



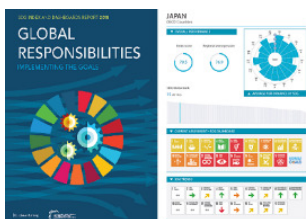
Construction of integrated circular production system by product lifecycle management and innovative dismantling technology development

**JST Connect 2020
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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

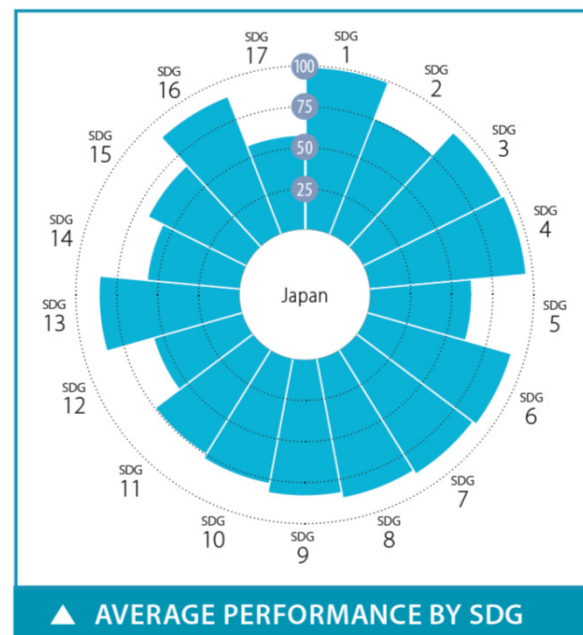
「Goal5: Gender Equality」

「Goal12: Responsible Consumption and Production」

「Goal13: Climate Action」

「Goal14: Life Below Water」

「Goal17: Partnerships for the Goals」



Good ← → Bad

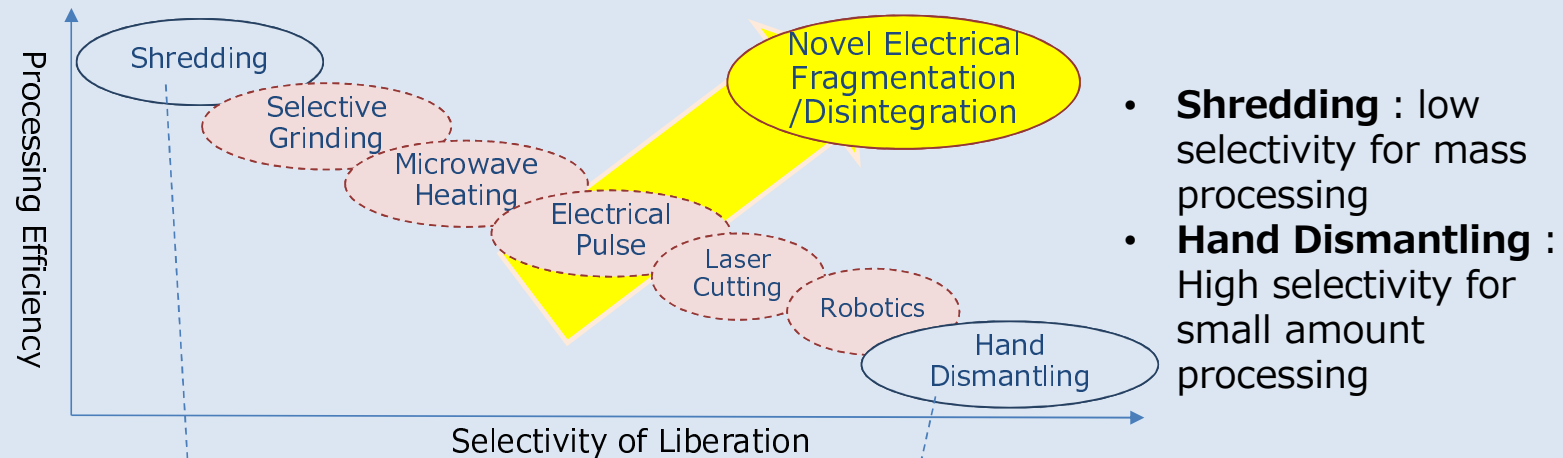
