A design method to surface of Japanese lacquer by UV projection for DIY fabrication

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ABSTRACT
We propose design methods that process the surface of Urushi, a Japanese traditional coating material, with computer technology and ultraviolet (UV) light control. Urushi changes their physical condition by absorbing UV light energy. Our research introduces design method with this physical feature for Personal Fabrication by utilizing UV laser and galvanometer mirror or UV lamp and paper.

Our contribution is to introduce the principle of the new fabrication method. This method is able to add a pattern onto the Urushi coated surface by controlling the UV light direction. We use two methods to control of the light. One method uses laser and galvanomirror. Another one uses a lamp and mask pattern. We introduce and compare these methods, and describe future of Urushi design.

Author Keywords
Personal Fabrication; design; Japanese lacquer; Urushi; UV energy projection;

ACM Classification Keywords
H.5 INFORMATION INTERFACES AND PRESENTATION; H.5.2 User Interfaces

INTRODUCTION
We propose a unique Personal Fabrication method to design a texture on the surface that is coated by Urushi. The movement of DIY and Personal Fabrication is coming. 3D printer and laser cutter contribute to realize new DIY style. These systems help us to produce a new implementation with highly versatile. Recently, not only researchers or engineers, but also hobbyist, such as MAKERs use them. Additionally, there are some cafes that install a laser cutter and a 3D printer in Tokyo. This trend shows DIY is one fashionable entertainment now. We hope to increase usable material for personal fabrication to boost this movement.

In this study, we focus on Urushi that is a traditional material in East Asia. Urushi is a natural material that is tapped from the trunk of the lacquer tree. It is important coating material for daily necessities such as the tableware, furniture and building [1], because it is resistant to heat, acid, water and humidity etc. Besides, it has various tolerances such as insect proofing and electric insulation, and also has adhesive property. In addition, the lacquerware can acquire a traditional design. For example, CHINKIN and MAKIE are well known methods. CHINKIN is a design method by engraving grooves and filling it with gold leaf or powdered gold. MAKIE is a design method by sprinkling gold or silver powder on the picture drawn with lacquer. Both 2 methods require technical skill. And cost is very expensive. So it is difficult to design the surface of Urushi as DIY even though Urushi is very familiar material. In this paper, we introduce two methods to put surface design on SHIKKI, Japanese-lacquered object, and propose the potential of Urushi as a base of Personal Fabrication material.

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RELATED WORKS
We introduce two important research fields to explore the possibility of Urushi; one is design works utilizing Urushi, and the other is energy projection method for design.

There are some great design works that utilize characteristics of Urushi such as high luster, electric insulation and decorativeness. We introduce two unique projects utilizing Urushi as a key material of the product. Toki et al. revealed the possibility of KANSHITSU method. This is a way of making forms by using composite material. This material consists of natural fiber such as hemp and Urushi as a resin for the structure [2]. Laser cutter can manipulate this composite material easily. Therefore they

apply it as a prototyping material in a design workshop. And they also use laser cutter to engrave the surface of KANSHITSU for CHINKIN design. On the other hand, Suzuki et al. creates Urushi Musical Interface [3]. It utilizes Urushi and gold to fulfill both a beauty of aesthetic and of functionality. Black lacquered surface of the instrument is decorated with gold inlay lines by using the CHINKIN technique. The gold inlay is a conductive surface, so when one touches it, the instrument will be switched on.

The researches using a method of projection are carried out as technique to enrich surface design in the real world. There are a lot of researches that utilize commercial optical projector to augment expression of real world objects [4] [5]. And also there are a lot of unique projection methods with specialized projection systems. Saaks et al. presented Shader Printer [6] and Slow Display [7]. They utilize UV laser projector as a trigger of chemical reaction on the surface of the design target to control the pattern or texture of the object. And Hashida et al. introduced Photochromic sculpture [8] and Hand-rewriting [9] with UV DMD projector system that controls the visual information using photochromic reaction. These studies can be regarded as energy projection method to control visual information. And we also adapt this energy projection method to control Urushi condition.

PRINCIPLE

Urushi is a resin composed of mainly Urushiol. This is an oily organic material found in plants in Asia and its characteristic is changed by UV light. Urushiol has a couple of double bonds and these bonds react to UV light as well as rubber or plastic. This is a case in oxidation reaction of an organic compound. This reaction changes their color, gloss and electrical resistance property.

