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# The *Urushi* Circuit

## - Use of a Traditional Craft Material for HCI -

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### Abstract

We propose a novel electric circuit that uses *urushi* lacquer to construct devices for human-computer interaction (HCI). *Urushi* has many interesting features. Among them, we focus on its insulating properties and susceptibility to ultraviolet (UV) radiation. We postulated that a UV laser could be used to remove *urushi* locally, and that several layers could be connected via removed points. This made it possible to fabricate an *urushi*-based multilayered electronic circuit (an *urushi* circuit). In this paper, we propose a method for producing an *urushi* circuit, and verify the feasibility of our method. In addition, we constructed a prototype multilayered electronic circuit and touch sensor.

### Author Keywords

*Urushi*; Traditional Craft; Electronic Circuit; Touch Interface

### ACM Classification Keywords

H.5.2. User Interfaces: Theory and methods

### Introduction

This study proposes an interface made with *urushi*, which is used in traditional Japanese crafts. *Urushi* is a natural material that is obtained from the trunk of the Japanese lacquer tree (*Toxicodendron vernicifluum*). It has many features, such as resistance to heat, acids,

water, and humidity, it is an adhesive, and has also been used for insect proofing and as electric insulation (Table 1).

Waterproof	Good
Chemical resistant	Good
Electrical insulator	High
Corrosion resistant	Good
Adhesive	High
Hard	Same hardness as iron
Antimicrobial	High
Heat resistance	120–300°C
Air conductivity	Good
Environmental adaptability	Good
Allergenic	None

**Table 1.** Features of *Urushi*.

Technology developments allow *urushi* lacquer to be used on any type of material. Consequently, it is used for art, tableware, furniture, ships, building, and many other purposes. Our target areas are wearable computing and ubiquitous computing. Some wearable-computing research is studying health management to improve the quality of life (QOL) [1]. Because such wearable computing systems make use of skin contact to monitor human health [2], some of these interfaces are used in delicate areas, such as the teeth and mouth [3-6]. Therefore, the material used for these interfaces must be safe for humans. Here, we propose a new electronic device that combines *urushi* and electronic circuits. The Japanese lacquer *urushi* has many excellent properties, as summarized above. It is an electrical insulator, has antibacterial properties, and is

non-allergenic after it has dried. Furthermore, *urushi* can be applied to almost any material, such as plastic, glass, metal, or paper, making it suitable for wearable computing devices.

Here, we propose a method of fabricating an *urushi* circuit and report the results of an experiment conducted to verify the feasibility of our method with a prototype *urushi* circuit. We also consider the future of *urushi* circuits.

## Method

*Urushi* resin is composed mainly of urushiol, which is an oily organic material found in plants in Asia. It can be dissolved by ultraviolet (UV) light, as urushiol contains two double bonds that react on exposure to UV light in an oxidation reaction. This reaction changes the color, gloss, and electrical resistance of *urushi*. Based on this phenomenon, we propose the fabrication of a multilayered *urushi* circuit by removing *urushi* locally.

Our method is as follows (Figure 1).

1. *Lacquer urushi on a base material*
2. *Print a circuit pattern using an electric conductor*
3. *Lacquer urushi on the electric conductor*
4. *Make through holes by dissolving the urushi using a UV laser*
5. *Print a circuit pattern using an electric conductor and connect it to the lower layer*
6. *Attach electronic parts to the circuit pattern*
7. *Cover the electronic parts with urushi as needed*

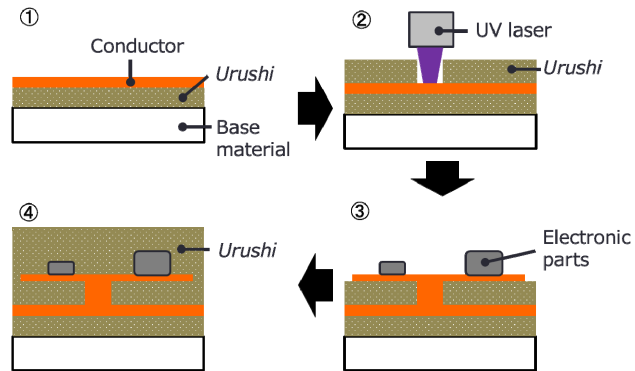


Figure 1. Fabrication of an *urushi* circuit.