▼ CURRENT ASSESSMENT – SDG DASHBOARD



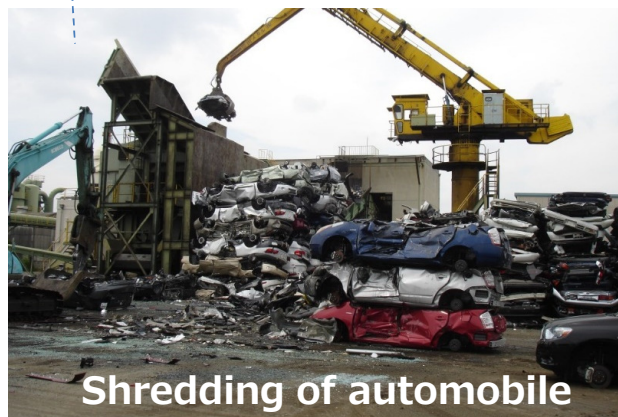


Technological issues for Resources Circulation

Practical dismantling technologies: Shredding and Hand Dismantling



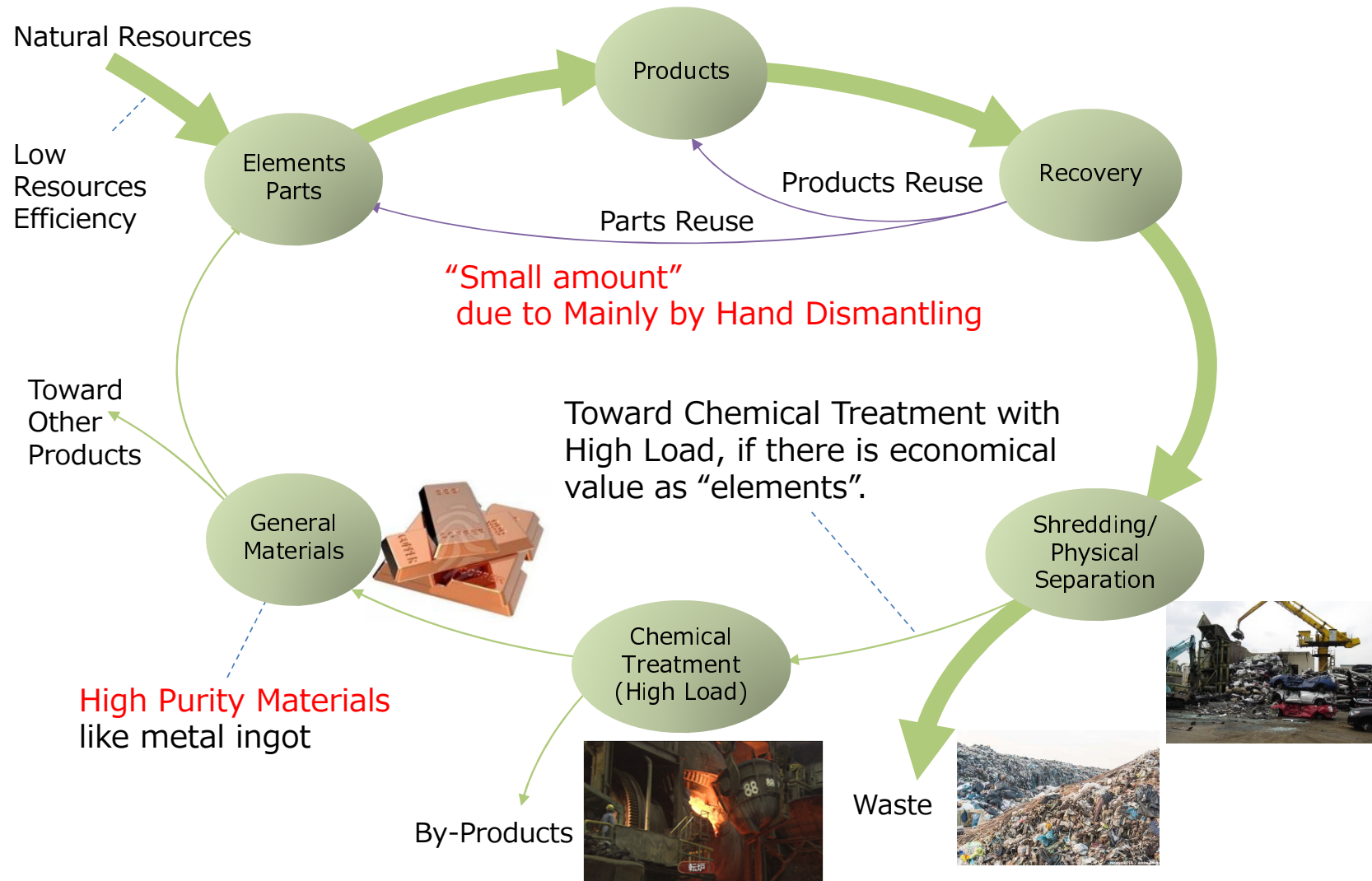
For sustainable usage of resources by reuse and recycling, **selective dismantling technologies** for spent products have been desired.





Current situation for Resources Circulation

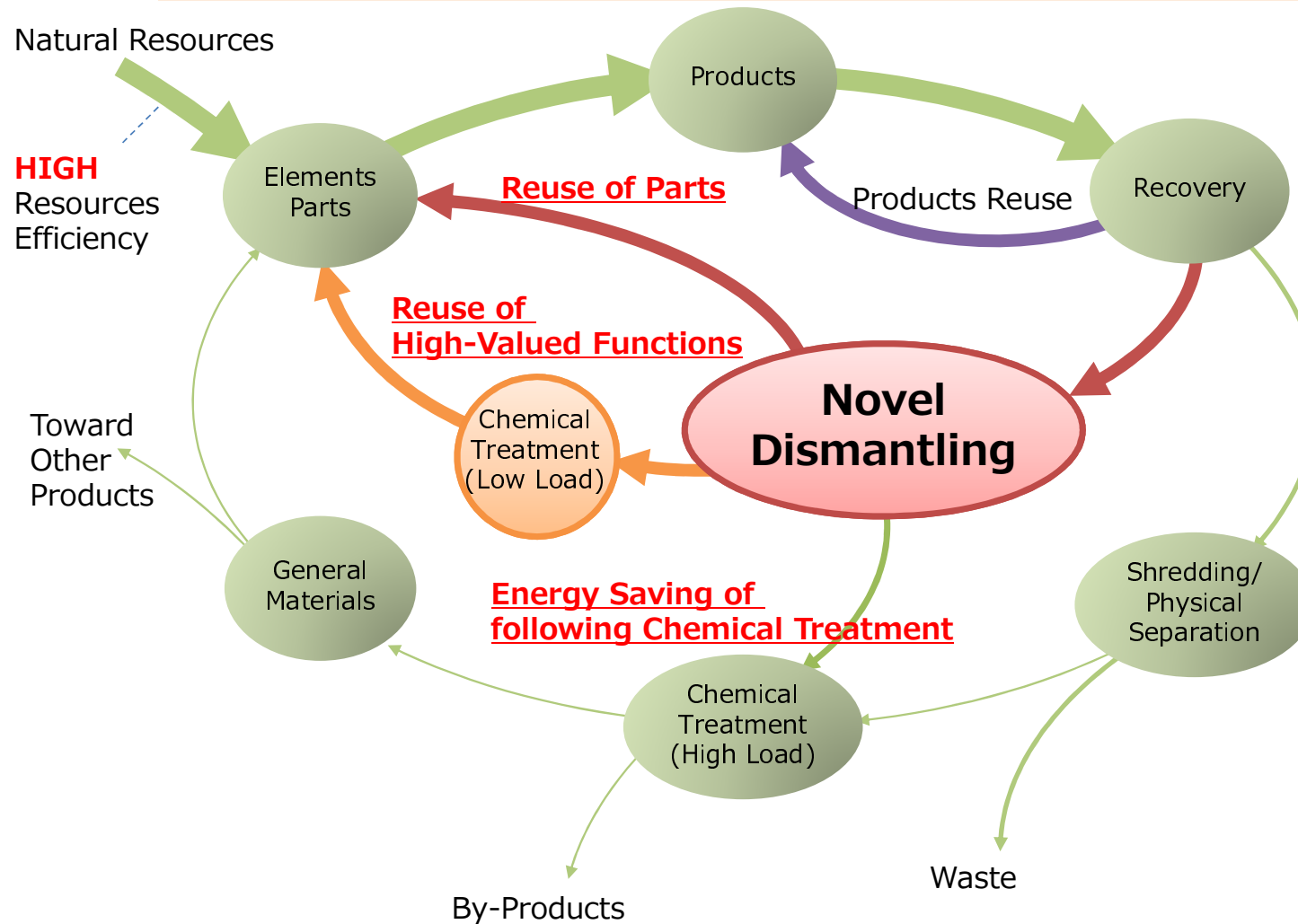
A Long-way circulation, with breaking due to low economical value





