# Construction of integrated circular production system by product lifecycle management and innovative dismantling technology development

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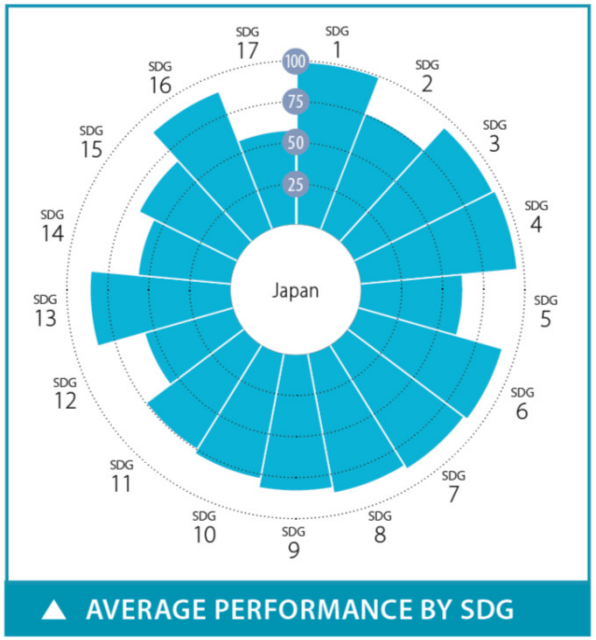
Waseda University
Chiharu TOKORO, Prof., Dr. Eng,
tokoro@waseda.jp

# Importance of “Resources Circulation” in SDGs Era


SDG INDEX AND DASHBOARDS REPORT 2018
“IMPLEMENTING THE GOALS GLOBAL RESPONSIBILITIES”
The Bertelsmann Stiftung and the Sustainable Development Solutions Network (SDSN)



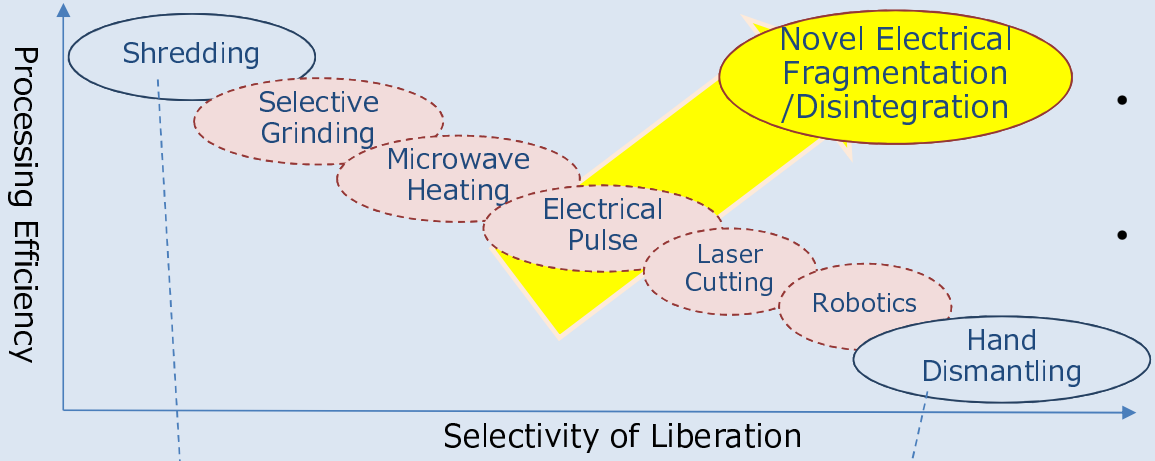

## Japan（Ranking #15） Low evaluation items

「Goal5：Gender Equality」
「Goal12: Responsible Consumption and Production」
「Goal13: Climate Action」
「Goal14: Life Below Water」
「Goal17: Partnerships for the Goals」

Good ⟷ Bad

# Technological issues for Resources Circulation

## Practical dismantling technologies: Shredding and Hand Dismantling




- **Shredding** : low selectivity for mass processing
- **Hand Dismantling** : High selectivity for small amount processing

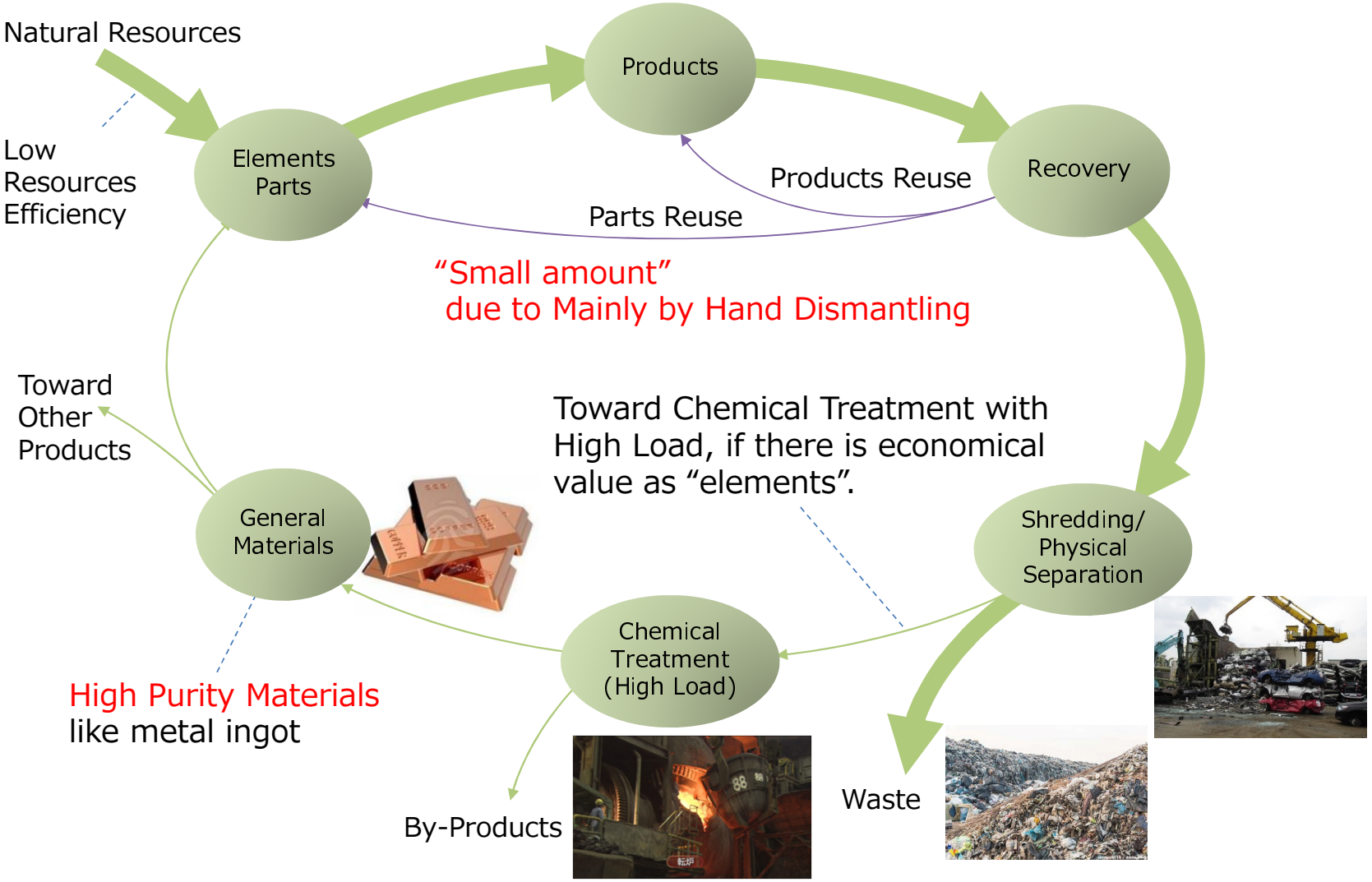
For sustainable usage of resources by reuse and recycling, **selective dismantling technologies** for spent products have been desired.


