Lasers in Manufacturing Conference 2021

RECILS: High resolution and high-speed SLA 3D printer using a plane building platform and a cylindrical window

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Abstract

We propose a novel stereolithography 3D printer configuration, called RECILS, achieved by combining a plane building platform (BP) and a cylindrical glass window (CGW). The BP is deployed above the sidewall of the CGW placed horizontally with a gap of 10 μm to 40 μm. UV curable resin is supplied into the gap and cured by the UV laser light passing through the CGW. The UV laser light with a spot size of 10 μm is scanned lineally along the gap by a polygon mirror. The UV light is modulated by the STL data, and the BP is translated in a direction perpendicular to the laser-scan direction, synchronized exactly with the laser scan. This operation is equivalent to a raster scan. The subsequent layers are formed below the previous layer and accurate 3D-modeling is enabled. Additionally, the use of a CGW eliminates peeling process and greatly reduces the manufacturing time.

Keywords: 3D printer, SLA, cylindrical window, raster scanning, UV-curable resin;

1. Introduction

Stereolithography (SLA) 3D printers are one of the most promising methods for forming 3D objects. However, they still have some challenges regarding manufacturing speed and the resolution of fine structures. In conventional SLA 3D printers, a key element of object forming platform is a 2-dimentional gap (2D-gap) with

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several tens of micron height consisting of a plane window and a plane building plat (BP). UV curable resin is injected into the 2D-gap and exposed by UV laser light through the window. The UV laser light is spatially modulated according to a desired pattern defined by Standard Triangulated Language (STL) data. The UV-exposed part of resin is cured and a single layer is formed between the windows and the BP. The formed layer is peeled from the window and a new gap filled with resin is formed. The sequential operation of the set of processes consisting of forming of 2-dimentional gap, spatially modulated UV-exposure and peeling an object forms a 3D object defined by a set of STL data. So far, objects with a volume of several liters with resolution of 100μm are realized. However, the peeling process makes the manufacturing time long, and the control of the gap between the window and the BP with an accuracy of order of μm is a challenging work. To solve these challenges, we propose a SLA 3D printer called RECILS with a novel configuration consisting of a plane building platform (BP) and a “cylindrical” glass window (CGW)

2. Structure and operation of RECILS

Figure 1 (a) shows a photograph of SLA 3D printing apparatus, RECLS with a size is 400(W)x250(D)x420(H), a desktop-computer size. Figure 1 (b) shows the side view of the object forming platform consisting of a “plane” BP and a CGW. The BP is deployed above the side wall of the CGW placed horizontally with a “one-dimensional” gap (1D-gap) of 10 to 40 μm (typically 20 μm). UV curable resin (light blue) is supplied into the 1D-gap and cured by the UV laser light scanned by a polygonal mirror along the 1D-gap. The laser light is modulated according to the STL data. The BP is translated in the direction perpendicular to the laser scan direction in exact synchronization with the polygonal mirror rotation. The UV laser light has a spot size of 10 μm at the surface of the CGW, and the translation of the BP is also controlled such that the spacing between each laser scan is 10 μm. Therefore, the accuracy of the laser spot position is controlled to be 10 μm and a manufacturing resolution of 20-30 μm can be achieved.

The operation of RECILS is illustrated in Fig.2 (a) and (b), and it is equivalent to a raster scan. We would like to strongly point out that this operation realizes the automatic peeling of the formed object form the CGW