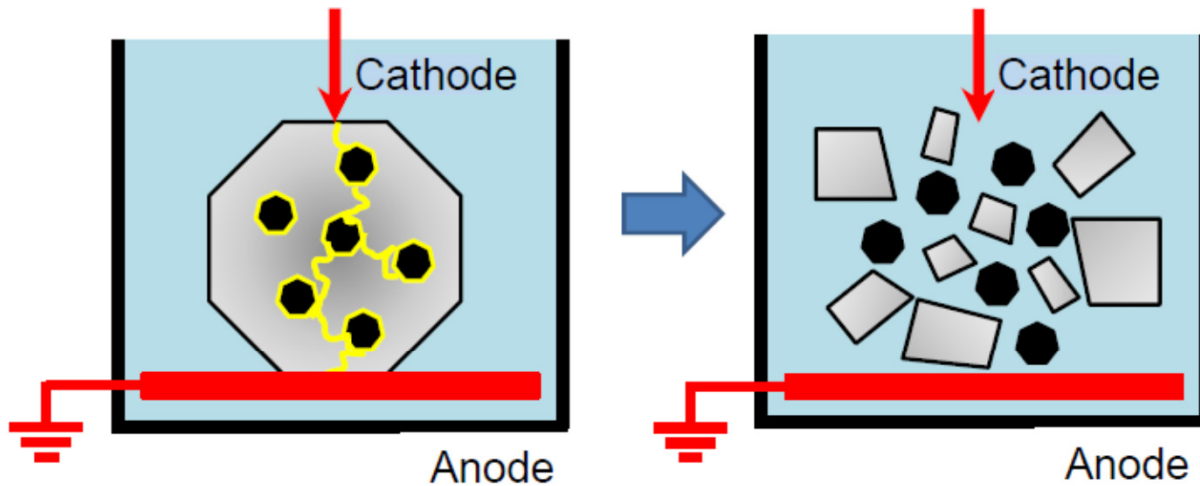
Sound Material-Cycle Society by Novel Dismantling Technologies

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



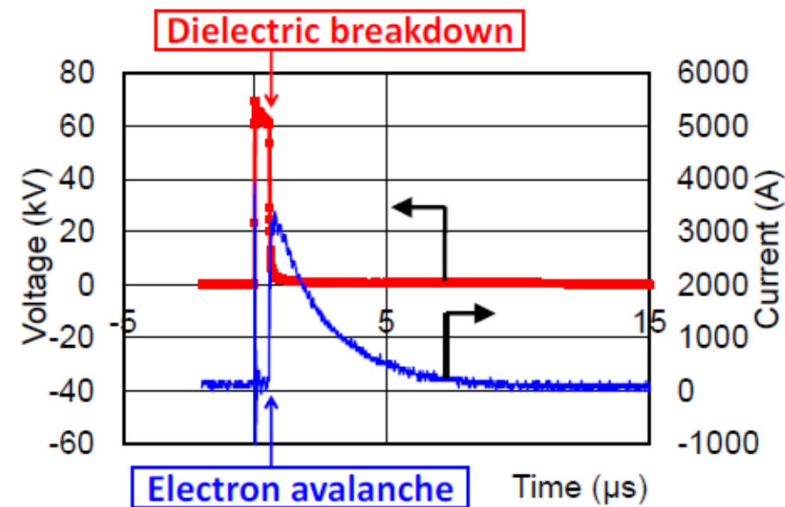
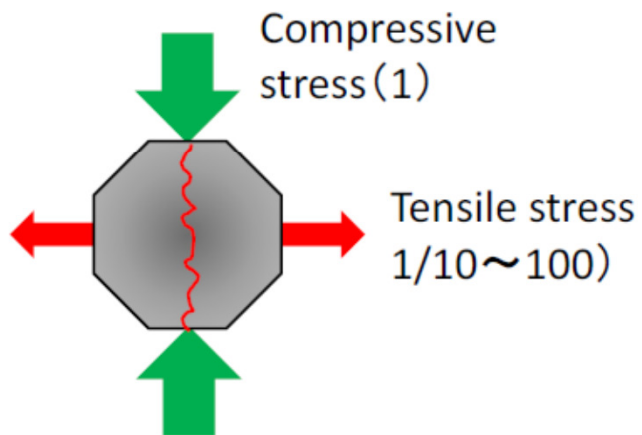


Fundamentals of Electrical Disintegration



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

High Electric Powder
with low Energy Consumption

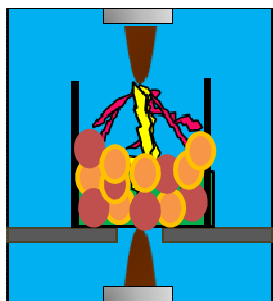




Novel Electrical Disintegration

Higher Selectivity and Higher Efficiency

Conventional



Effect of Shock-Wave
by dielectric breakdown
of water

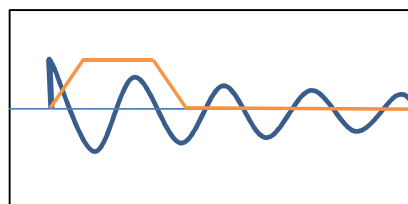
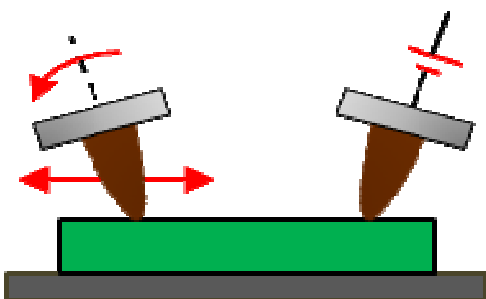
Limited Selective Grinding

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

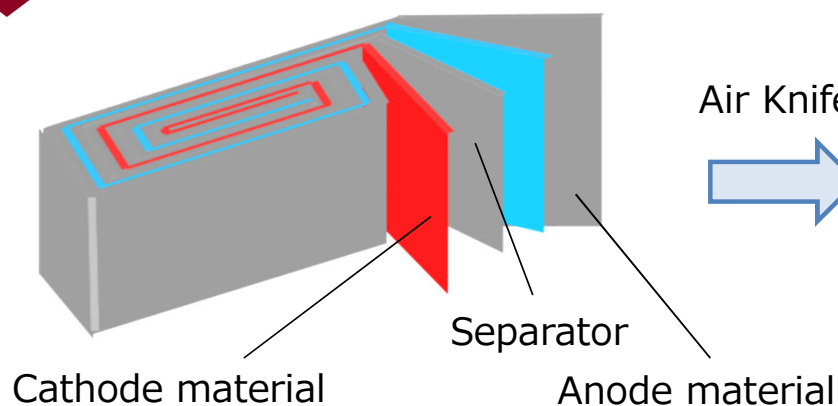
- Discharging path
- Waveform of current/voltage
- Repetition rate