The main advantages of this method are that it is a contactless process and involves high working accuracy. A machining method using a drill or knife would damage the entire *urushi* surface by causing cracks or bending. In comparison, a UV laser dissolves only the irradiated area, without contact and we can control the power, diameter, and direction of the laser precisely [7]. Consequently, we believe that our method has the potential to fabricate very accurate *urushi* circuits approximately the same as those of current laser-processing machines.

### Verifying Our Method

To verify our fabrication method, we irradiated *urushi* on a copper board using a UV laser (405 nm, 200 mW, ray diameter = 1, 2, and 3 mm). The distance between the UV laser and *urushi* was 5 mm (Figure 2). The *urushi* was about 10 μm thick. We checked the continuity of the irradiated area every 1 minute of irradiation. If *urushi* is dissolved completely, the irradiated area will short-circuit.

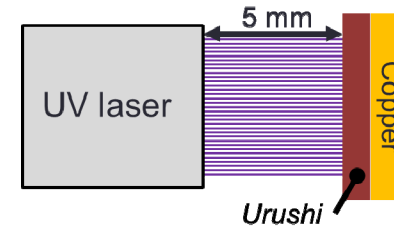


Figure 2. Diagram of the experiment.

The experiment showed that the UV laser could dissolve the *urushi* quickly (Table 2, Figure 3). The dissolving time was inversely proportional to the diameter of the ray. It was possible to control the dissolution rate by changing the power of the ray.

		Irradiation time with the UV laser [min]					
		1	2	3	4	5	6
Diameter irradiated [mm]	1	X	X	X	O	O	O
	2	X	X	O	O	O	O
	3	O	O	O	O	O	O

X: insulation; O: conduction

Table 2. The time taken for conduction.

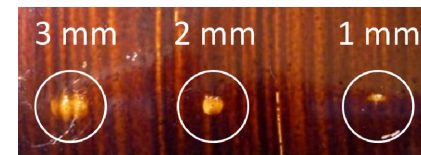


Figure 3. Area irradiated by the UV laser.

### Prototyping

#### Two-Layer Circuit

We developed a prototype to verify the possibility of fabricating a multilayer circuit using *urushi*. The

prototype circuit consisted of two layers of *urushi*. The bottom layer was used to coat a copper plate, which was connected to the ground (GND). We removed part of the *urushi* with a UV laser to connect the GND to the upper layer, and painted silver (Ag) ink on the bottom layer. The top layer included some electronic parts and Ag ink. We also removed the *urushi* in several areas using the UV laser to connect them to the GND. The circuit was used to control the brightness of two light-emitting diodes (LEDs) via variable resistance (Figure 4). We confirmed that this circuit worked as expected (Figure 5).

#### ***Touch Interface***

Based on the above result, we designed a touch interface with an *urushi* circuit. *Urushi* has a comfortable moist feeling. Therefore, a touch interface made with an *urushi* circuit should enhance the touch interaction.

We propose two types of touch sensor (Figure 6). One we call "Makie", in which a conductor pattern is printed on the *urushi*. This conductor is not only an image but also a capacitive sensor. The other, we call "Cover". In this type, the circuit pattern is covered with *urushi*. We can enjoy the texture and glossiness of the *urushi* because the circuit pattern is hidden. Furthermore, we can choose the degree of transparency and color of the *urushi* and decorate the surface with several types of *urushi*.

First, we attempted to develop the two types of touch sensor (Figure 7). The base material used was an acrylic plate. After lacquering, we printed Ag ink on the *urushi* using silk-screening.

