国際エネルギー資源学分野　International Energy Resources

より効率的なリソース利用による二酸化炭素の削減

Carbon dioxide reduction through more efficient resource utilization

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Our world faces the greatest challenge in the history of mankind. For about 200 years since industrialization established a constant rise in wealth, this progress was accompanied by a rising atmospheric CO_2 level. Today it is common knowledge that the constantly increasing emission of CO_2 causes the anthropogenic greenhouse effect and climate change. For future prosperity, it is necessary to abandon fossil fuels and replace gas, oil, and coal by renewable resources.
One important factor is the utilization of waste biomass for the production of energy and chemicals. Also the development of the artificial photosynthetic conversion of CO_2 is a promising alternative to conventional technologies. And at last, sustainable management of resources requires the recycling of waste materials for a closed loop of carbon materials.

The most challenging issue of our time is the rise of the atmospheric CO_2 level. With human activities burning fossil fuels, we affect the global carbon cycle (Fig.1) over a time span that is much longer than our own life. The reduction of CO_2 emissions requires the termination of the use of gas, oil, coal.

1.Chemicals from waste biomass

Biomass can be used to fill the gap. It is not only a potential source of energy, but offers also many ways for production of chemicals, which are conventionally produced from fossil oil (Fig.2). We focus on the conversion of biomass that is commonly considered as waste. Materials, such as food waste, straw from wheat or maize, or rice husk, can be used to convert into valuable chemicals such as formic acid, acetic acid, lactic acid, which could be the foundation for a chemistry based on biological sources.

As an alternative pathway to fermentation in bioreactors, such chemicals can be obtained by hydrothermal conversion in water at temperatures between 200 and 300 °C. At very low reaction times of seconds up to a view minutes, more than 30% of the biomass is converted in the presence of inorganic catalysts.

2.Artificial photosynthetic conversion of CO_2

Another promising way is the artificial photosynthetic conversion of CO_2 into fuels and chemicals. That is, solar energy is used to produce organic molecules and hydrogen directly from CO_2 without the help of biological organisms.
In our approach, CO_2 or $NaHCO_3$ (sodium hydrogen carbonate) can be converted to formic acid or other chemicals at a temperature of about 300 °C and in the presence of metal powder from iron, aluminium, zinc, or manganese. The reaction with hydrogen derived from water yields more than 60-90% with a selectivity of near 100%.

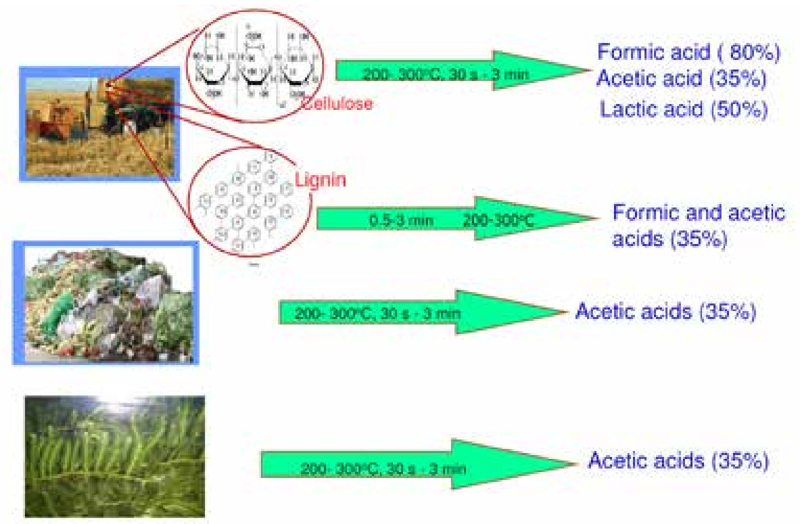

Fig.1 Chemicals from waste biomass

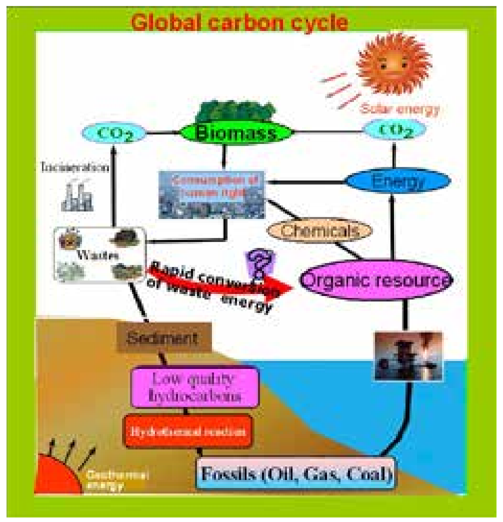

Fig.2 Global carbon cycle.