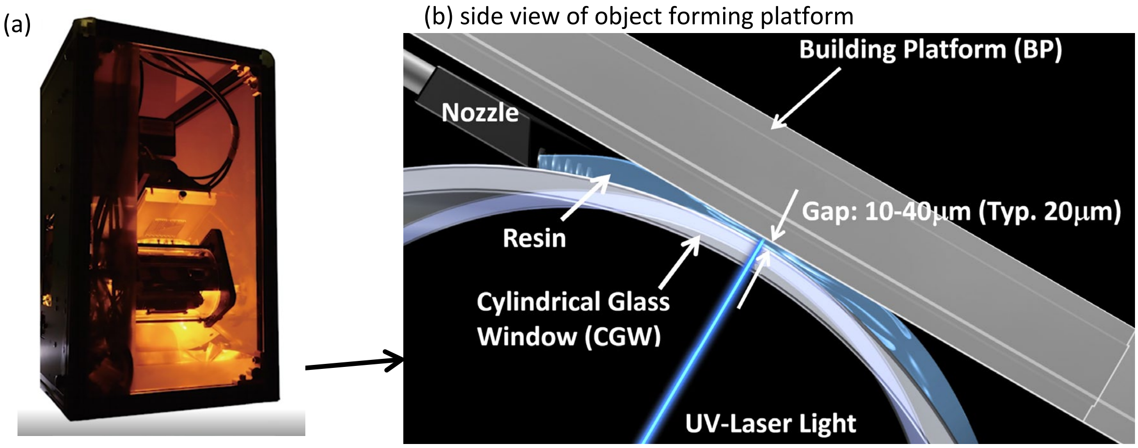

Fig. 1 (a) Photograph of RECILS. (b) The side view of the object forming platform of RECILS. Resin (light blue) is supplied from the left-hand side of the CGW and flows into the 1D-gap. The thickness of the resin is controlled by the 1D-gap between the CGW and the BP or the formed object. This structure is feasible to maintain a uniform gap hight. Uncured resin returns to the resin bath and it is re-pump-upped again.

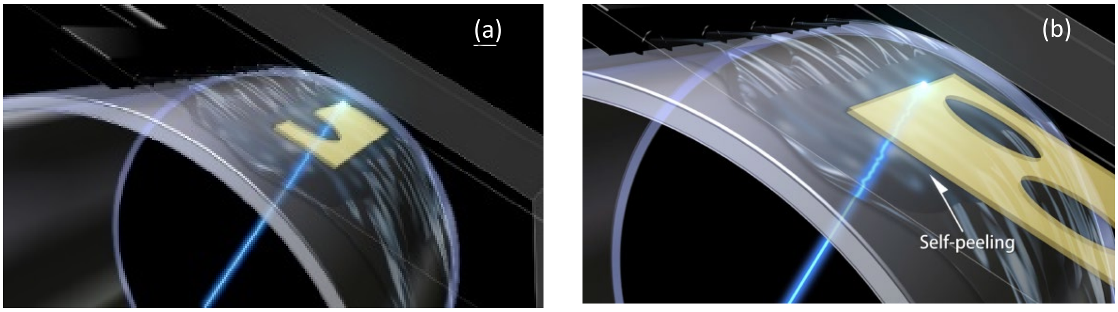

Fig 2. Images of RECILS in operation. The blue line is a UV-laser light and a yellow plate is a cured resin formed bellow the BP. (The BP is erased in (a) and (b).) The BP translates from the left to the right in exact synchronization with the laser light scanned by a polygon mirror. This translation of the BP enables the formed object to peel from the CGW. An image of the operation at the half point of forming a single layer is shown in (a). (b) shows the situation just before the completion of one layer.

and resin supply to the 1D-gap takes place easily. That means, resin supply, UV-light exposure and peeling take place simultaneously. Subsequent layers are formed below the previous layer after the BP steps up by a height of the gap. This layer-by-layer forming creates the object with fine structure. In addition to this high resolution, the auto-peeling process makes the manufacturing process time of RECILS faster than conventional SLA 3D printers. The gap height is adjustable between 10 μm to 100 μm depending on the required resolution for the object.

When the molding operation of RECIS is videotaped and played back in reverse, the operation is the same as that of the slicer. The name of RECILS is a coined word which spells each alphabet of “SLICER” backwards.