**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

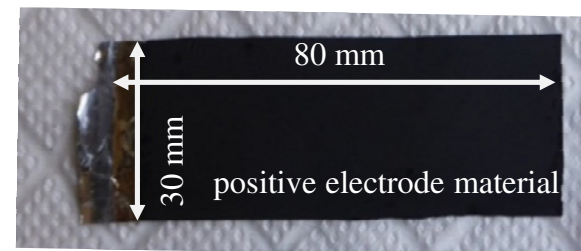


Air Knife

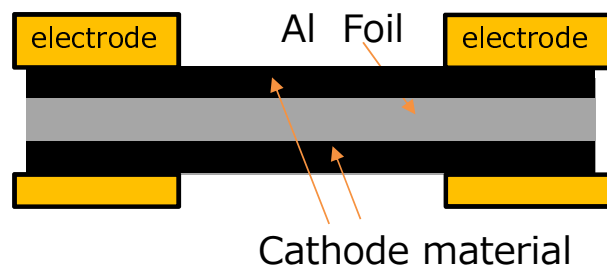


Cathode material

Test piece



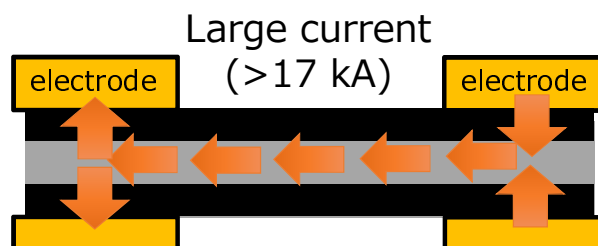
Peeling mechanism



$t=0$:

A Capacitor bank is charged with high energy.

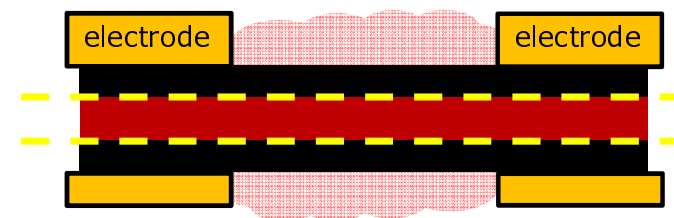
A switch between the capacitor and the test piece is just switched on.



$t < 1 \mu\text{s}$:

Large current ($> 17 \text{ kA}$) flows through the Al foil.

Temperature of the Al foil rise by Joule heat



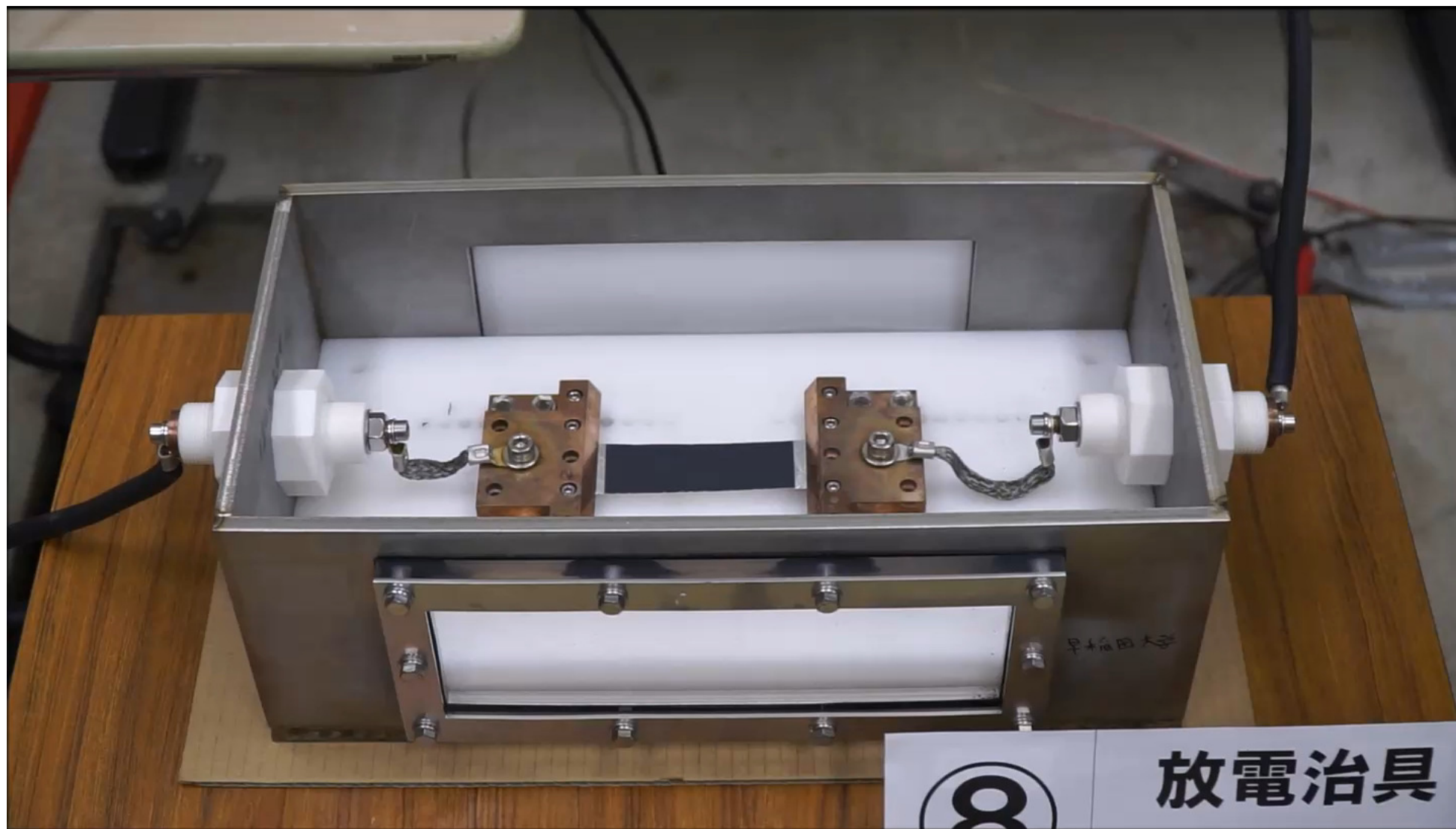
$t < 200 \mu\text{s}$:

Temperature rise to melting point of PVdF ($> 170^\circ\text{C}$). 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



