# Soft- and near-field lithography on glass hemisphere surface for spherical zone plates

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The future trend in the development of biosensors, medical diagnosis and lab-on-chips for point-of-care service demands the capability of imaging objects (such as bacteria and cells) in close distance. Toward this end, we have proposed a novel design as shown in figure 1 for the next generation of miniaturized imaging technique with the resolution around 200 nm, close to the diffraction limit. In this innovation, the hemisphere glass ball does not have any focusing function because the microbes are located in the centre of the sphere. Instead, the focusing is done by the spherical zone plate fabricated on the top of the sphere surface. Conventional zone plates in x-ray optics are used to focus lights from far distance with a plane wave. In our system, the zone plate is used to focus light from a point source, therefore, the whole set of dimensions of the spherical zone plate needs to be re-formulated. Following the light paths as shown in figure 2, the radii of the *k*-th zone plate is readily derived as follows, where *n* is an integer and $\rho_0$ is the focal length of the zone plate:

$$r_n = R \cdot \arccos\left[1 - \frac{\lambda}{2nR(R+\rho_0)}\left[\frac{\rho_0}{n} + \frac{\lambda}{4n}\right]\right]$$

The imaging is planned to be carried out using the 632 nm wavelength at the first instance. There is a large freedom in determining the ball radius from 1 mm to 10 mm, the image position can also be decided in the range of several millimeters away from the ball surface. When these two parameters are fixed, the zone radii can then be calculated using the aforesaid formula.

The challenge in this work is to fabricate the metallic zone plate on the uneven surface. We have developed a novel hybrid nanofabrication technique to produce the large-area high-resolution zone plates on glass hemisphere surfaces. As show in figure 3, the whole process comprises three major steps: (1) the fabrication of an imprint template on silicon for the re-designed zone plate by electron beam lithography (EBL) and plasma dry etch; (2) replication of the zone plate pattern on a PDMS substrate by a nanoimprint process followed by a metallization and lift-off to form a soft mask plate; (3) the soft mask plate is then brought to contact with the glass ball surface to perform a soft imprint with near-field exposure tactics for the pattern transfer using a conventional mask aligner with a 350 nm I-line.

Figure 4 is the SEM micrograph showing the portion of the zone plate pattern in PMMA resist. The inset is the fabricated imprint templates on Si with two different sets of dimensions, one for 632 nm light and the other for 1550 nm. Beautiful light effect is observed due to the diffraction effect from the 632 nm zone plate. These two templates are then used to fabricate the soft- and near-field mask plates, which will be further used for the combined soft and near-field lithography to fabricate the spherical zone plates on the top of the glass ball.

By summary, we have developed a novel concept of a future micro-imaging system with an innovative lens – a spherical zone plate built on a glass ball. To realize such an ambitious task, we have developed a soft- and near-field lithography which is generally applicable for the replication on uneven surfaces. Initial encouraging progress has been achieved and the demonstration of the imaging function by the novel system is still under the way. We believe the new type of zone plates has great potentials for applications in life science, medical care, material sciences as well as micro X-ray optics system.

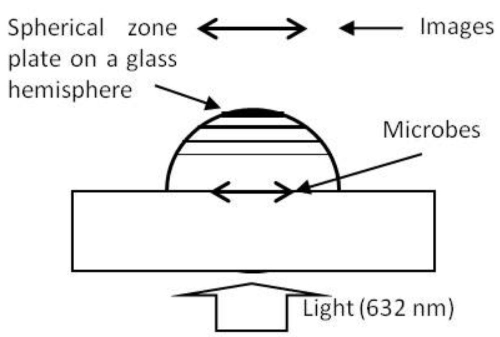


Fig. 1 Schematic of a highly integrated micro imaging system. The hemisphere glass is a supporting component with no focusing function. The metallic zone plate fabricated on the top of it does the imaging.

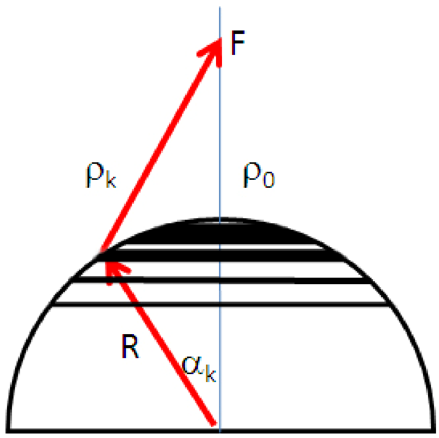


Fig. 2 the light path for the zone plate on the glass hemisphere to focus a point light source.

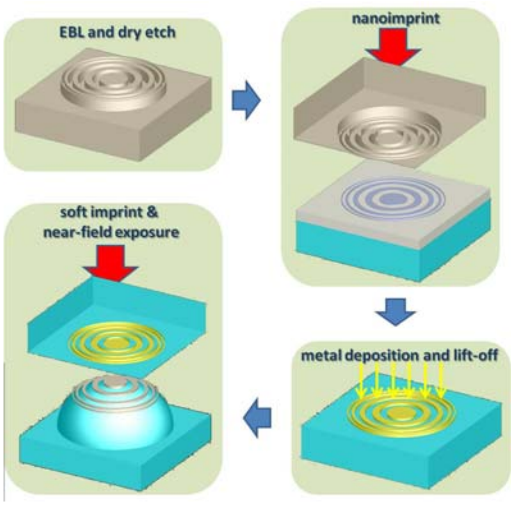


Fig. 3 the process flowchart of the proposed hybrid nanofabrication technique to produce the large-area high-resolution zone plates on glass hemisphere surfaces

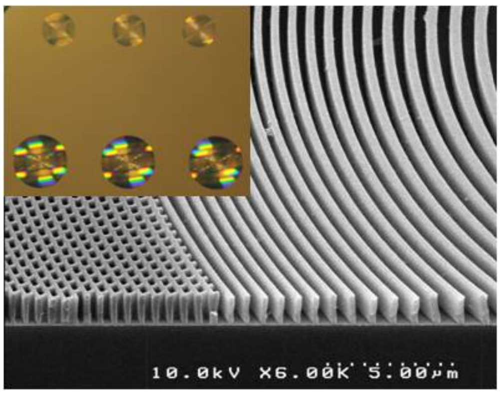


Fig. 4 the SEM micrograph showing the portion of the zone plate pattern in UV-III resist. The inset is the fabricated imprint templates on Si with two different sets of dimensions, one for 632 nm light and the other for 1550 nm.