DESIGN

We propose two design methods. One method utilizes UV lamp as an energy source, and white paper as a mask. Another one utilizes UV laser and galvanometer mirror.

UV Lamp & paper

It is possible to add patterns on the Urushsi surface without setting up of specialized software for a UV lamp and the paper method. User uses white inkjet printing paper as a mask of the UV light. White inkjet paper reflects UV light. Therefore, the mask area keeps its color and un-mask area is decolorized.

Mask Material test

We choose white paper because it contains fluorescent whitening agents that enhance the whiteness of paper by reflecting UV light clearly. We measured the effect of mask materials. Figure 1 shows the experimental setup. We use 15W 352nm UV lamp (EFD15BLB-T) as UV light source, and UV power meter (TM-208). We tested several materials that were easily available. Table 1 show the effect of mask material. According to this table, inkjet paper is best for this purpose.

Figure 1: Experiment set up to measure the effect of UV mask.

Table 1: Result of mask effect

Mask material	UV power[uW/cm2]
No mask	854
Transparent Acryl	100,8
Note book paper	70.3
White copier paper	43.3
copier paper	27.3
Recycle copir paper	2.2
inkjet paper	0

Procedure

The typical procedure is described below.

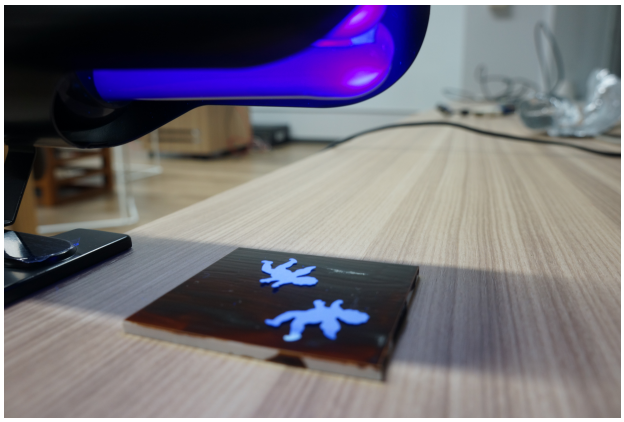

Figure 2: Experiment set up for UV lamp and paper method.

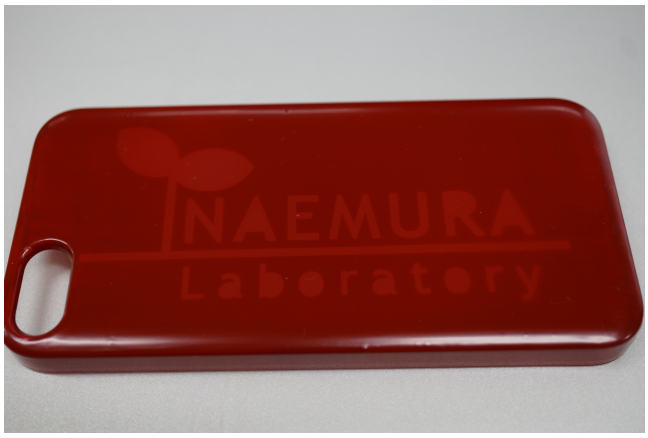

Figure 3: Result of UV lamp and paper method with red colored Urushi for iPhone case.

1. User designs the mask pattern and prints it on white paper.
2. User trims it by a laser cutter, a cutting plotter or a cutter knife by hand.
3. User puts the mask is on the lacquered product.
4. User exposes materials to UV lamp until the material color alters.

Figure 2 shows the set up of UV lamp method and Figure 3 is a sample result. The experimental lamp is the same one which we use the mask material test.

UV Laser projection

We prototyped raster scan type laser projector that is constructed with UV laser, 2-axis galvanomirror (General scanning Inc., VM500) and a control circuit system. We chose the laser that enables focus adjustment. And we control the diameter of UV laser spot to 1.5mm. Its wavelength is 405nm and power is 200mW. The UV ray hits the galvanomirror where it is then reflected down to the stage. The mirrors are controlled by DA converter MCP4922 and Arduino that connect with a laptop. Laptop sends the control signal that is based on PNG image file. User inputs PNG data for the design.