Shredding of automobile


Hand Dismantling of Household Appliances

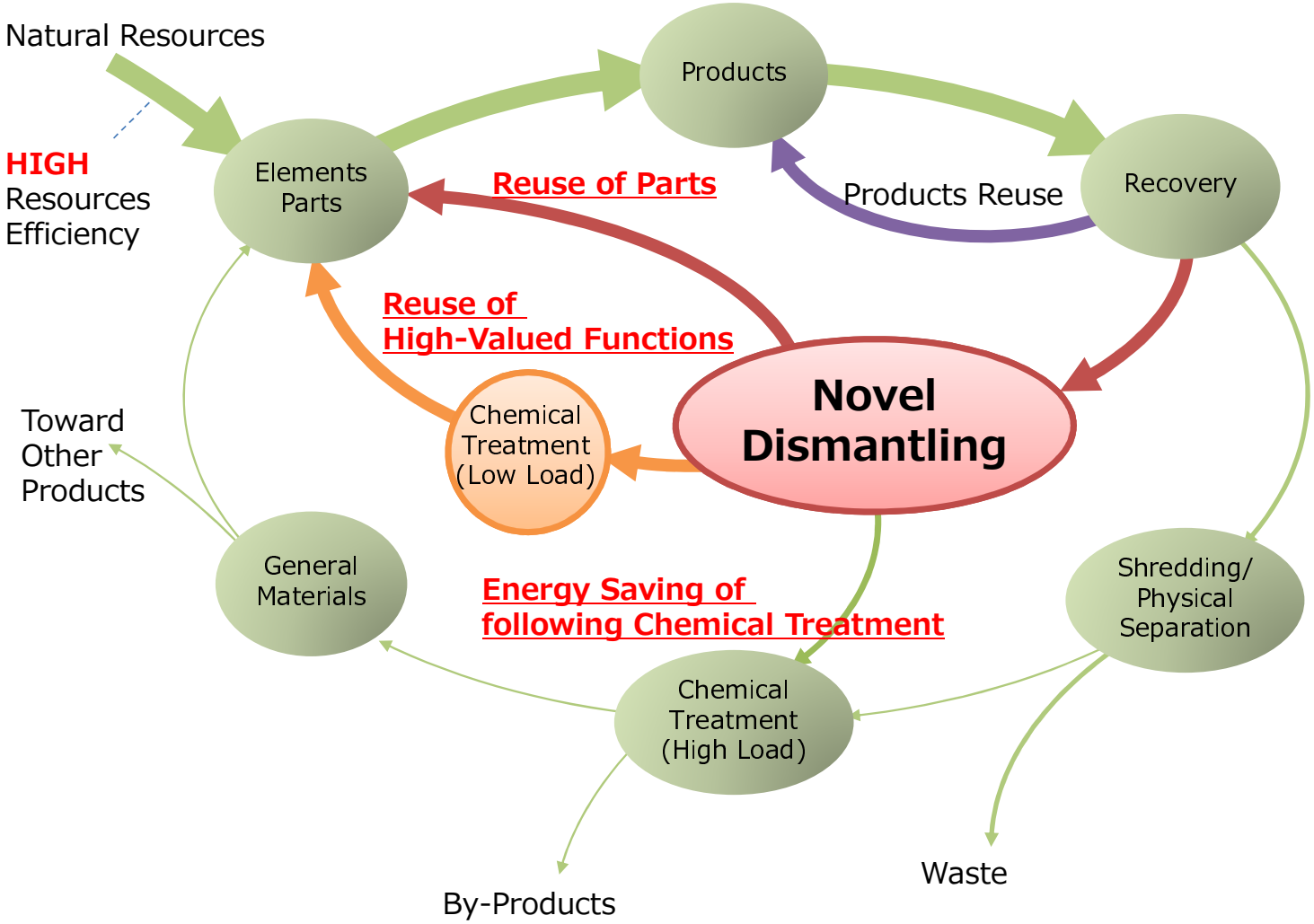
# Current situation for Resources Circulation