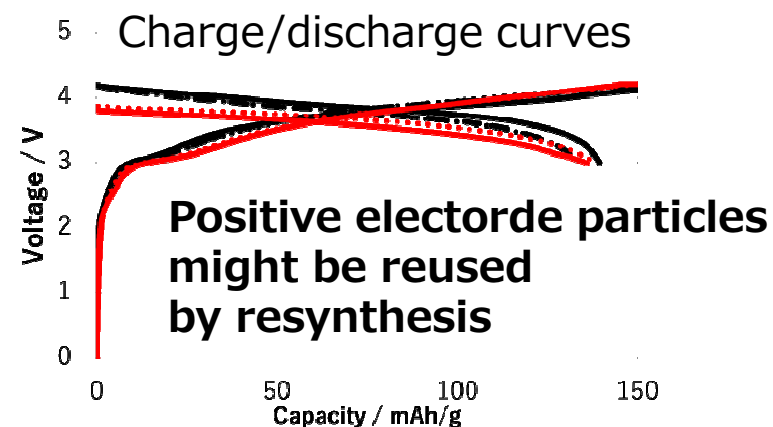


Positive electrode active materials after the separation

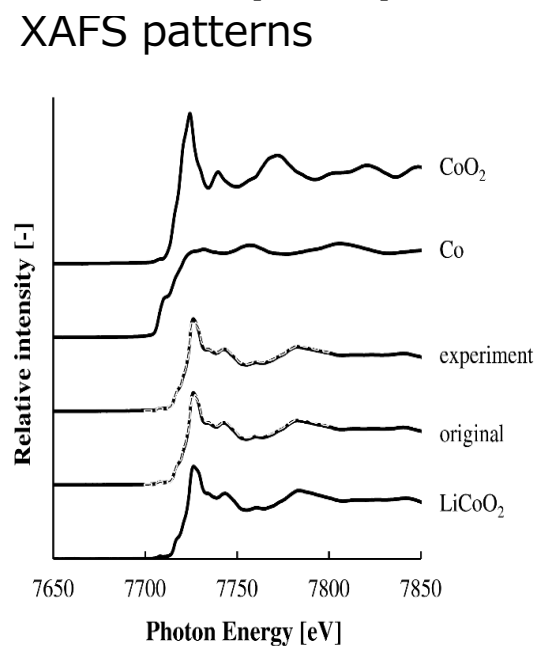
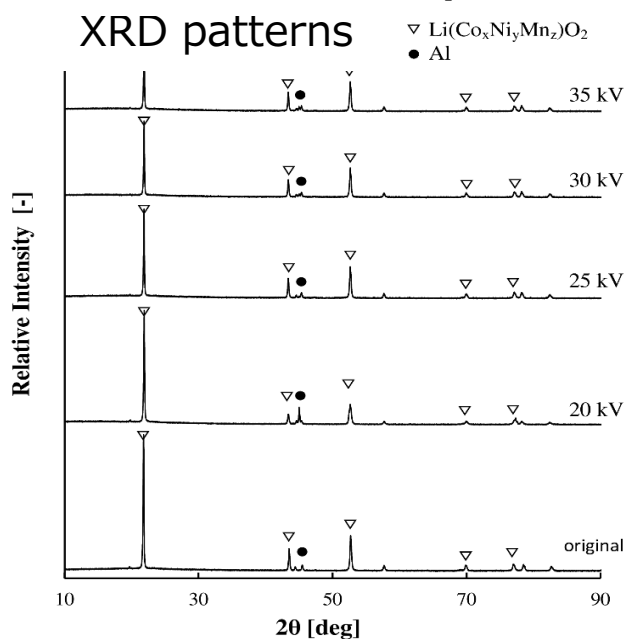
Separated Al foil



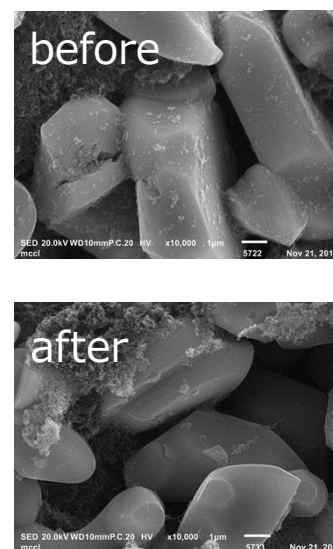
Separated positive electrode particles



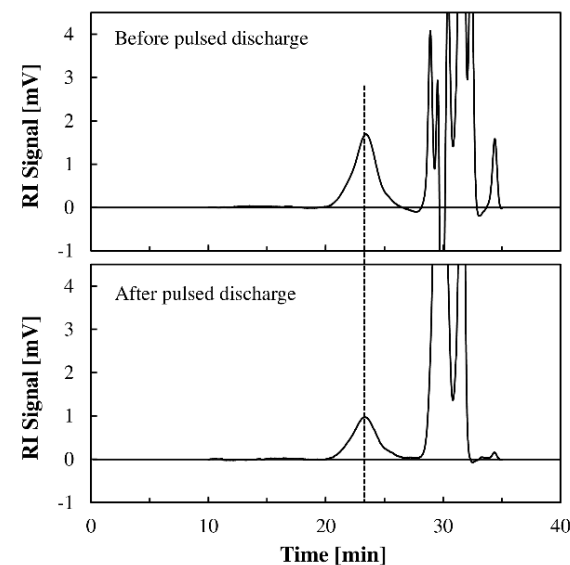
Chemical forms of particles and binder (PVdF) were not changed



SEM images



GPC analysis

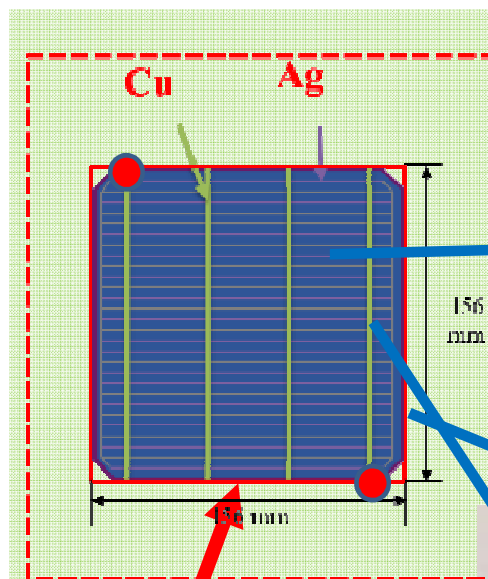




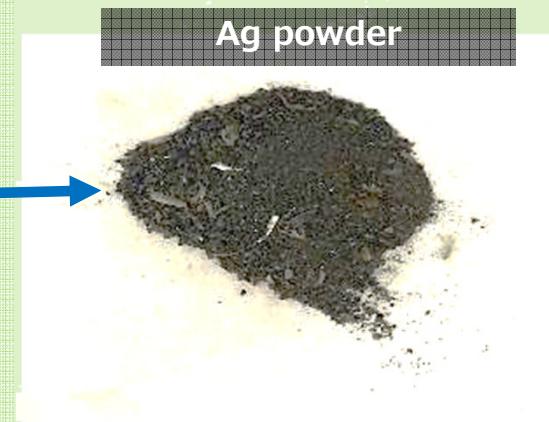
Cu/Ag recovery from cell sheet of PV panel



