Proposal of Lens Shaping Method Using UV Printer

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ABSTRACT
We proposed a lens forming method that does not require post-output processing using an ultraviolet (UV) printer. The transparent ink is first laminated to form a shape. A UV printer then smooths its surface by filling the layer roughness with a gloss. We implemented a tool to design the lens shape by inputting the lens diameter, focal length, etc.; with this tool, multiple lenses can be arranged and output as data to be printed by a UV printer.

ACM Classification Keywords
H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous.

Author Keywords
UV printer; Lens; Digital fabrication

INTRODUCTION
Lenses have a variety of uses ranging from daily necessities to precision instruments. In recent years, with the spread of digital machine tools such as 3D printers, the scope of personal manufacturing has expanded. However, despite the abundance of digital machine tools, it is still difficult to shape lenses; thus, in our research we focused on implementing ultraviolet (UV) printers to this process. UV printers are a type of inkjet printers that use ultraviolet cured ink. Though it should be noted, that it is possible to print with clear ink in addition to CMYK ink using these printers. Moreover, transparent ink can be printed with two types of texture, namely gloss and matte. It is also possible to laminate the ink and make it thicker.

We proposed the possibility of shaping various lenses by laminating transparent ink and smoothing their surfaces by gloss printing (Fig. 1).

RELATED WORK
Chung et al. [2] proposed a method using UV cured resin for forming micro-lens arrays. They used a unique inkjet printer to shape the lens with UV curable resin droplets and controlled the lens curvature with the amount of droplets etc. Morita et al. [4] made a simple condenser lens for laser heat treatment by using clinical numerical control (CNC) milling to cut an acrylic plate; silicone oil was applied to reduce surface roughness. There are also methods of producing lenses with stereolithography 3D printers [1][3]. In these methods, polishing is used to enhance surface smoothness and transparency.

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Figure 1. Examples of shaped lenses using our method.

The lens shaping method proposed by our research allows for relatively easy lens size and shape designs. In addition, as processing after output is unnecessary, concave lenses and lens arrays, which are notably difficult to polish, can be easily formed.

PROPOSAL

Concept
The following three features summarize the concept of our research: First, the diameter and focal length of the lens can be freely designed, and can be arrangement multiple lenses. Second, shaping is performed with only the use of a UV printer. This method does not depend on the skills of an individual user. Finally, we implement a tool that designs the lens shape and outputs it as data to be used by UV printers.

Shaping method
In our research, we used the Roland DG UV printer VersaUV LEF-12i [5], targeting both plano-convex and plano-concave spherical lenses and shaping them on an acrylic (or similar material) plate. First, the lens shape was determined by its diameter and radius of curvature (Fig. 2). The radius of curvature is determined by the focal length of the lens and the refractive index of the material. As a result, the shape of the lenses is determined by their lens diameter, focal length, and the refractive index of the material used. Next, we split the lens shape into each layer based on the thickness of the ink (about 0.035 mm) as shown in Fig. 3. The shape of each layer is a circle that is smaller in the upper layer for convex lenses. In the case of concave lenses, the outer diameters

are uniform and the upper layers have the form of a donut with larger inner diameters. Next, each layer was printed sequentially using transparent ink to form the lens shape. We used the transparent ink in matte mode in this process because of its higher accuracy in printing. Though the shape has been completed at this point, lamination traces are still noticeable. Finally, the transparent ink was printed twice using gloss mode over the entire surface. The surface was then smoothed out by filling in the lamination trace (Fig. 4).

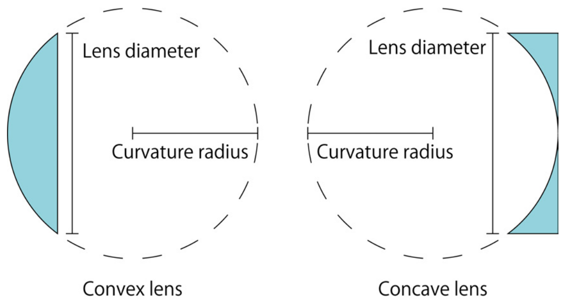

Figure 2. Shape of plano-convex / plano-concave spherical lens.

