NEC develops non-edible-plant-based bioplastic featuring elegance of traditional Japanese lacquerware

- ”Urushi black” bioplastic -

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Development of Japanese lacquerware-like “Urushi black” bioplastic

NEC has developed a new cellulose-type bioplastic featuring high decorativeness of traditional Japanese lacquerware, which will be applied to high-value added products requiring environmental friendliness and high decorativeness.

A top level Japanese lacquerware (by Dr. Yutaro Shimode)

“Urushi black” bioplastic

- Cellulose resin based on non-edible plant Resources (wood, stem)
- Special coloring agents
- Realizing “Urushi black” (formed by injection molding.)

Cross section

Appearance of test plate

Base material

Luxury cars (interior components)

High class building material

High-grade electronics

High class stationery, watch, etc.
What is Urushi (Japanese lacquer)?

- Urushi, a natural organic compound mainly consisting of urushiol (phenol resin derivative) is a highly decorative traditional painting material for goods and arts, especially progressed in Japan. Therefore, it is named as Japan, Japanese lacquer or Urushi.
- Japanese lacquerware is an art work highly evaluated internationally. However, higher class ones require more effort to fabricate (repeated coating and polishing of lacquer), thus its mass production is difficult.

Preparation of Urushi and production of Japanese lacquerware

**Natural Urushi**

- Urushiol
  - + Impurity
    - Water
    - Elastomer
    - Protein

Homogenization, Filtration, Water reduction,
+ Mixing of additives (iron compound etc.)

**Refining and coloring**

**Painting and curing**

Cross section
- Urushi layer
- Ground layer
- Wooden basis (base material)

**Polishing**
Collaborating lacquerware artist: Dr. Yutaro Shimode

- Dr. Shimode (Ph.D.) is a top-level lacquerware artist in Japan.
- He is the third-generation president of Shimode makie-studio and a professor at the Faculty of Cultural Studies of Kyoto Sangyo University.
- He has been producing many excellent Urushi arts, such as Makie in the national Kyoto guest house, etc. Recently, he reproduced the Urushi arts in Kodai-ji temple by adding his original excellent technologies.
- He received many national prizes and has been highly estimated in many international exhibitions.
Realization of “Urushi black” with cellulose-based bioplastic

- Target levels were set by analysis of top-level Japanese lacquerware model.
- “Urushi black” has been realized by compounding cellulose resin and special coloring additives.

Fabrication of top-level lacquerware model (Dr. Shimode)

Cross section analysis

Analysis of lacquerware model

<100μm

Urushi layer

Water balls

Color hue (especially brightness)

Glossiness

Cross section

Pursuit of low brightness, high glossiness +α

Realization of “Urushi black” by compounding

• High dispersion of black colorants and high-refractive-index additives in resin.
• Molded in ordinary molding process.

Transparent plastic plate

Coating of lacquer and polishing

Target levels were set by analysis of top-level Japanese lacquerware model.

“Urushi black” has been realized by compounding cellulose resin and special coloring additives.
Fabrication of top-level lacquerware model (Shimode model)

- Top-level Japanese lacquerware model was fabricated by Dr. Y. Shimode.
- Appearance of highest grade lacquerware (ultimate “Urushi black”) was attained by repeated coating of lacquer (urushi) on a transparent plastic plate and polishing of the surface.

Urushi layer
Cross section (<100μm thickness)

Transparent plastic plate (5mm thickness)

Optical characteristics of lacquerware model
- Extremely low brightness (~1)
- Top-level glossiness (~100)

+α = “depth” and “warmth”
original characteristics of urushi
Achievement of low brightness with cellulose bioplastic

Low brightness has been achieved by addition and mixing (fine dispersion) of surface-treated fine carbon particles.

![Diagram showing carbon particle characteristics and brightness comparison.](image-url)
Realization of high glossiness with cellulose bioplastic

Glossiness has been improved by addition and mixing (fine dispersion) of specific organic compounds with high refractive indices.

Specular glossiness 20°

- Lacquerware model
  - + High refractive index additives

- Cellulose resin
  - Additive A
  - Additive B
  - Additive C
  - Additive D
  - Additive E
  - Additive F

- Example: aromatics
  - + Normal refractive index additive (plasticizing component)
  - + High refractive index additives

(Evaluation of test pieces)
Simultaneous achievement of low brightness and high glossiness

- There was **trade-off** between brightness and glossiness, which has been **resolved by compounding technology using particular additives**.