**A Long-way circulation, with breaking due to low economical value**

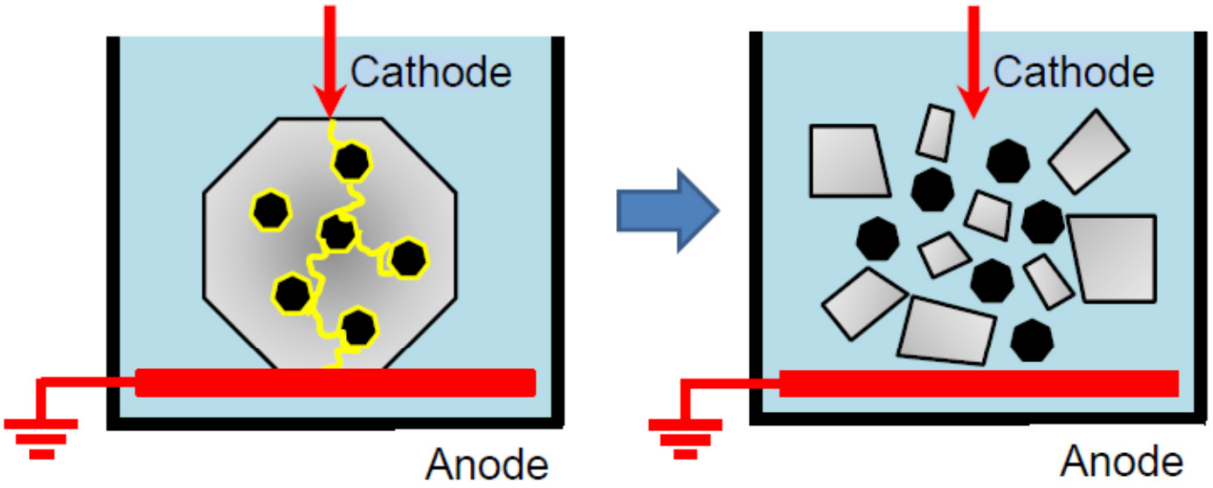


# Sound Material-Cycle Society by Novel Dismantling Technologies

**Many Short-pass circulation, with reuse of high-valued functions**

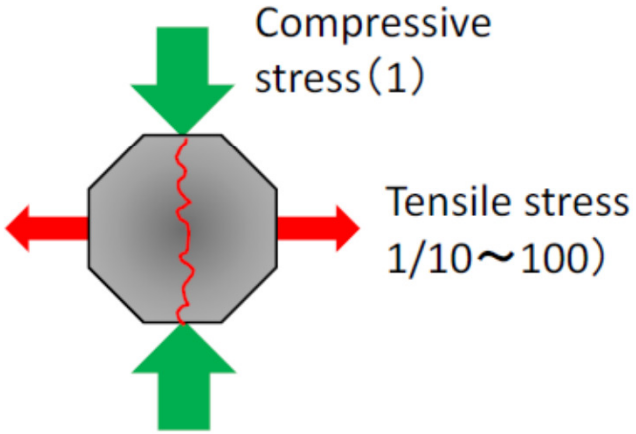


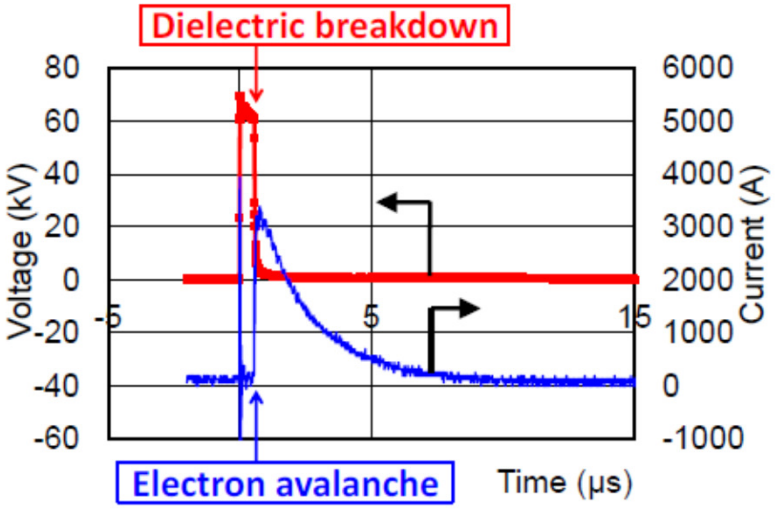
# Fundamentals of Electrical Disintegration




**100 W in 1 s**
**= 2 GW in 50 ns**

High Electric Powder
with low Energy Consumption

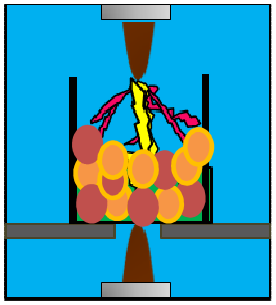


# Novel Electrical Disintegration

Higher Selectivity and Higher Efficiency

**Conventional**



Effect of Shock-Wave
by dielectric breakdown
of water

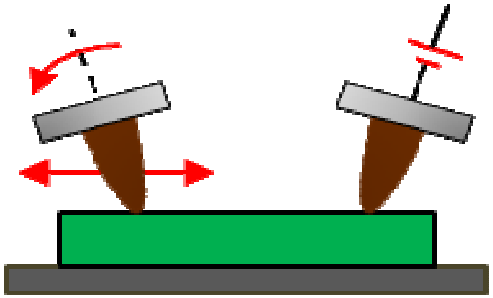
Limited Selective Grinding

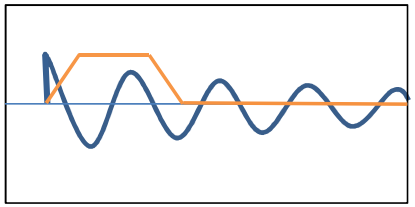
**Shock-wave + Joule heat**
**by plasma conversion and high current**

**Selective heating**
**Selective reaction**
**Selective peeling**
**Selective disintegration**

**Novel**

Control of discharging path





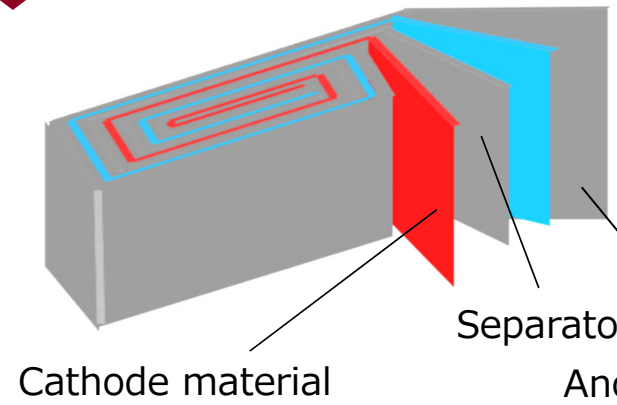
Control of waveform

Precise Control of
- Discharging path
- Waveform of current/voltage
- Repetition rate

**Control of repetition rate and location of Shock-wave and Joule heat**

**Selective Peeling/Disintegration for a wide variety of reuse and recycling**

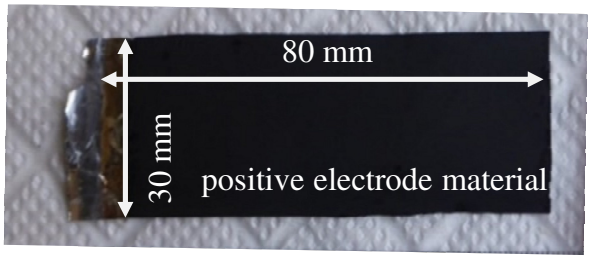
# Separation of positive electrode particles from the Al foil



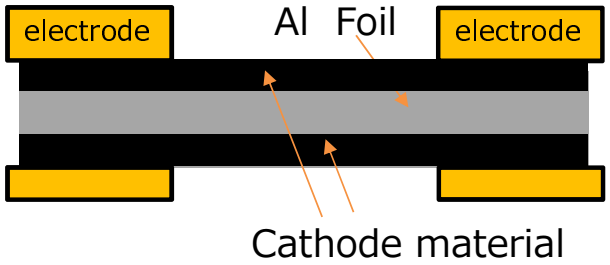

Air Knife

Cathode material

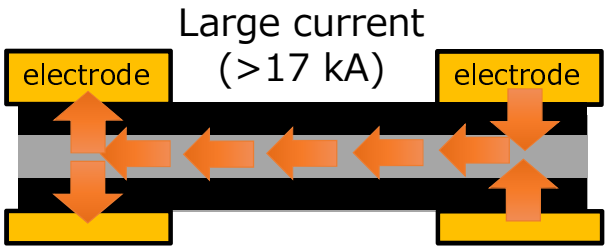
Test piece



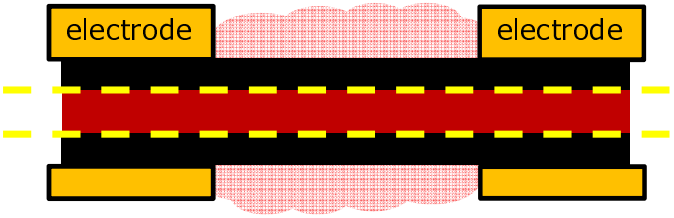

Peeling mechanism




t=0 :
A Capacitor bank is charged with high energy.
A switch between the capacitor and the test piece is just switched on.

