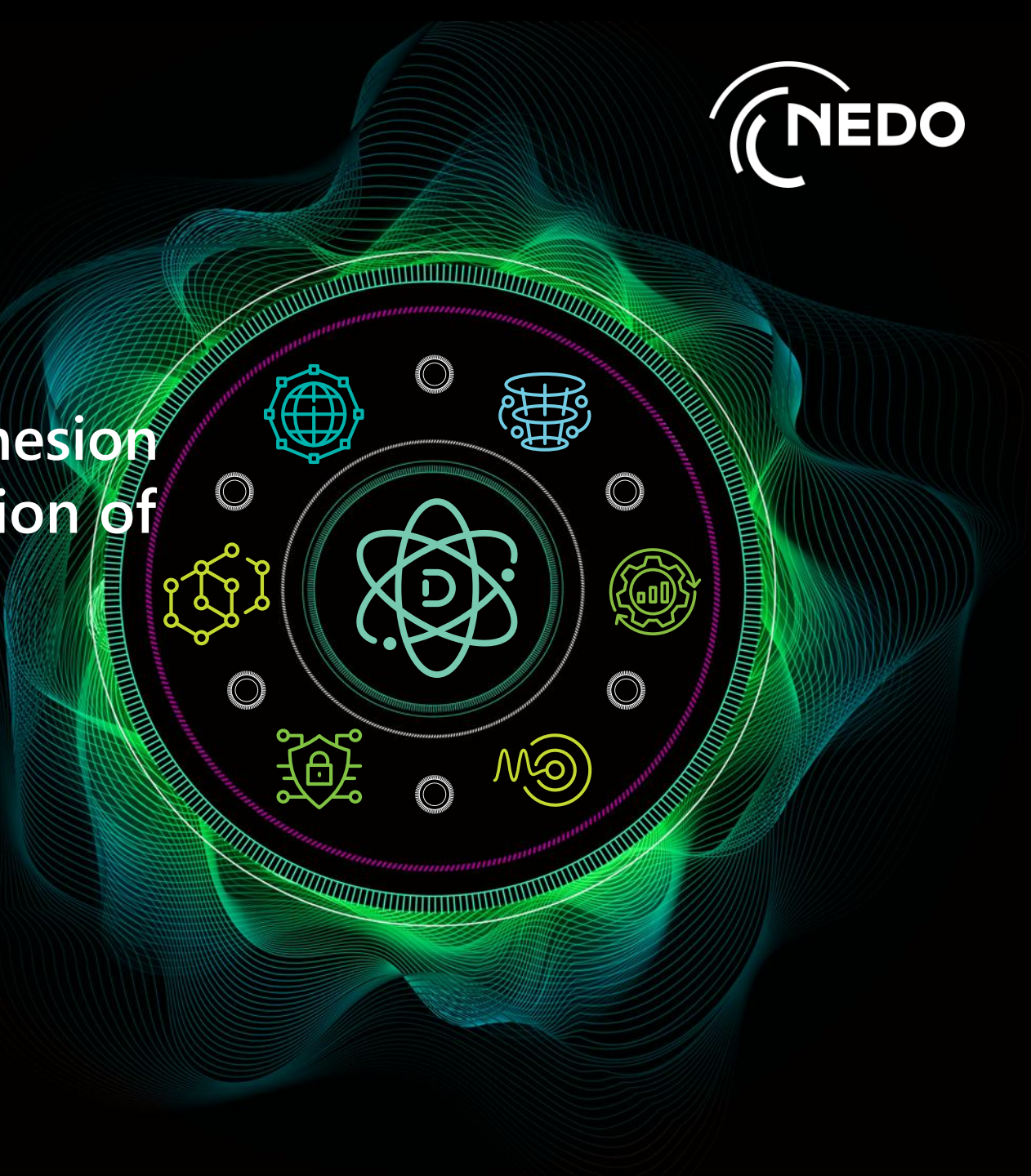
Quantum Computing Use Cases

Development of Dismantlable Adhesion Technology Toward the Construction of an Advanced Recycling System

AIST, Aica Kogyo,
Cemedine and The University of Tokyo



New Energy and Industrial Technology Development Organization (NEDO)

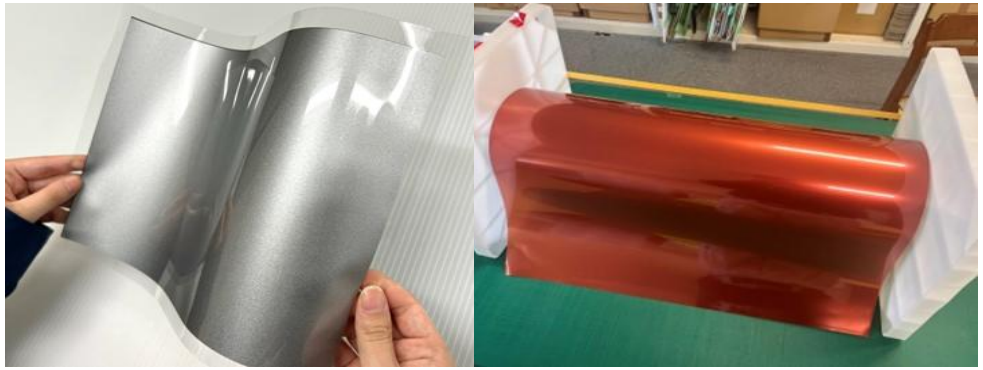
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Validation

Industry	Process Manufacturing
Process	material search, verification experiment, Evaluation
Method	combinatorial optimization
Category	Ising*