Optimization of surface structures of carbon particles as well as molecular structures of high refractive index organic compounds, and fine dispersion of these additives.

Using mirror-finished metal mold

**Brightness (SCE)**

- Large and surface-untreated carbon
- Small and surface-treated carbon
- Additives (medium refractive index)
- Additives (high refractive index)
- Lacquerware model

**Glossiness (20°)**

- Coating of urushi + Polishing
- Transparent plastic plate
- Bioplastic containing specific additives

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Appearance and optical characteristics

- Low brightness, high glossiness and \( +\alpha \) (depth, warmth) characteristic of Urushi have been achieved.

(The depth and warmth are supposed to be influenced by the chemical structure of cellulose resin.)

<table>
<thead>
<tr>
<th>Cellulosic bioplastic plates</th>
<th>Lacquerware model</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Colorant</strong></td>
<td></td>
</tr>
<tr>
<td>Carbon particle (small, surface-treated)</td>
<td>Carbon particle (small, surface-treated)</td>
</tr>
<tr>
<td><strong>Additive</strong></td>
<td></td>
</tr>
<tr>
<td>Medium refractive index organics</td>
<td>High refractive index organics</td>
</tr>
<tr>
<td><strong>Brightness</strong> ( L^*(SCE) )</td>
<td>2</td>
</tr>
<tr>
<td><strong>Glossiness</strong> ( (20^\circ) )</td>
<td>78</td>
</tr>
<tr>
<td><strong>Glossiness</strong> ( (60^\circ) )</td>
<td>85</td>
</tr>
</tbody>
</table>

Appearance

Using mirror finish mold + adjusting molding condition
"Urushi black" bioplastic

(Molded resin plates)
Other characteristics of "Urushi black" bioplastic

Practical characteristics including mechanical strength, thermoplasticity, and surface hardness were brought to good levels, and these will be further improved. (The values in the table are representative ones, which will be adjusted depending on application areas.)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>&quot;Urushi black&quot; bioplastic</th>
<th>Petroleum-based resin (ABS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexural strength (MPa)</td>
<td>(~80)</td>
<td>78</td>
</tr>
<tr>
<td>Elastic modulus (GPa)</td>
<td>(~2.2)</td>
<td>2.7</td>
</tr>
<tr>
<td>Breaking strain (%)</td>
<td>(&gt;10)</td>
<td>&gt;10</td>
</tr>
<tr>
<td>Izod impact strength (kJ/m²)</td>
<td>(~6)</td>
<td>22</td>
</tr>
<tr>
<td>Surface hardness (Pencil hardness)</td>
<td>(~HB)</td>
<td>2B</td>
</tr>
<tr>
<td>Glass transition temperature (°C)</td>
<td>(&gt;90)</td>
<td>102</td>
</tr>
<tr>
<td>Thermoplasticity: MFR (g/10min)</td>
<td>(~400)</td>
<td>280</td>
</tr>
<tr>
<td></td>
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</tr>
</tbody>
</table>
The bioplastic is manufactured by mixing specific additives and cellulose resin*. *short-chain organic acid bonded cellulose using non-food plant resource

The composite can be formed into products using ordinary injection-molding process for plastics. → Lacquerware-like products of various shapes can be mass-produced.
Targeted application areas

- Achieving **high decorativeness of Japanese lacquerware**, we aim to apply the new bioplastic to higher-value-added products.
- NEC will create business partnerships with material producers and product producers to realize the use of the material in various products by 2020.

**High decorativeness**

- **Office machine**
- **Medical and welfare apparatus**
- **Social infrastructure instruments**
  - Durability
  - Strength
  - Heat resistance
- **Automobile**
  - Interior parts
- **Building interior products**
- **High class home electronics**
- **High grade stationery, watch, cosmetic case, etc.**

**Synergetic effect of environmental friendliness and decorativeness**

** NEC’s bioplastic **
A new bioplastic has been developed which realizes the elegant black color (“Urushi black”) of high-grade Japanese lacquerware.

- The bioplastic simultaneously has achieved environmental friendliness (use of non-edible-plant resource) and “Urushi black” for the first time.
- The material can be mass-produced into lacquerware-like products of various shapes using ordinary injection-molding process.
- Practicality such as strength and formability, and optical properties will be further enhanced.

Toward 2020, NEC will pursue business partnerships aimed at application of the bioplastic in various products.