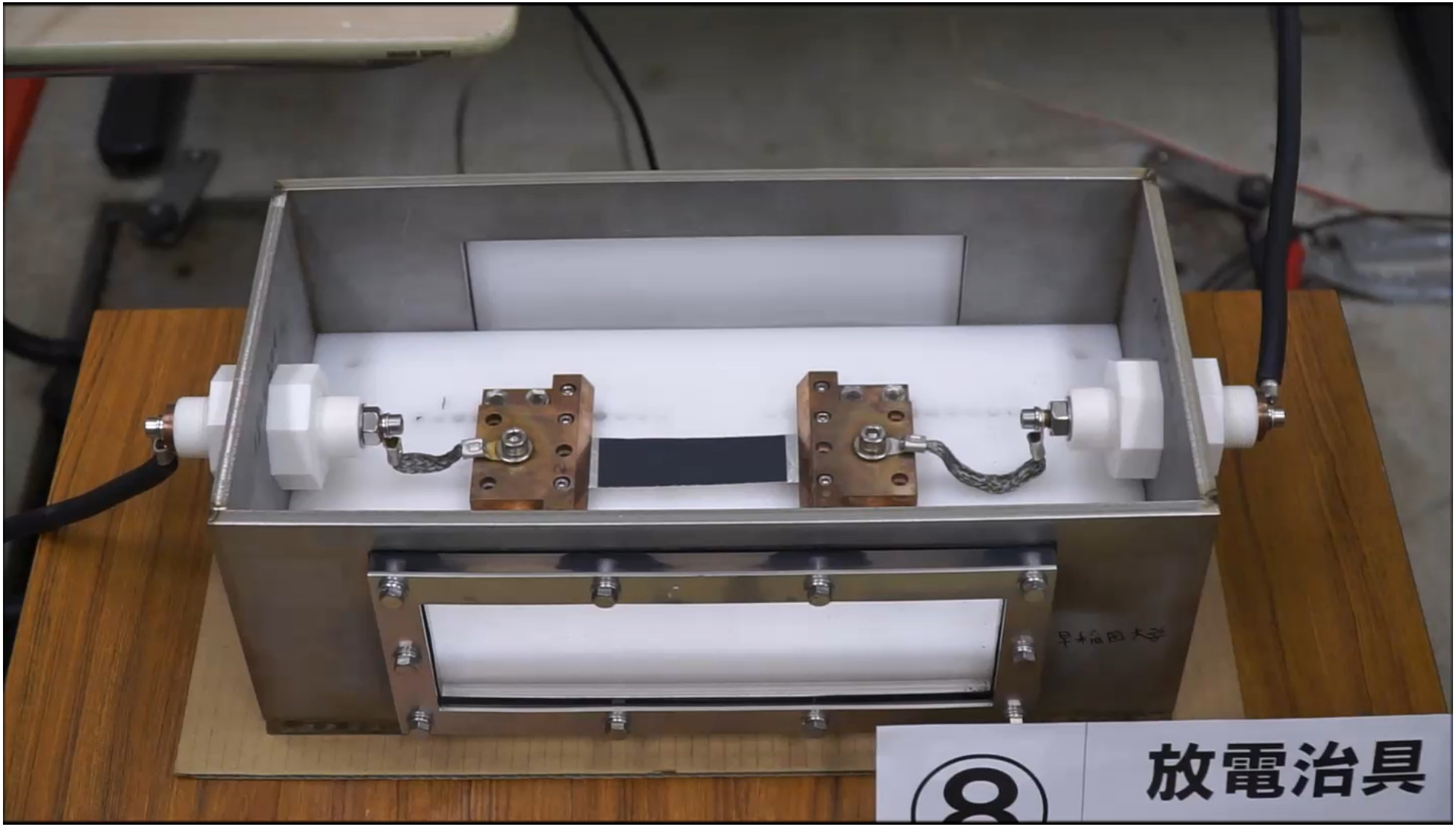



t<1μs :
Large current(>17kA) flows through the Al foil.
Temperature of the Al foil rise by Joule heat




t<200μs :
Temperature rise to melting point of PVdF (>170℃). The adhesive loses its adhesion due to the high temperature.
Shock-waves by plasma and stress due to thermal expansion acts on the weakened-adhesion interface between the Al foil and the cathode material.