Figure 3 shows a picture RECILS is forming 2 sets of 3D microchannel, and the finished product is shown in Fig. 4. The objects are formed between the BP and the CGW. The UV laser light scanning below the objects is confirmed as a blue line. The UV light source is a GaN semiconductor laser with a wavelength of 405nm and the typical power of 300mW.

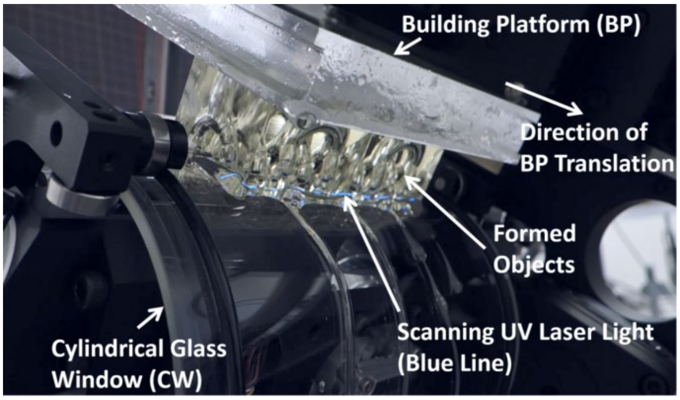

Fig 3. Photograph of operation of RECILS fabricating objects. Each object has a size of 40mm x 40mm x40 mm. In this operation, two microchannels are formed along the laser scan direction. The BP is translating from the left to the right, and the objects are peeled automatically from the CGW.

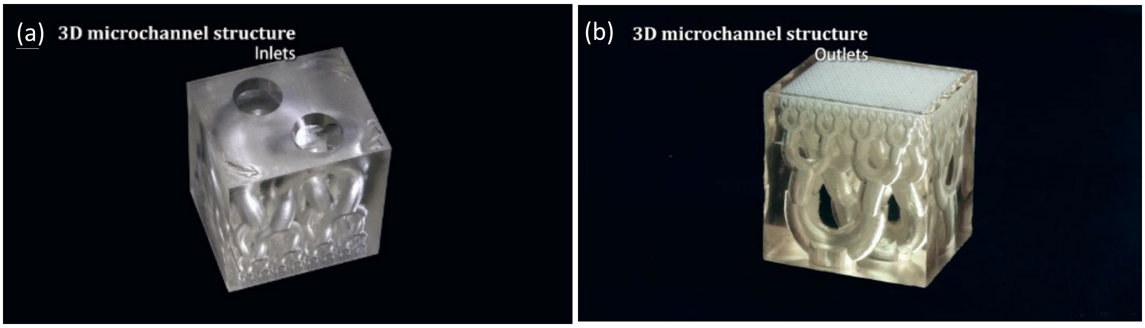

Fig. 4 3D microchannel formed by RECILS. The size of this object is 40x40x40 mm^3. (a) and (b) show the inlet face and the side view of the 3D microchannel, respectively. The forming of the inlet face is shown in Fig. 2 (a) and (b). Each inlet divides into two channels and this bifurcation takes place 11 times in 40 mm height. 11-times bifurcation forms 2048 outlets and there are 4096 outlets in total. The 4096 outlets for each channel are placed like a checkerboard pattern.

3. Formed objects

Figure 5 shows an example of a fully formed object created by RECILS. There are 2 channel inlets at the bottom of the cube. Each channel bifurcates into two branches. This bifurcation takes place 11 times within a 40 mm height and thus each inlet is split into 2048 outlets. Therefore, there are 4096 outlets on the top surface of the cube. The inside of the channels is metal-plated, which can be prevent chemical damages on the surface of the object for chemical applications.

RECILS can form objects with fine structures with a manufacturing resolution of 20 to 30 μm with fairly fast manufacturing time. This feature is expected to make it possible to apply this technique for manufacturing microreactors, and radio and electronic components operating at frequencies between microwave and THz (Otter, 2017), (Konishi, 2020). Additionally, a hybrid using resin with metal coatings has superior characteristics to metal 3D printing from the standpoint of machine cost, material cost and energy consumption. RECILS also has the potential of size scalability and it is easy to extend this technique to large scale manufacturing.