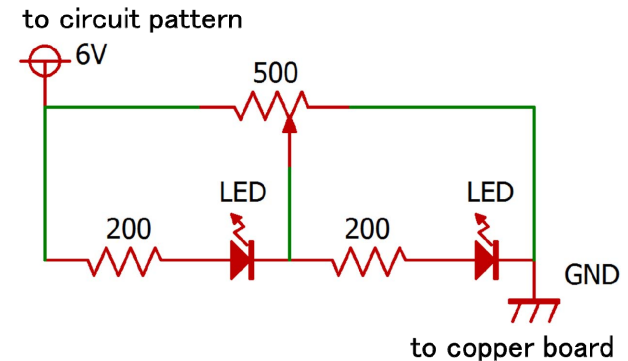


Figure 4. Circuit diagram.

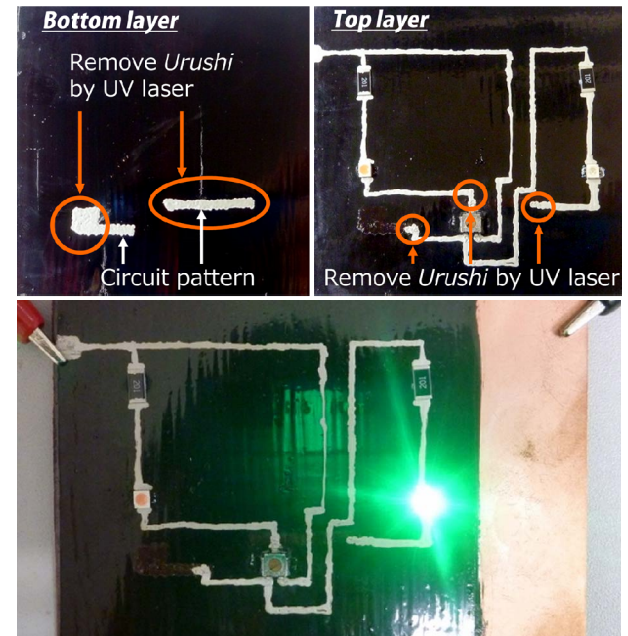


Figure 5. A two-layer *urushi* circuit.

To verify the utility of the *urushi*-based touch sensor, we connected sensors to a touch-detecting circuit built on a bread board (Figure 8). This circuit checked the change in the capacitance of the sensor. When touched, the capacitance changed significantly. The circuit detected this change and turned on three LEDs. The detecting test confirmed that both touch sensors could detect the touch of a finger (Figure 9).

Next, we combined the two-layer *urushi* circuits and *urushi*-based touch sensor via a detecting circuit (Figure 10). In this system, we replaced the three LEDs on the bread board with a two-layer *urushi* circuit. Then, two LEDs on the *urushi* circuit would light on touching the *urushi*-based touch sensor. We confirmed that this system worked. Consequently, we achieved input and output with an *urushi* circuit.

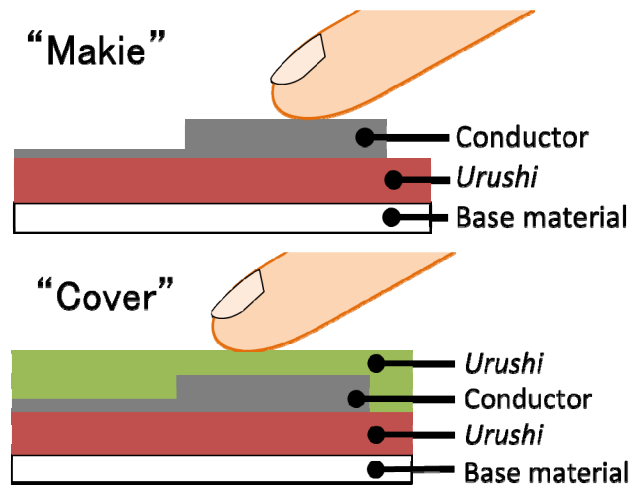


Figure 6. The proposed touch sensors.