# Separation of positive electrode particles from the Al foil

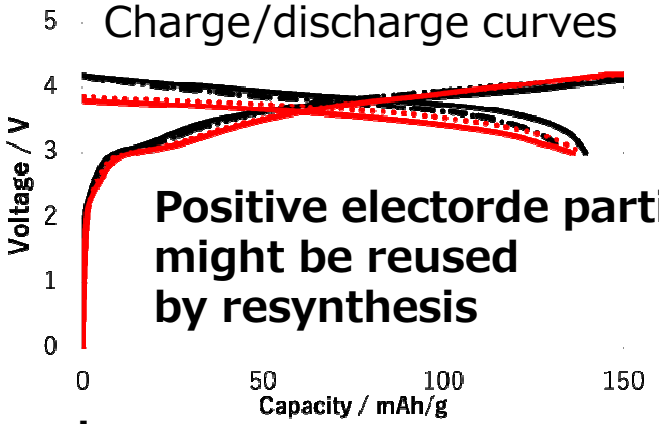


# Positive electrode active materials after the separation

Separated Al foil

Separated
positive electrode particles

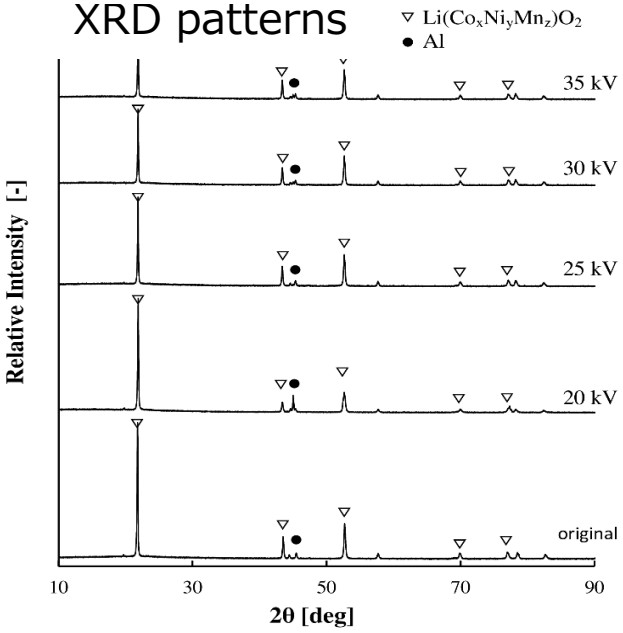
Charge/discharge curves



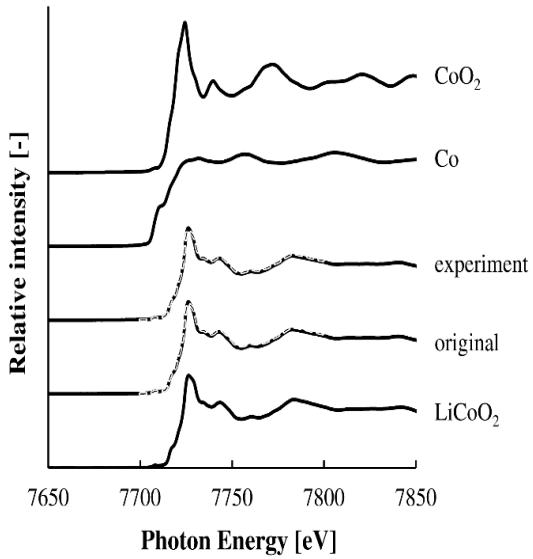

**Positive electorde particles might be reused by resynthesis**

**Chemical forms of particles and binder (PVdF) were not changed**

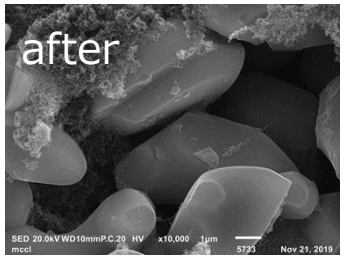
XRD patterns



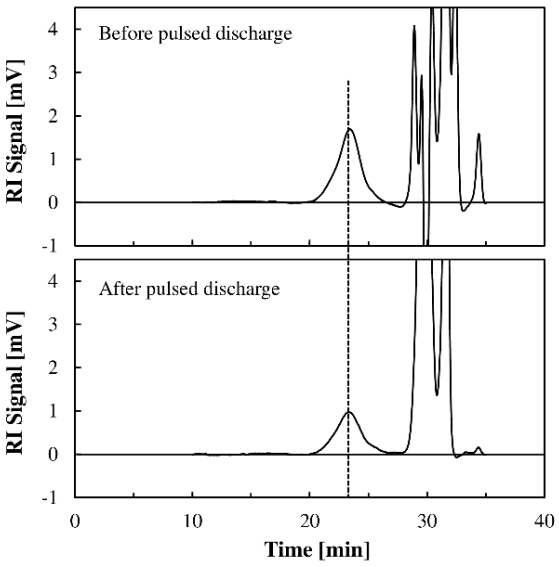

XAFS patterns



