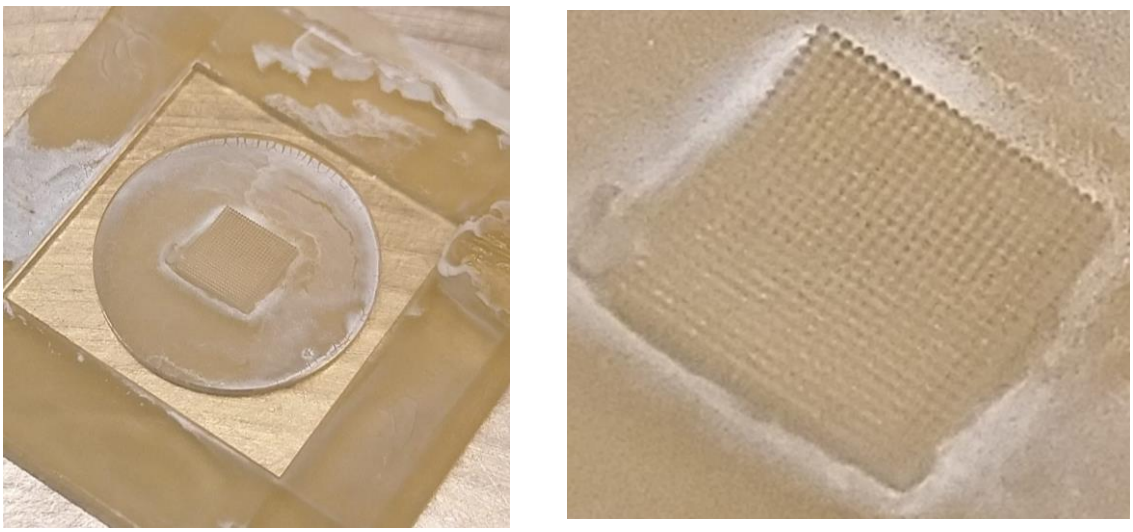


Figure 6

Finished component Dimensional Verification:

Due to the high light absorption value, the optical profilometer was unable to measure the geometry of the component. A suitable instrumentation could be a confocal microscope.

Effectiveness of the DXRL for the fabrication of light concentrators: Deep X-Ray lithography (DXRL) is effective in the fabrication of these kind of geometries in the PMMA, where large thickness (in the order of 1 mm) is necessary, and at the same time a high lateral resolution in the pattern is requested.

Measurement authors: the sample preparation and the reported measurement has been performed by Dr. Amardeep Bharti, Dr. Benedetta Marmiroli and Alessio Turchet.

This report has been written by Alessio Turchet

Trieste, 01/06/2022