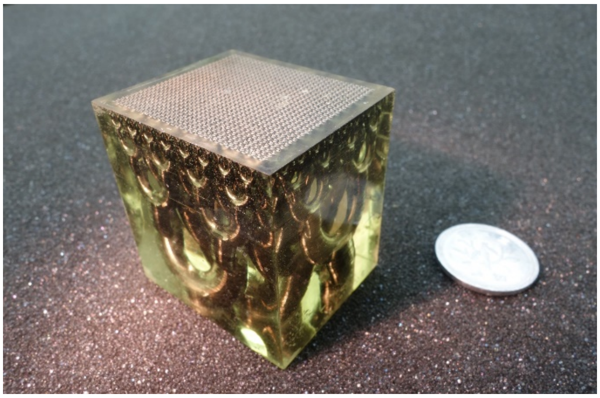

Fig. 5. Micro channels formed in a 40x40x40 mm^3 cube. The inside of the channels is metal-plated.

4. Conclusion

We propose a novel type of SLA 3D printer named RECILS. Unique features of the RECILS include (a) liter-size object forming with 20 to 30 μm resolution, (b) reduction of manufacturing time by half to a third compared to those required by conventional SLA 3D printers, (c) compact machine dimensions of RECILS with relative to the dimensions of the manufacturing objects, (d) flexible scalability of object dimensions keeping high manufacturing resolution.

We propose a novel type of SLA 3D printer named RECILS. Unique features of RECILS include (a) forming palm-sized objects with 20 to 30μm resolution, (b) reduction of manufacturing time by 33% to 50% compared to conventional SLA 3D printers, (c) compact machine dimensions relative to the dimensions of the objects produced, and (d) flexible scalability of object dimensions while maintaining high resolution.

RECILS realizes these features by employing a 1D-gap made by a "plane" BP and a "cylindrical" glass window (CGW). The resolution of RECILS is determined by the 1D-gap height, the spot size of the UV-laser light and the accuracy of the translation stage of the BP. We believe that further improvement of the laser scan optics and the laser scan mechanism would achieve a resolution of less than 10μm. Reduction of manufacturing time is realized by using a CGW which eliminates the need for a separate peeling process of the UV-cured resin.

The very simple object-forming platform reduces the required machine size of RECILS. The maximum size of the manufacturable objects is determined only by the size of the BP translation stage and the width of the cylindrical glass window. Therefore, RECILS can be easily adapted to manufacture objects with a wide range of dimensions. In addition, the manufacturing speed is also scalable with the intensity of the UV-laser light.

These unique features of RECILS are expected to create new application fields. For example, as demonstrated here, we expect to be able to manufacture durable micro-protective layers (metal plating) to protect plastics from reaction with chemicals. Also, waveguide applications for next generation mobile systems, beyond 5G and 6G are also possible. The radio frequency for 'beyond 5G and 6G' is assumed to be more than 100GHz, which corresponds to a wavelength of less than 3mm. The size of waveguides for these applications is required to be less than 1mm with surface roughness of 20 to 30μm. This type of waveguide structure can be formed with RECILS. In addition to these unique applications, it is possible to form structures which are impossible to be formed with conventional 3D printers, like enclosed hollow spaces filled with air and structures with a partition plate floating in space like a ceiling. Based on the above, we believe that RECILS has the potential to create new applications and open up new markets in the world of 3D printing.

Acknowledgements

We would like to express our gratitude to Hiroyuki Yasukochi, the inventor of RESILS (Japan patent 5724317, US patent 10022911) and our collaborator in this project. This work is supported by the Center of Innovation Program funded by the Japan Science and Technology (JST) and JSPS KAKENHI Grant Number JP21H01320.

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