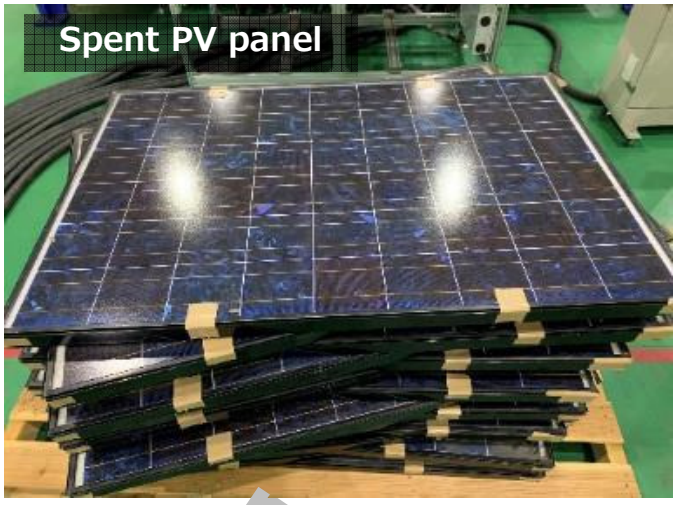

SEM images

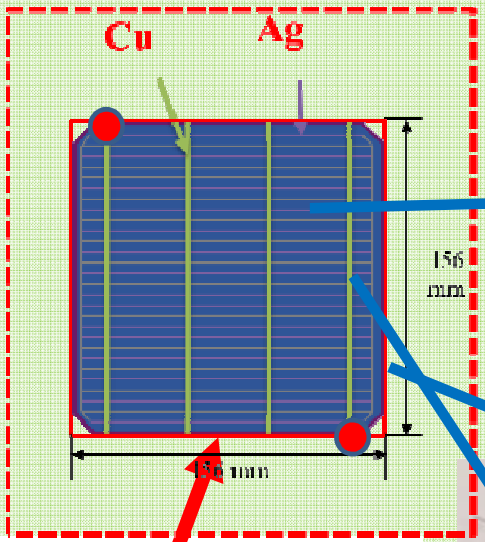




GPC analysis

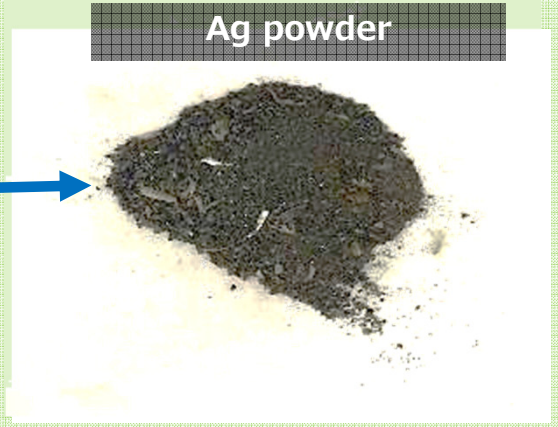


# Cu/Ag recovery from cell sheet of PV panel

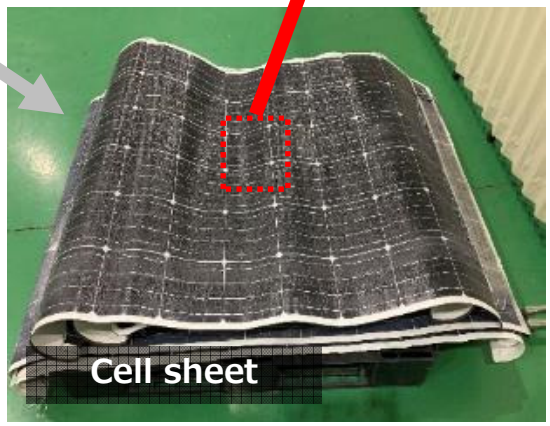


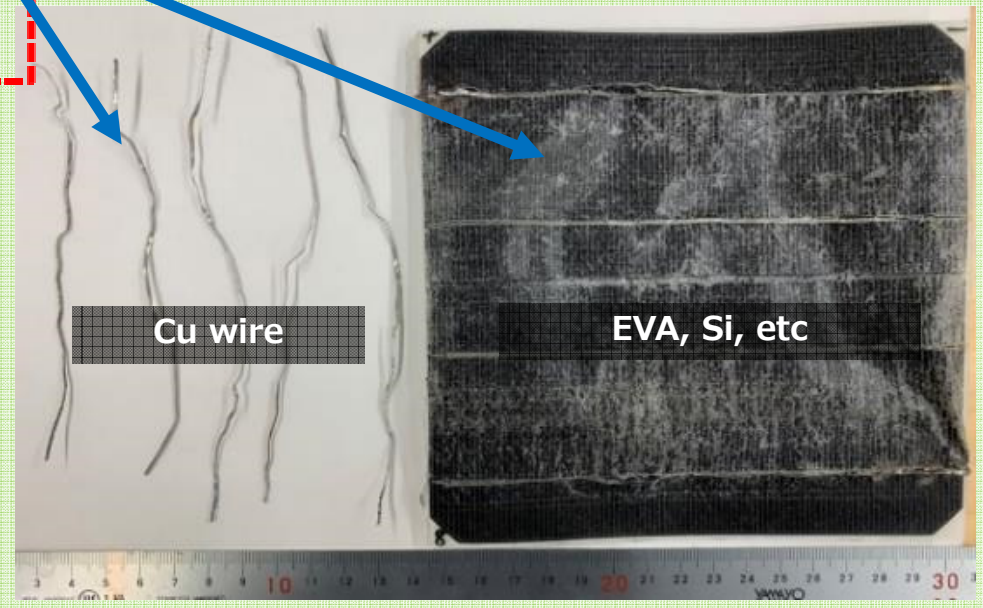




Novel electrical pulsed discharge

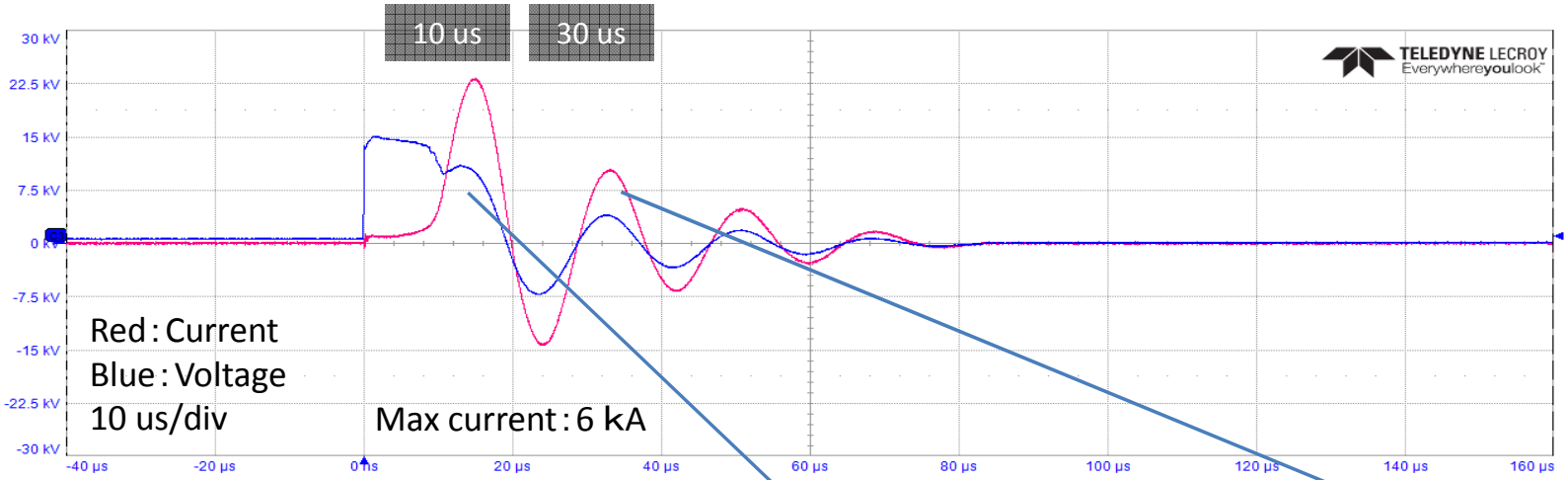



Conventional mechanic separation

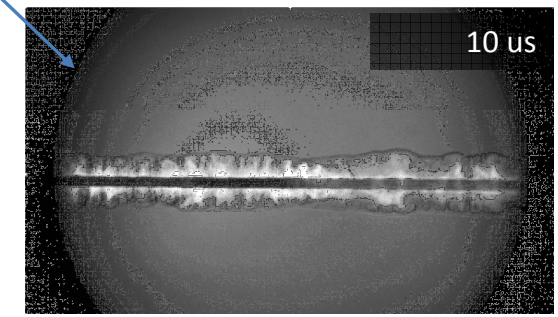



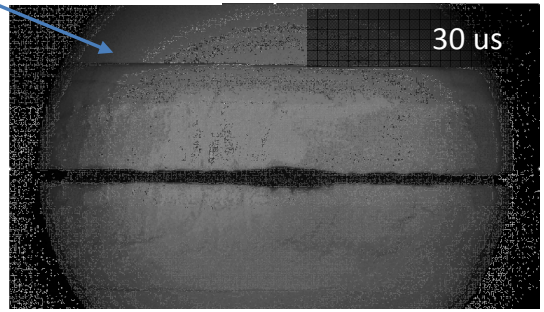



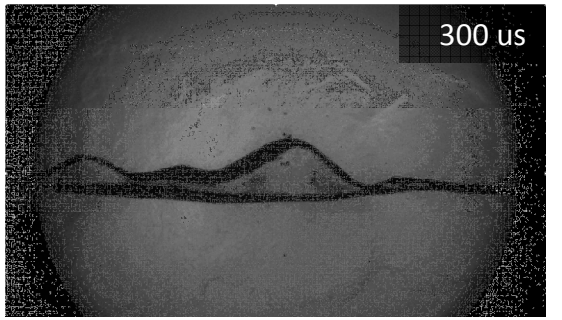
# Ag wire explosion and shock-wave propagation