Monochromatic PNG data of 1024x1024 pixel is used as the control data of the laser. The control software carries out the positioning of the mirror 60 times per 1 second via serial communication through Arduino circuit. The control software reads pixel color of monochromatic PNG one by one and moves the dot position of the laser. It irradiates a laser for 1 second and moves next point. To prevent the laser heat problem, the laser is hit only for 1 second. It repeats this routine 60 time so one dot get laser exposure for 60 seconds in total.

The typical procedure is described below. Figure 4 shows the set up for this method and Figure 5 shows an example of this method.

1. User designs monochrome image.
2. User adjusts the size of the laser spot and position.
3. Laser shoots the UV ray to a lacquered target.

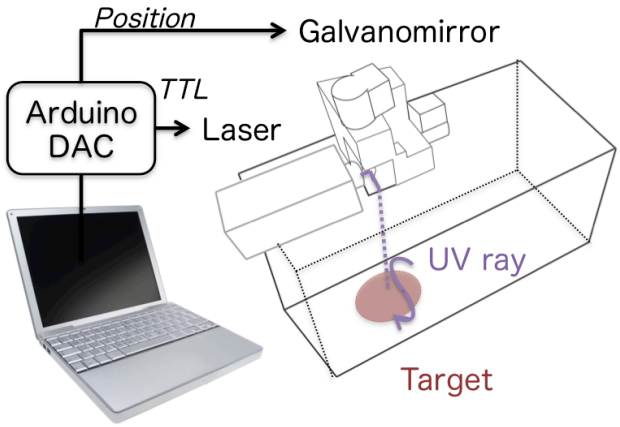

Figure 4: Experiment set up for UV laser system.

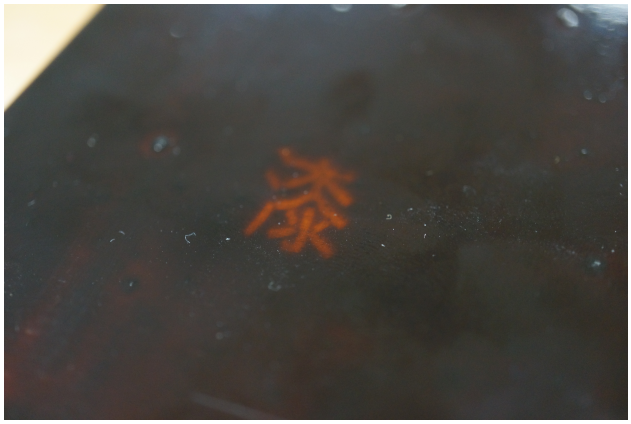

Figure 5: Result of UV laser system with Urushi on copper board.

EVALUATION

We confirmed time length of chromaticity change at the same level for each method. The result shows that 100 hours of the UV lamp projection is almost as same color difference as 60 seconds of the laser projection. We captured the surface color by the scanner (Canon LiDE 210) and measured Lab parameter by Abode Photoshop. Figure 6 is the graph of the color difference. The dot line indicates the color difference of the laser sample that has been projected 60 second and the curved line is UV lamp sample data. According to this result, UV lamp is faster than the laser system if the user wants to draw larger pattern around 67.5 square centimeter specifically.

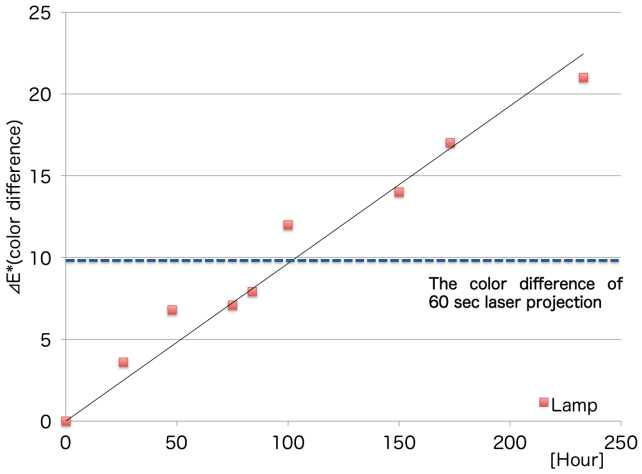

Figure 6: Color difference by UV lamp projection (The dot line indicates the color difference of the laser sample that has been projected 60 second).

DISCUSSION

We discuss three aspects of this research, comparison of each method, limitation and future.

Comparison

Each method has characteristic. We outlined them and consider proper use.