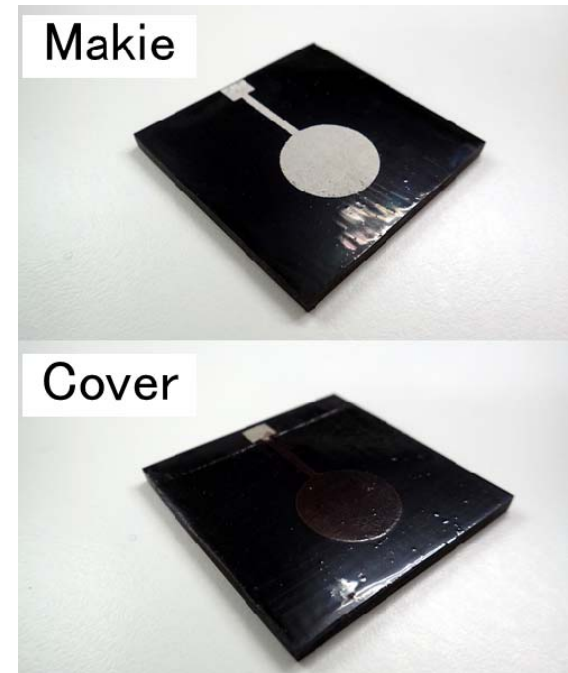


Figure 7. The prototype touch sensors.

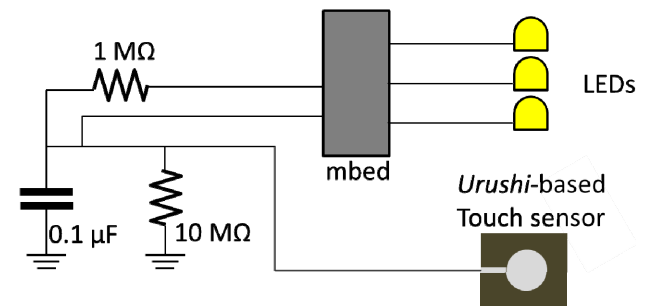
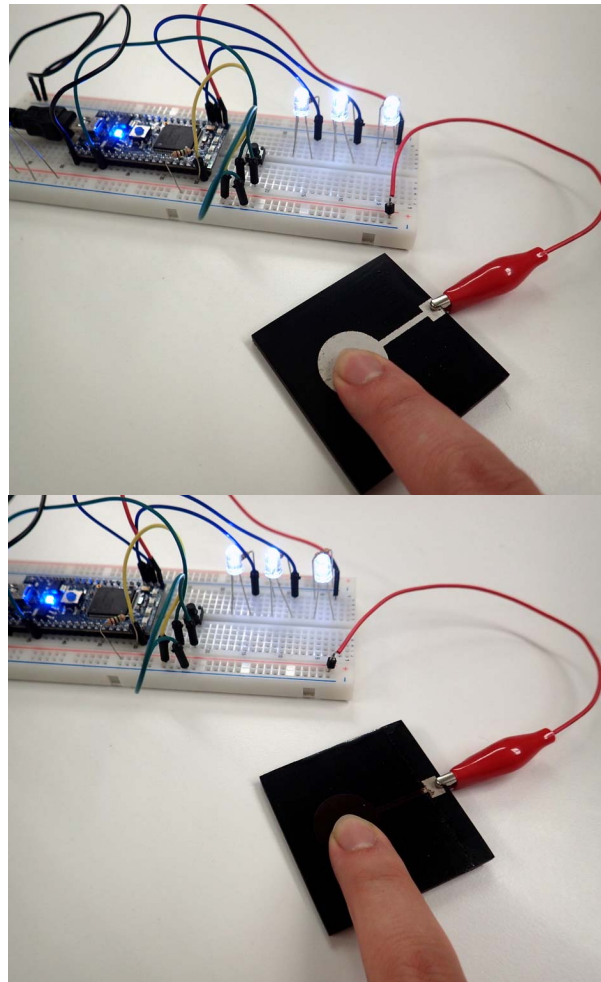
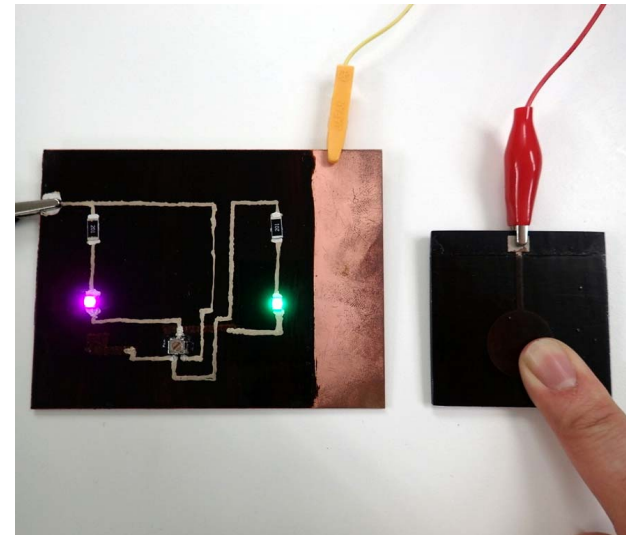