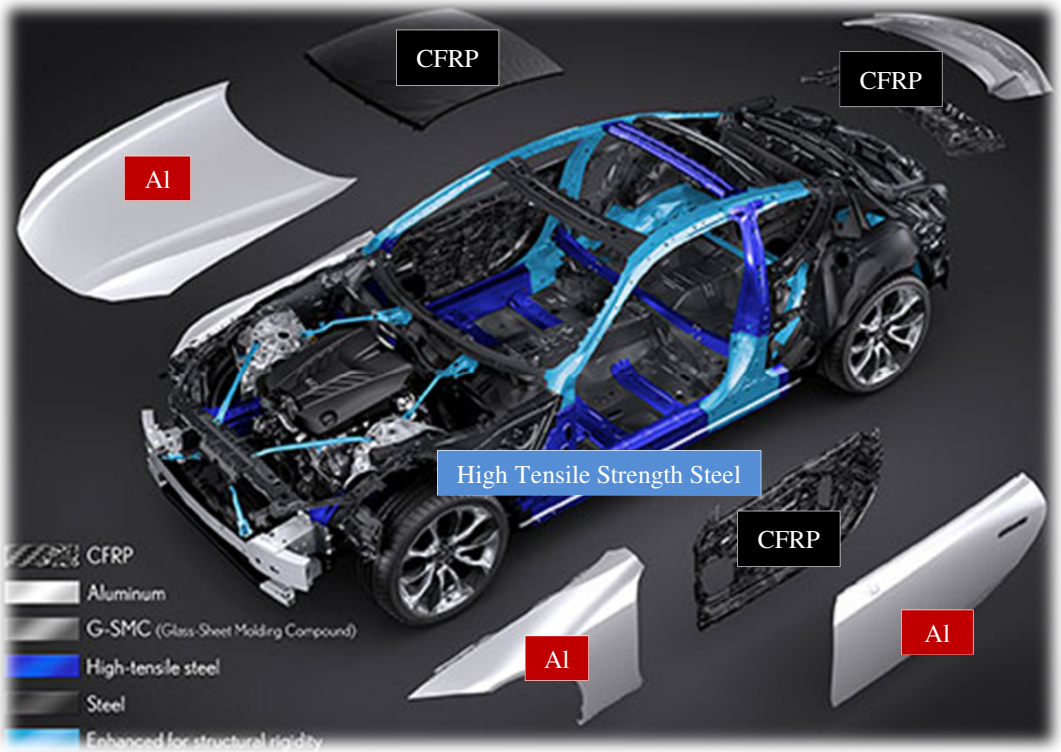




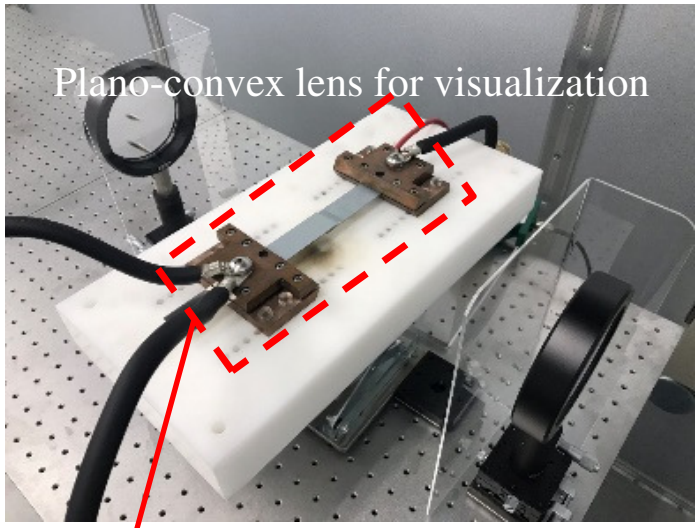



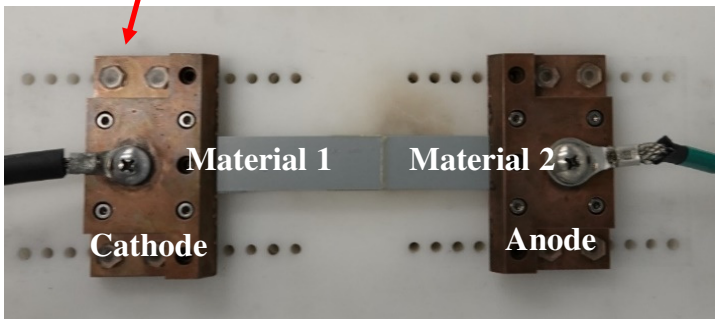



# Application to the separation of “Adhesive”




https://www.lexus.com.bh/lexus-lc-performance-multi-material-body

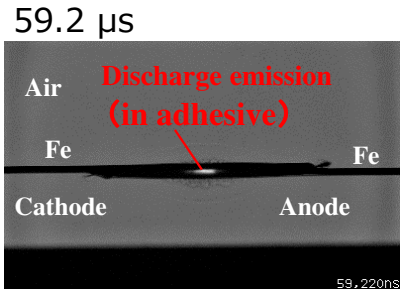


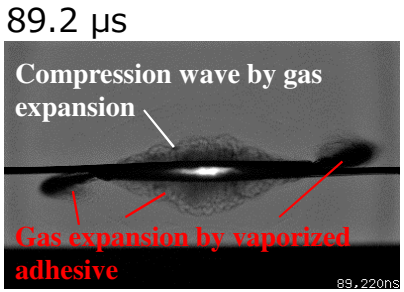



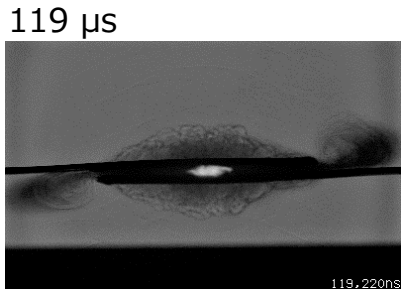

Sharp separation of “adhesive”. → **Eliminate of the bottleneck for multi-material**

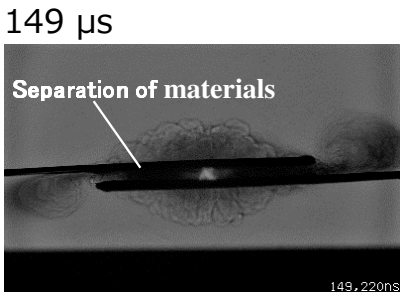
# Separation of Adhesive-joining by Electrical pulsed discharge

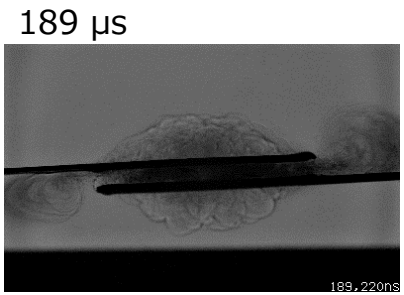
Visualization by Shadowgraph method, High-speed camera: HPV-X2, interval: 5 μs

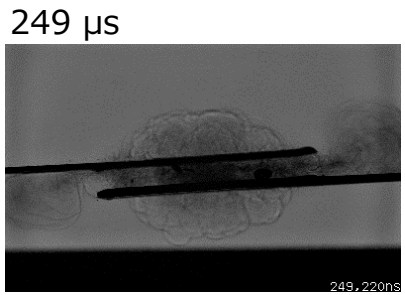



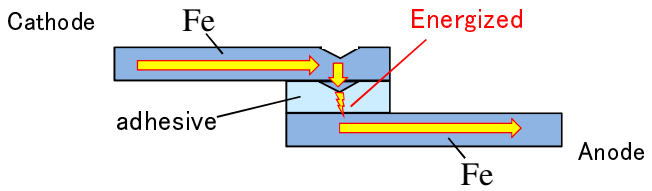



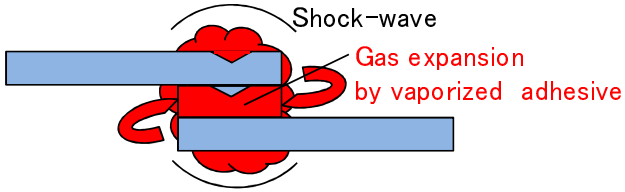



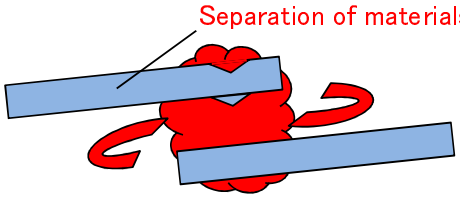

$t < 60$ μs

- High voltage application (5 kV)
- Dielectric breakdown of adhesive
- Generation of Plasma in adhesive




$t < 100$ μs

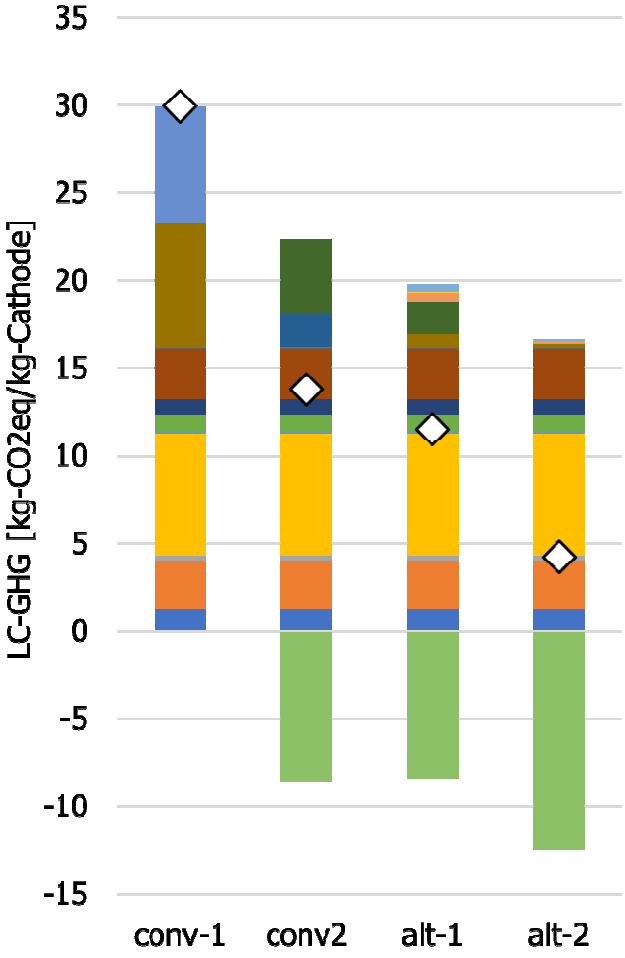
- Vaporization of adhesive by Plasma
- Gas expansion