Spent PV panel



Novel electrical pulsed discharge

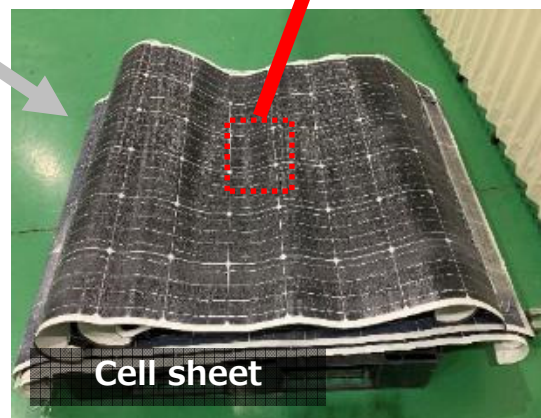


Ag powder

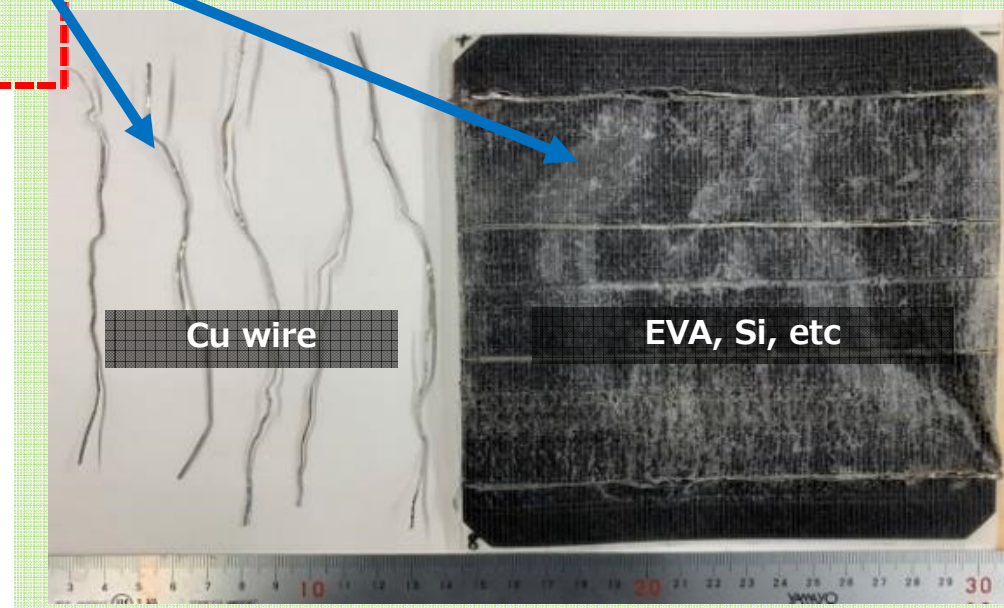
Conventional mechanic separation



Glass plate



Cell sheet

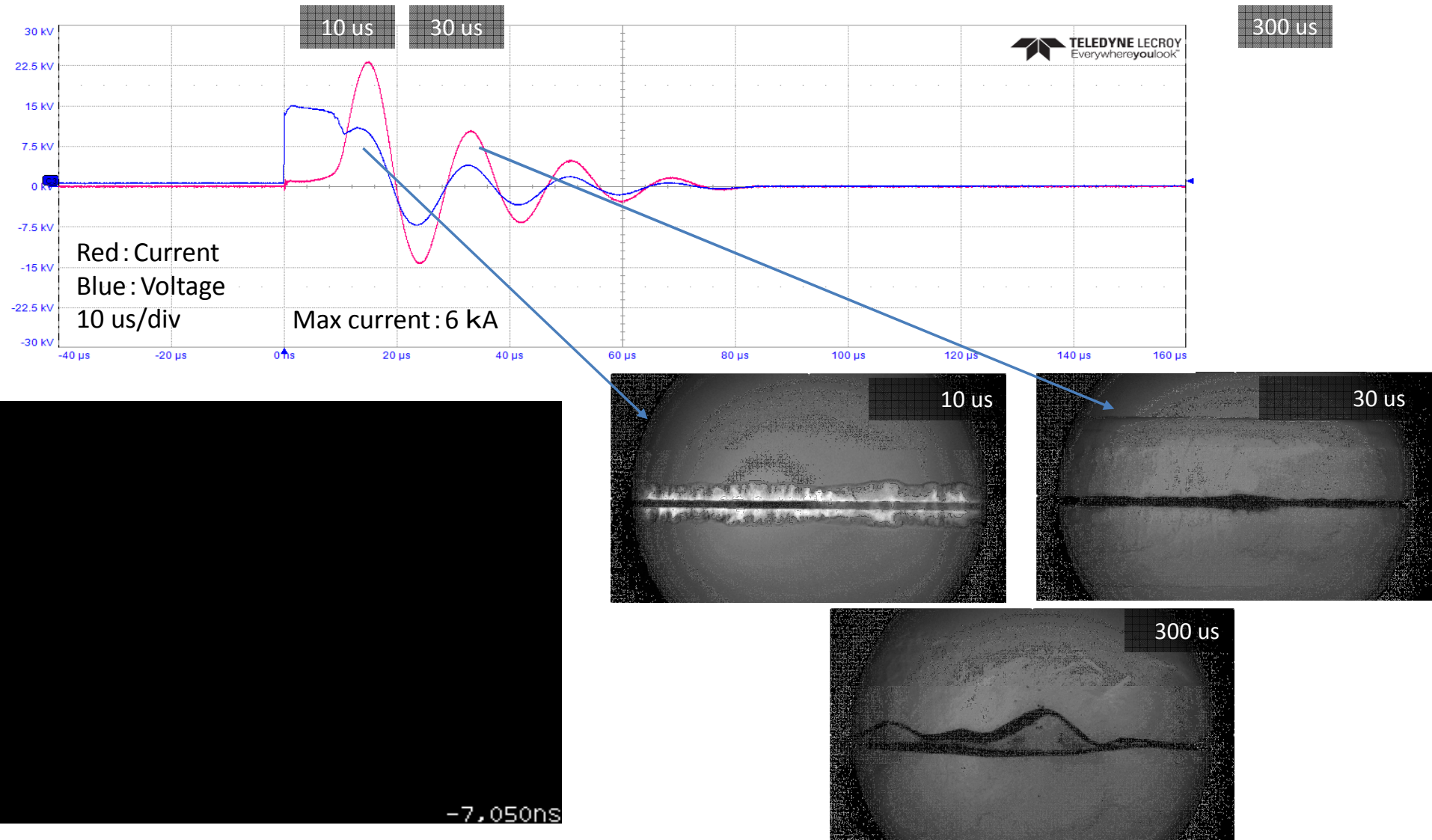


Cu wire

EVA, Si, etc

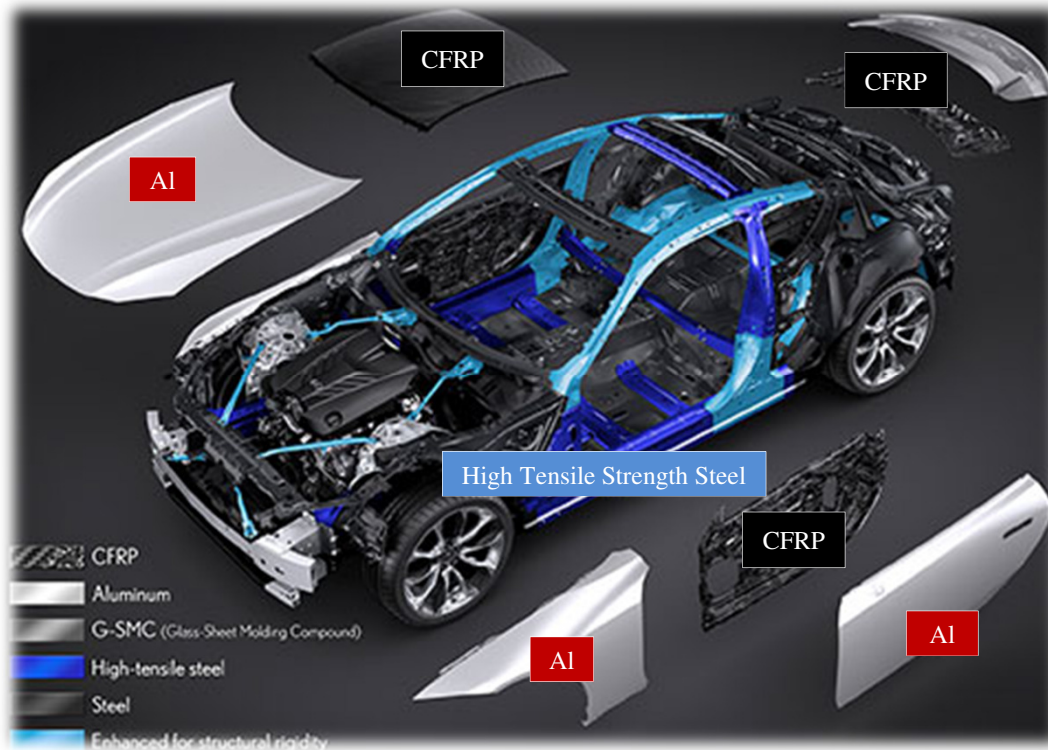


Ag wire explosion and shock-wave propagation