Further investigations show that the metal composition in electronic waste is applicable as a catalyst for this reaction with similar yields. Therefore, aluminium powder produced with high energy demand can be replaced by waste materials, which are difficult to treat otherwise.

3. Depolymerization of polyolefins at moderate with aluminum-titanium catalysts

Polyolefins are the most produced plastic materials in the world. Their applications range from packaging materials and films to low performance household articles. Most of these materials have a very short lifetime, being disposed rapidly. Some waste polyolefins are mechanical recycled without reaching the former properties (down-cycling). However, most of the polyolefin waste is incinerated or used as fuel in coke ovens and blast furnaces, ending up as carbon dioxide in the atmosphere. For the sake of the development of a recycling oriented society, it is desirable to convert waste polyolefins into valuable resources.
Aluminum-titanium catalysts are frequently used for the polymerization of olefins, known as Ziegler-Natta-catalysis (Fig.3). These catalysts work in principle in both directions, polymerization and depolymerization. Therefore, old used plastic could be degraded to olefins, which could be used again for the production of plastic materials – a resource cycle is established. Catalysts used for polymerization, however, are sensitive to water, oxygen, and other contaminants. Moreover, the temperature required for the plastic degradation would also destroy the catalyst. Therefore, it is necessary to develop new catalysts with higher temperature stability and less sensitivity to chemical impacts.

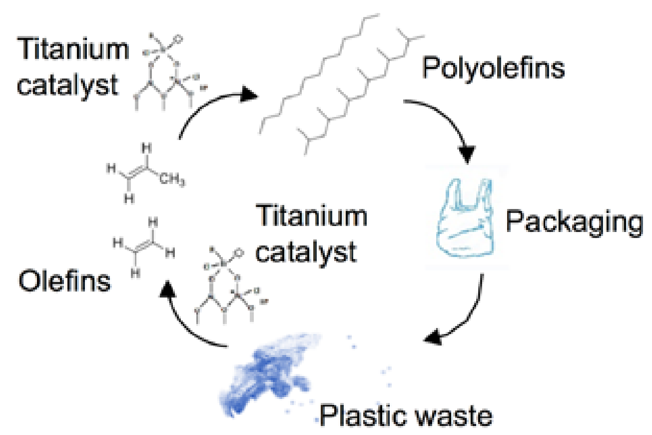

Fig.3 Resource cycle.

4. Stakeholder analysis and agent-based modeling of geothermal resource utilization

In order to limit our impact on the global climate it is necessary to meet our energy needs while reducing our usage of fossil fuels. One very promising alternative is found in geothermal energy, which can be extracted from the earth and used directly or transformed into useable electricity.
In addition to the technical obstacles of finding and developing viable geothermal resources, there are many social challenges that must be overcome at each stage of the utilization process. Japan has a long history of direct geothermal use, which has contributed very strongly to Japan's cultural identity. Because of this, many people worry that further utilization may stretch the capacity of the resource too far and cause damage long-standing traditional usage. In order to balance the respect that is owed to historical practice with the resource development that is needed for a sustainable future, it is necessary to understand the perspective of all stakeholders and work to create options that are agreeable to all parties.
Agent-based modeling is a computational methodology that uses simple rules for individual interaction in order to understand complex aggregate behaviors. It has already been used in other areas of resource development to help forecast potential outcomes of applied stakeholder and policy strategies. It is a powerful tool that may also be used in understanding how geothermal resources are currently being used and how usage could be expanded in ways that have the consensus of stakeholders.

Outlook

This kind of CO_2 conversion will become essential for our lifestyle that depends so urgent on energy and plastic materials, both provided by fossil fuels. Only if we accomplish the step from a fossil fuel based to a sustainable society, mankind might challenge the future.