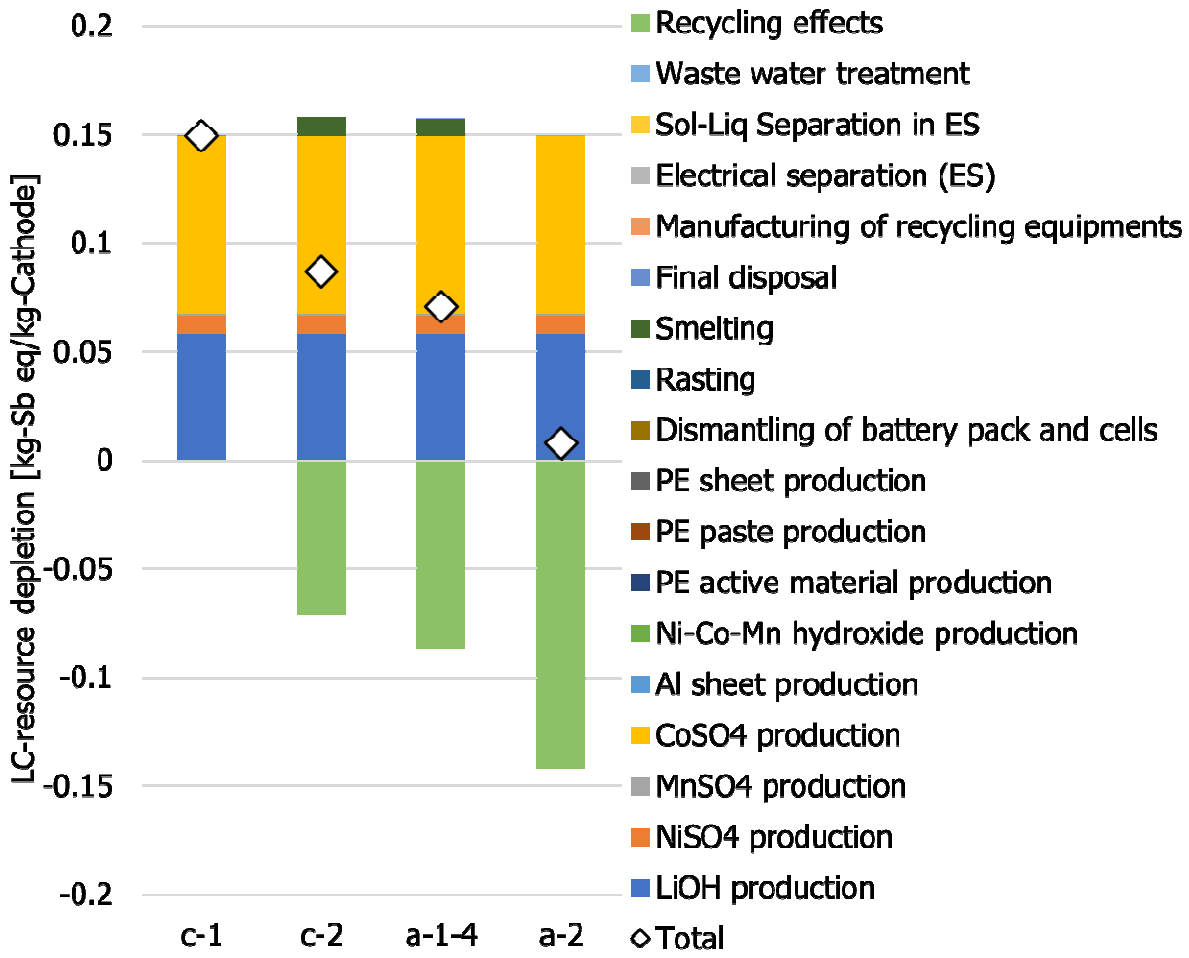



$t \geqq 100$ μs

- Separation of materials by gas expansion of vaporized adhesive

# LCA for LiB recycling by the novel process




conv-1: conventional process without any recycling
conv-2: conventional process with roasting and conventional smelting

alt-1: novel process with elemental recycling
alt-2: novel process with positive electrode active materials reuse

# MIRAI PROJECT by Japan Science and Technology Agency (JST)

## Construction of integrated circular production system by product lifecycle management and innovative dismantling technology development

**Project Leader :** Chiharu Tokoro, Professor,
Faculty of Science and Engineering, Waseda University

**Collaborating Institutions :** Kumamoto University, The University of Tokyo, Tohoku University, Tokyo Institute of Technology, Saitama Institute of Technology,
Honda R&D Co., Ltd., Nissan Motor Co., Ltd., ADEKA Corp., Matsuda Sangyo Co. Ltd., Toray Industries Inc., NPC Inc., HAMADA Co. Ltd., Lexer Research Inc., etc.

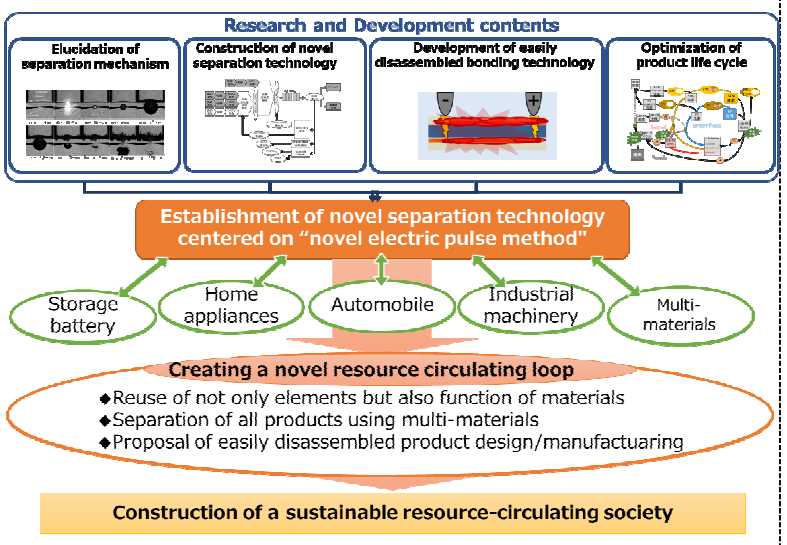
### Objective :

Development of the novel separation technology between different materials by pulsed electric discharge and the life cycle simulation to optimize product design/manufacturing assuming separation for reuse/recycling, toward the construction of a novel integrated circular production system.

### Research Summary :

High resource efficiency and waste minimization are a big issue to realize a sustainable society. Especially in recent days, the trend of “multi-materialization” that combines different materials is growing in the automobile industry and sophisticated separation technology for them is strongly desired.

In this project, we develop the novel, high-selectivity, and high-efficient separation technology for different materials by pulsed electric discharge. To accomplish it, the separation mechanism and optimum control method are elucidated as fundamental research and development. At the same time, we promote easily disassembled design and manufacturing processes based on the above mentioned obtained knowledge. We contribute to the realization of a resource-circulating society by it coupled with the simulation tool to optimize a product life cycle based on the novel manufacturing system.




WEB http://www.tokoro.env.waseda.ac.jp/

# Project members

早稲田大学
WASEDA University

熊本大学
Kumamoto University

東京大学
THE UNIVERSITY OF TOKYO

TOKYO Institute of Technology

TOHOKU UNIVERSITY

R&D
Honda R&D Co.,Ltd.
株式会社本田技術研究所

MATSUDA SANGYO CO.,LTD

ADEKA CORPORATION

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# Summary

- Novel electrical disintegration enabled selective peeling and selective disintegration of multi-material, LiB positive electrode, and PV panel.
  - Combination of Jules heat by high current and shock wave by dielectric breakdown enabled selective heating, selective reaction, selective peeling and selective disintegration.
  - Precise control of discharge path and waveform of voltage/current is key technology for them.
- Peeling of positive electrode particles from Al foil in LiB
  - Positive electrode particles could be peeled from Al foil without less damage and reused.
- Metal recovery from PV panel cell
  - Cu and Ag wires were selectively recovered from the cell and they were completely liberated.
- Peeling of adhesive between multi-material
  - Adhesive failure and cohesive failure were possible for metal-metal bonding. After peeling, metals can be reused without any breakage.

**Acknowledgement**

This work was supported by JST-Mirai Program Grant Number JPMJMI17C1 and JPMJMI19C7, Japan.