Figure 8. The proposed touch interface.



**Figure 9.** Detecting touch using the proposed touch sensor.



**Figure 10.** Combination system.

### **Future Impact**

*Urushi* not only has decorative beauty but it also has many useful features, is resistant to the environment, and is harmless to humans when dry. We Japanese have used it for thousands of years. Using these features, we anticipate devising *urushi* circuits for different applications from conventional circuits. Some possible applications are listed below.

### ***Current uses of urushi with new functions***

*Urushi* lacquer is already used to coat many goods in regular use, and furniture. It would be possible to add a new function to a lacquered item by adding a circuit without changing its appearance and the cost should be low.

### ***Attractive circuits***

*Urushi* surfaces are very beautiful and the material adds artistic value to the object that it covers. In addition, metal patterns can be placed on an *urushi* surface using the *chinkin* and *makie* methods. The *chinkin* method involves engraving grooves in the lacquer and filling them with gold leaf or powdered gold. The *makie* method sprinkles gold or silver powder on a picture drawn with lacquer. In addition, circuit patterns themselves are works of art [8, 9]. By combining our technique and gold decoration, we believe that new interactive art can be developed, like the *urushi* musical interface [10]. The *urushi* and gold are used to achieve both aesthetic beauty and functionality. The black lacquered surface of the instrument is decorated with gold inlay using the *chinkin* technique. The gold inlay is a conductive surface, and touching it turns the instrument on. In the future, *makie* will serve as an actual electronic circuit and enhance the value of electronic devices so that such devices will be loved.

### ***Safe electronic equipment to the touch***

Hardened *urushi* is antibacterial and does not cause allergic reactions. Therefore, it can be used to build toys for children, tableware, and furniture. We hope that people will love *urushi* products and develop a new *urushi* culture in the future.

### ***Personal fabrication with urushi***

In the next 10 years, we would like to spread the use of *urushi* for fabrication. The time of "do it yourself" (DIY) and personal fabrication is coming. Three-dimensional (3D) printers and laser cutters are contributing to

realizing a new DIY life style. These systems will help us to produce versatile new implementations for researchers, engineers, and hobbyists. Some cafes in Tokyo have installed laser cutters and 3D printers. This shows that DIY is now fashionable entertainment. We hope to increase the usable materials for personal fabrication to boost this movement. Liquid *urushi* can cause rashes in some people, although new types of *urushi* seldom cause a rash. Neither of the authors has ever developed a rash. People who are sensitive to *urushi* can protect themselves by wearing latex, nitrile, or rubber gloves that are easily obtained. Therefore, we should be able to use *urushi* casually. We have already developed a new method for DIY to add a pattern to an *urushi*-coated surface by controlling the UV light direction [7].

### **Conclusion**

We proposed an *urushi* circuit that uses a traditional craft material for human-computer interfaces (HCIs). To achieve our goal, we proposed a method for fabricating an *urushi* circuit by UV laser, and confirmed the feasibility of our method. We also fabricated prototype output and input circuits, and verified that these worked. As future work, we will improve our method to fabricate more precise circuits. We will also develop an *urushi*-based interface system that includes all parts (*e.g.*, a microcomputer, analog circuit, input and output parts, etc.) of a HCI.

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