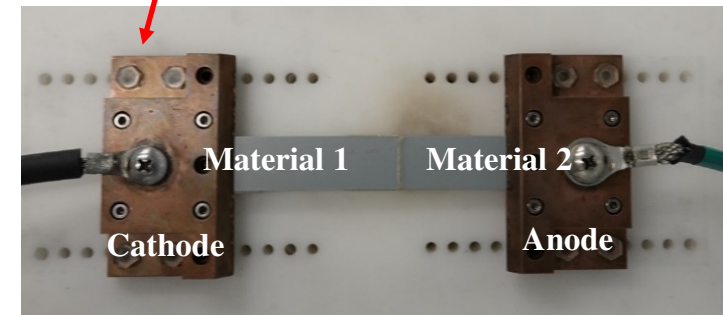
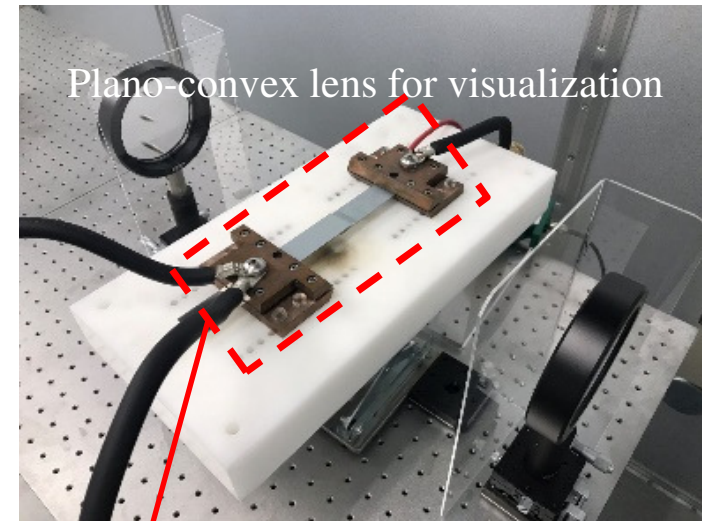




Application to the separation of “Adhesive”



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



Sharp separation of “adhesive”.

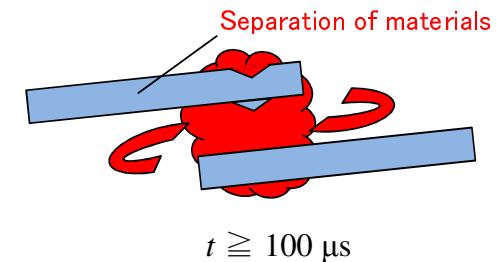
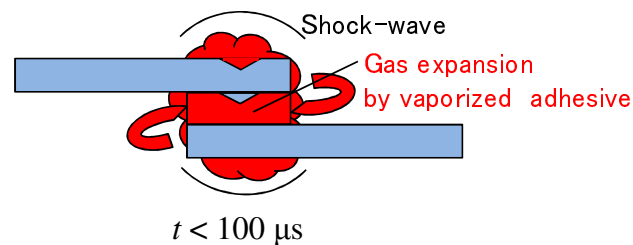
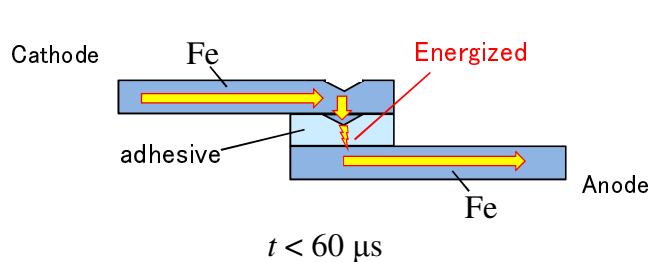
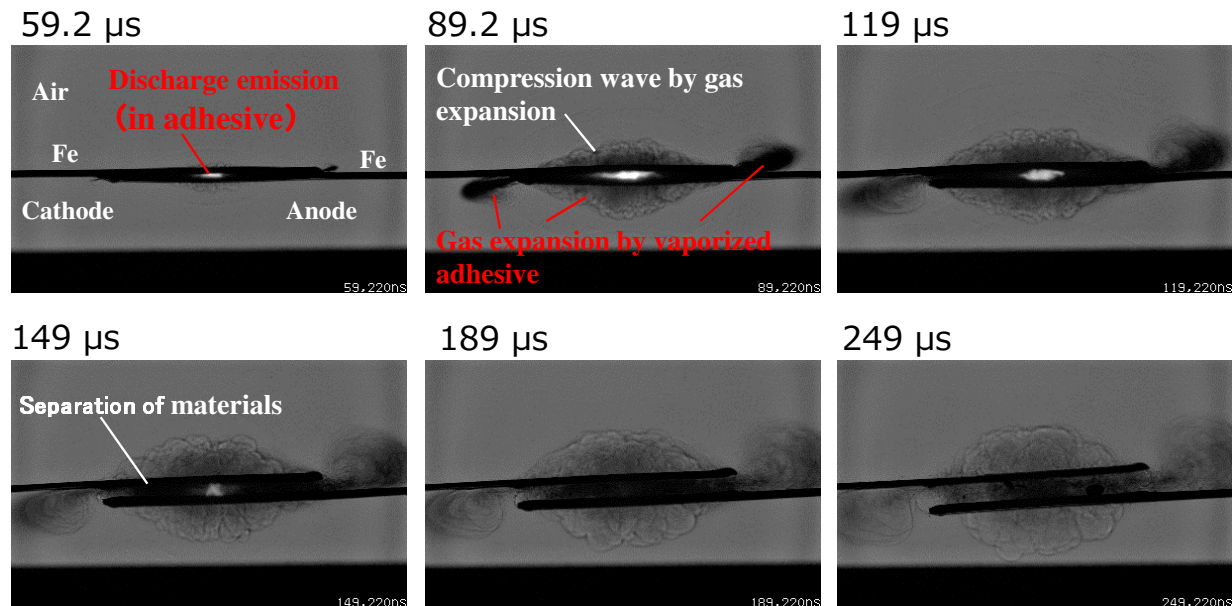