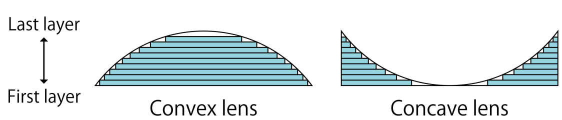

Figure 3. Cross section of layer.

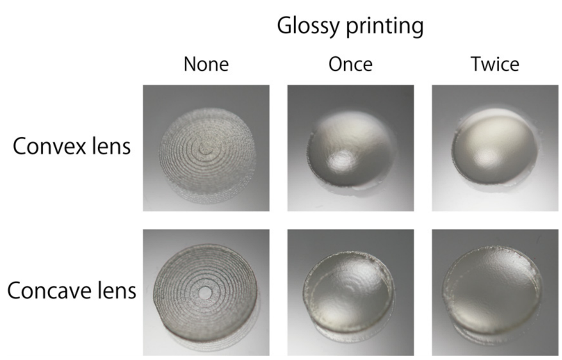

Figure 4. Transform of lamination trace by the number of times of glossy printing.

IMPLEMENTATION

We implemented a tool to generate print data for lens shaping by the proposed method. We utilized Adobe Illustrator script in producing our print data as it is the recommended software for the UV printer VersaUV used in our research. This tool consists of two scripts of lens design and data output.

The first step in using this tool is to input the three parameters of lens type, diameter, and focal length in the lens design script (Fig. 5 left). At this time, it is also possible to specify the thickness of the lens instead of the focal length. In addition, the parameters related to the printer are also adjustable, though the default values are enough in most cases: the thickness per print is 0.035 mm, the printable thickness is 2 mm, and the refractive index is assumed to be 1.5 following common transparent resin values.

After entering these parameters, the divided shapes (Fig. 3) are drawn on individual layers of Adobe Illustrator (Fig. 5 right). The operation of the lens design script ends with this final step. Multiple lenses can be determined by either duplicating the drawn shapes or executing the script once again. By executing the data output script, each layer is exported as an individual EPS format file, and print data of each layer is completed. These data group can be read by the output software of the UV printer; lenses can be then shaped by sequential printing on an acrylic or similar plate beginning with the lower layer.

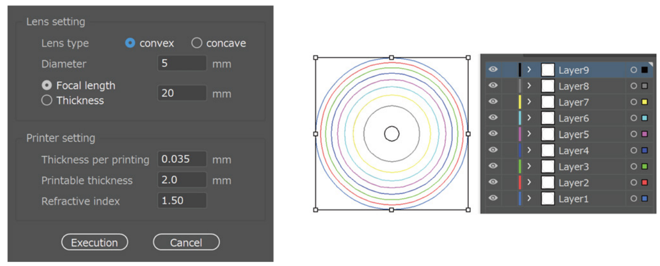

Figure 5. Parameter input UI for lens design script (left) and shape depicted (right).

APPLICATION

Since UV printers can use CMYK ink, the proposed method can also form color lenses (Fig. 6). In addition, since a multiple lenses can be arranged, lenses such as compound eyes can also be shaped (Fig. 7).

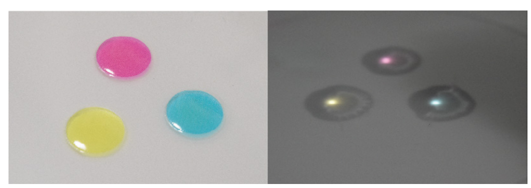

Figure 6. Color lens and state of light collection.

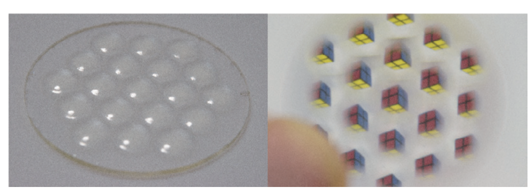

Figure 7. Compound eye lens and reflected image.

FUTURE WORK

We have started to test the characteristics and limitations of the shaped lenses. We also try to develop further types of lenses, including a double-faced lens and a lenticular.

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