Feature of paper method

- Essential parts are relatively available.
- User can carry out positioning by hand easily.
- It takes time in comparison with a laser for small area.
- It is necessary to adjust the energy irregularity of multiple lamps if user wants to design large pattern. The best way is to use flat surface source such as light guide plate of LCD.

Feature of Laser method

- In the case of small pattern area, it is shorter processing time than the paper method.
- Laser is strong and dangerous for human. So it needs the case of protection such as a microwave oven.
- It needs registration of the laser projection area and a target setting position.
- The parts are not easily available.
- Due to a galvanomirror system, it is necessary to implement the adjustment system of the focus depending on the projection distance.

Proper use

We propose proper use for each method. According to this comparison, the laser method is better for small pattern design. On the other hand, the paper method is better for DIY because the materials are commodity.

Limitation

The biggest problem caused by the laser method is burn. Lacquer is a kind of resin and the heat of the laser burns it. We introduce three key points to prevent a safety problem. The first point is the substrate of Urushi product. The substrate should be high thermal conductivity for radiation of heat such as metals. The second point is the spot size of the laser. Its diameter must be 1.5 mm at the minimum in order to prevent concentrating of energy on one point too much. The third is the exposure time of laser projection. To prevent heat problem, system have to control the time of laser exposure based on the base materials.

Other problem of this system is to adjust laser spot size. When a user wants to change the spot size, user has to know existing focus size. However, it is difficult for the user to see the laser spot size because it is too bright and harmful. Therefore, we use bi-stable thermo-chromic ink named frixion [10] to check the size of laser. This ink alters invisible at 65 degrees over, so our laser can erase this. For this reason, we use this ink to control the focus size. At first, user paints a piece of paper with this ink and put it on the place of the target. After that, laser shoots the painted paper and user checks the size of dot and adjusts it to 1.5 mm spot size.

Getting burnt by the heat becomes the problem in the case of the technique with the laser in particular. Therefore if a user wants to use something flammable instead of metal materials, it needs cooling down. When we used acrylic material, we put air-cooling or installed material underwater.

Another current limitation is color. Our proposal controls only contrast of Urushi. If user wants to use several color, it might be a solution to coat the surface with several layer of Urushi by using different color in advance.

Additionally, this chemical reaction is not reversible. User can draw patterns but cannot undo it. If the user fails drawing, he needs to repaint it with Urushi.

Future works

Urushi can produce colored paint such as red or black by mixing the color pigments or additive. The problem of this colored lacquer is high flammability. It does not have sufficient durability of the laser. Hence we use colored lacquer only for the paper method. In the future, we would like to design cooling or heat controlling method of the laser system, to use colored Urushi.

And we are also interested in electric insulation characteristic of Urushi too. We have already implemented an embedded system utilizing a silver nano ink print pattern and lacquer on the copper. This leads further Personal Fabrication method that we can design both function and decor. Figure 7 is one functional prototype. We coated copper with Urushi, and remove the pattern a bit by laser projection and paint simple LED circuit.

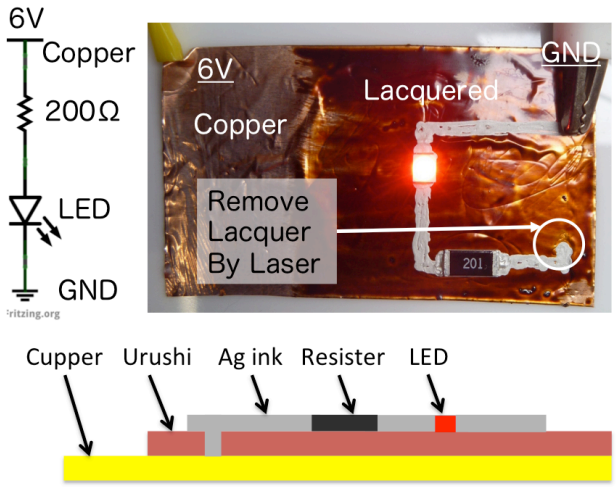

Figure 7: Functional prototype of the circuit on the lacquered copper.

CONCLUSION

In this research, we present the basic study of the surface design of Urushi by controlling UV light projection. We propose two energy projection methods. One method is the combination of UV lamp and paper. Another one is UV laser and galvanomirror. In the future, we will elaborate the technique to combine electronic circuit and multiple layers.

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