Background

- With the shift toward multi-material automotive design and the circular economy, demand is rapidly increasing for adhesive technologies that maintain high bonding reliability while allowing easy disassembly during disposal or repair
- In conventional adhesive development, many design factors—such as material composition, adherends, surface treatment, bonding conditions, and disassembly conditions—interact with one another. As a result, optimizing materials and process design requires an enormous amount of prototyping and evaluation
  - ✓ **With the promotion of resource circulation and the move toward a circular economy, the social implementation of dismantlable adhesion technology is increasingly required**
- Until now, skilled researchers have repeatedly conducted prototyping and evaluation based on experience and know-how in order to search for optimal conditions. However, as performance requirements become more advanced and diverse, **conventional development methods face growing challenges in terms of longer development periods and higher costs**



Photograph of a three-dimensional decorative film

Issues and motivation to be solved

- Designing materials and processes that simultaneously satisfy multiple performance requirements—such as adhesive strength, durability, dismantlability, and cost—results in a vast number of possible design-variable combinations
- Furthermore, because multiple performance criteria must be optimized at the same time, **conventional trial-and-error methods and classical computation alone require significant time and computational cost for exploration, making efficient search difficult even for highly experienced researchers**
- **Adhesive development is an experiment-centered process involving repeated prototyping and evaluation, which leads not only to prolonged development times and increased research costs, but also to challenges related to dependence on skilled researchers and the transfer of know-how**
- Using automotive three-dimensional decorative film as a use case, the goal is to accelerate the development of dismantlable adhesive technology by leveraging quantum-classical hybrid optimization techniques to rapidly extract promising adhesive materials and process conditions from a vast design space. In doing so, **the aim is to automate and advance adhesive development, significantly shorten development time, improve the recyclability of automotive components, promote resource circulation, and reduce CO_2 emissions**

Reference: AI and Robot Department, New Energy and Industrial Technology Development Organization (NEDO), "Cyber-Physical Development Project for Quantum-Classical Hybrid Technologies" (https://www.nedo.go.jp/content/800030349.pdf)
*Ising: A computing approach, mainly associated with quantum annealers and simulators specialized for the Ising model, in which a problem is first formulated as an Ising model and then solved computationally. It is particularly well suited to problems that involve finding the optimal combination from a vast number of possibilities.

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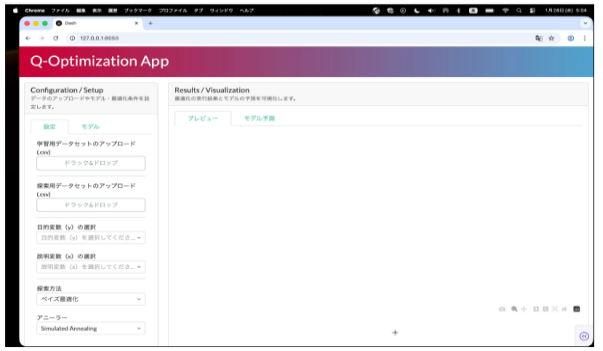
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Problem formulation for quantum computer

- **Adhesive composition, additives, blending ratios, surface treatment conditions, bonding conditions, and dismantling conditions were defined as design variables**, and **the problem was formulated as a combinatorial optimization problem (QUBO) in which multiple evaluation metrics**—such as adhesive strength, durability, dismantlability, and cost—were incorporated into the objective function. In addition, an AI prediction model trained on experimental data was used as the objective function, and promising material and process conditions were rapidly explored through quantum-classical hybrid optimization
  - ✓ An objective function integrating multiple evaluation metrics, including adhesive strength and durability, was defined to search for material compositions and process conditions that maximize overall performance
  - ✓ Constraints were set based on available materials and additives, blending ratios, manufacturing conditions, and practically required adhesive strength and durability
  - ✓ Input data included adhesive compositions, material properties, adherend information, surface treatment conditions, and experimental evaluation data such as adhesive strength, durability, and dismantlability
- Using Fixstars Amplify, the combinatorial optimization problem (QUBO) was solved rapidly, and **FMQA-based quantum-classical hybrid optimization was applied to efficiently search for promising adhesive material design conditions from a vast space of material and process parameters**

Expected business benefits

- **Quantum-classical hybrid optimization is expected to greatly improve the efficiency of adhesive material development and accelerate the practical application of dismantlable adhesive technology for automotive decorative films**. This will enable high-quality recycling of decorative films and multi-material components, contributing to reduced use of virgin materials, lower CO2 emissions associated with manufacturing and disposal, and the realization of resource-circulating manufacturing
  - ✓ By applying FMQA, it was confirmed that promising adhesive material candidates can be efficiently explored even from a limited amount of experimental data
  - ✓ Compared with conventional trial-and-error development, there is a prospect of reducing the number of prototyping and evaluation cycles
- Through application to product groups including automotive three-dimensional decorative films, contributions are expected toward resource circulation and CO2 emissions reduction



No-code executable quantum/classical adhesive development application

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More use cases are available on our website. We invite you to explore them.
https://www.quantum-computing-use-cases.nedo.go.jp/english/

More Use Cases

New Energy and Industrial Technology Development Organization (NEDO)
AI and Robotics Department (e-mail: quantum_ai@ml.nedo.go.jp)

This collection of use cases was obtained as a result of the work commissioned by the New Energy and Industrial Technology Development Organization (NEDO) "Cyber-Physical Development Business of Quantum/Classical Hybrid Technology/Study of Use Case of Quantum Technology" and the “Post-5G Information and Communications System Infrastructure Reinforcement R & D Project (Quantum Industrialization)/Comprehensive Study for Promoting the Industrialization of Quantum Computers”.