Eliminate of the bottleneck for multi-material



Separation of Adhesive-joining by Electrical pulsed discharge

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



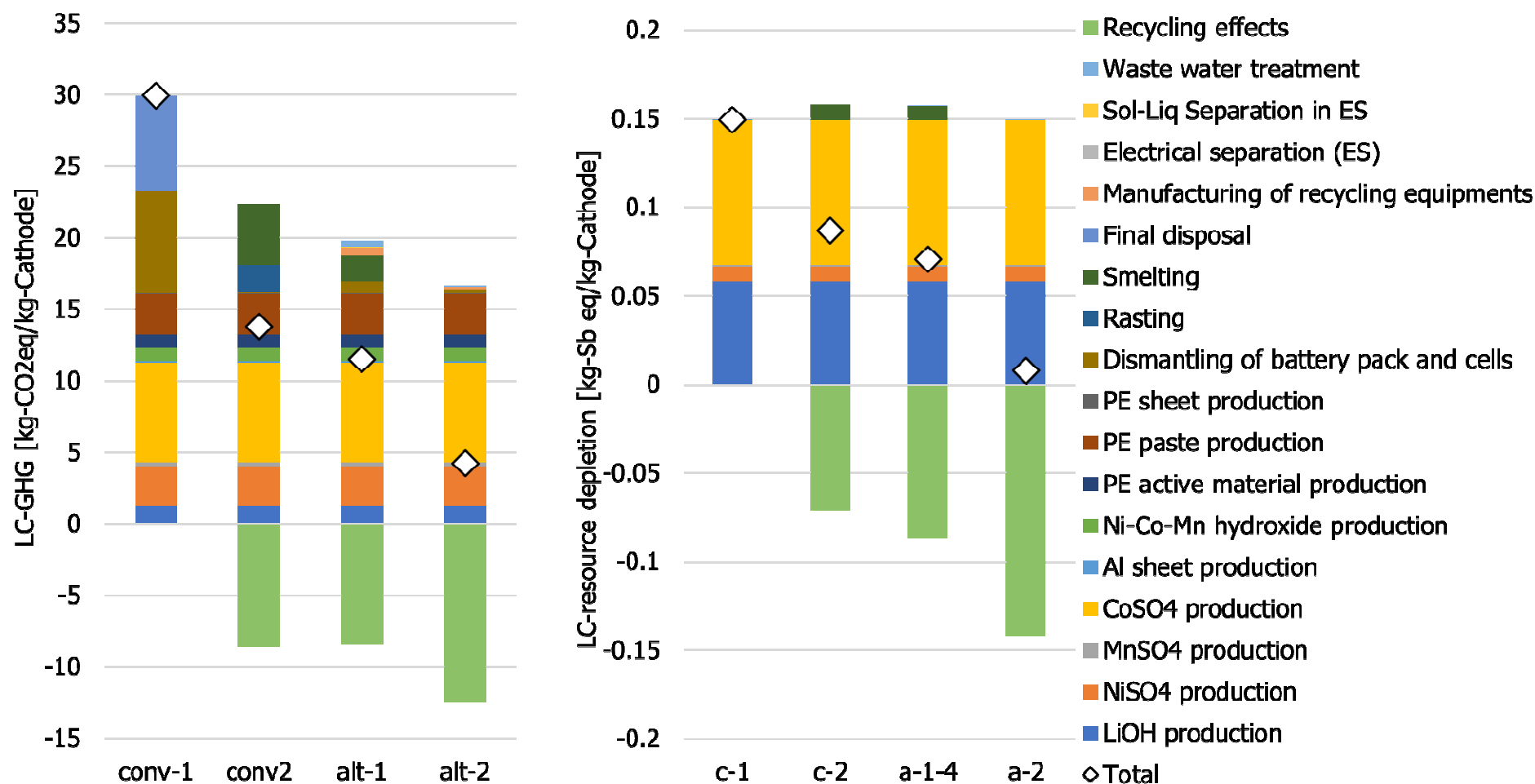
- High voltage application (5 kV)
- Dielectric breakdown of adhesive
- Generation of Plasma in adhesive

- Vaporization of adhesive by Plasma
- Gas expansion

- 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.



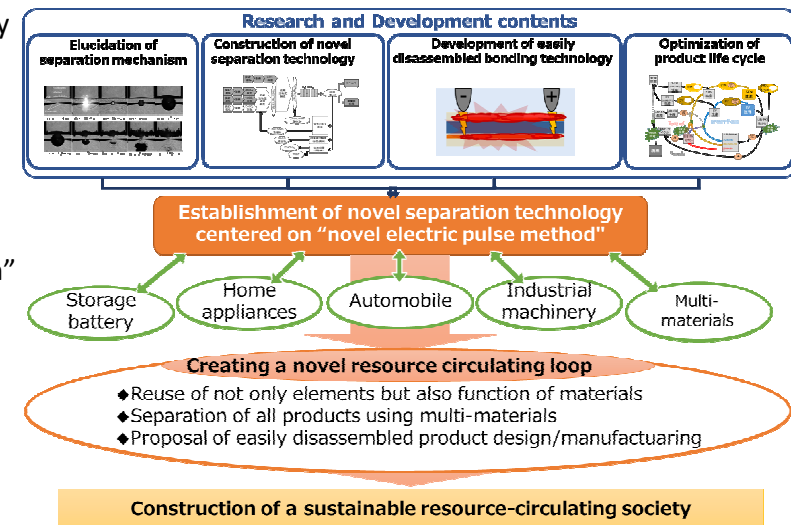
Objective :

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



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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 Joule 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.