

Hydrogen from Waste Aluminum: New Approach to Utilize Waste Packaging Materials into Electricity

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Abstract—Authors have developed the multipurpose hydrogen generation cartridge using recovered aluminum from aluminum-containing waste materials. This cartridge contains recovered aluminum and reactants, and with small fuel cell the generated electricity is used for electricity demands at small residential. This system offers advantage of sustainability of energy and reduction of daily electricity cost, because the system is using waste, which causes some social costs.

Keywords—hydrogen, fuel cell, aluminum, waste

I. INTRODUCTION

ALUMINUM is one of common materials in our society. However, aluminum-refining process is energy-consuming, and its price is unstable due to the increasing demand from emerging countries. Therefore, aluminum should be recycled as much as possible, energy-wise and material flow-wise. One of typical application of aluminum is aluminum-coated packaging materials (e.g. snack packages, tablet-like drugs), and nearly 150,000 ton/year of aluminum is used for this application in Japan (Fig. 1).



Fig. 1 Aluminum-coated packaging materials

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Today, these aluminum-coated packaging wastes are simply burned and buried (one-way material flow), and such aluminum is barely recycled due to its low melting point (660 C) and its thinness.

If we recover such aluminum from the wastes, it may reduce the production volume of new aluminum, and we can reduce the energy that is required for the aluminum production from bauxite. Also, if such recovered aluminum is used for hydrogen production and generation of electricity, we can also cut the fossil energy demand.

For that purpose, the authors and partners are currently working on R&D on Waste-to-Hydrogen system, by developing the innovative “hydrogen-on-demand” cartridge. The overall system contains waste collection, dry distillation process, hydrogen generation cartridge, and electricity for home application (Fig. 2).

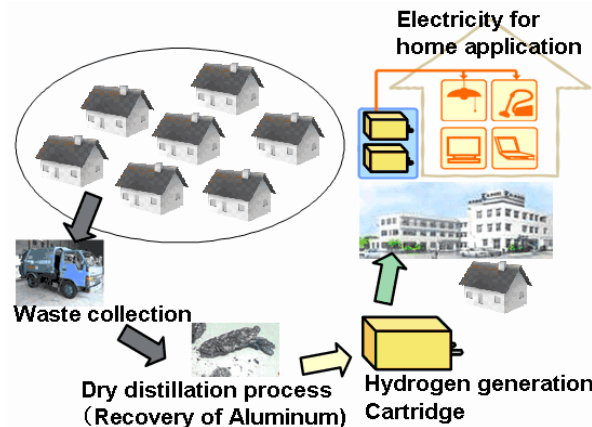


Fig. 2 Concept of “Waste-to-Hydrogen system” for home application

II. WASTE COLLECTION

Aluminum-coated packaging wastes are produced from packaging factories (e.g. snacks, drugs, and drinks) as the industrial wastes, so, we may obtain the aluminum-coated wastes from the household as well as from the packaging factories (Fig. 3).

If the base material is plastic or resin, such aluminum-coated packaging wastes can be processed directly into the dry distillation process. If the base material is paper, the wastes have to the paper-aluminum separation process (Fig. 4)

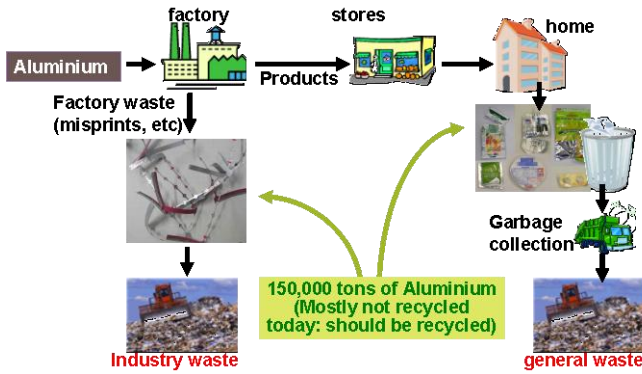


Fig. 3 Aluminum coating wastes from household and factory



Fig. 4 Paper-Aluminum separation process

III. DRY DISTILLATION PROCESS

With partner company, Diamond Engineering Co. Ltd. (Uozu, Japan), the authors have developed special dry distillation process to recover aluminum from such waists using the prototype dry distillation reactor (Fig. 5).

Our investigation reveals that the optimum temperature is around 450-600 C. By this temperature, most of packaging materials (paper, plastics, and resin) are gasified. The Authors have further optimized the process by using generated gases as the fuel for dry distillation, so that virtually there is no energy input (net) for the process.



Fig. 5 Prototype dry distillation reactor

Size(mm):
1000 W x 4900 L x 2100 H
Capacity
50 kg/h (design)
Temp:
450-700 C (by hot air)
Rotating rate:
2-8 rpm

Fig 6 shows the recovered aluminum examples; the left sample contains carbon due to the non-optimized process, and the right one is recovered by the optimized process. The purity of the aluminum recovered by the optimized process around 95-98 %, chemically (evaluated by volumetric determination). Recovered aluminum is also highly porous, and it shows high reactivity.

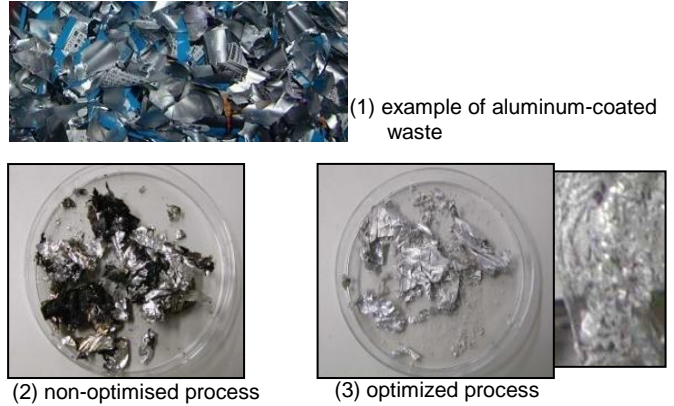


Fig. 6 Recovered aluminum from the dry distillation process

The optimization requires the control of distillation temperature, oxygen concentration, and process time. These conditions depend on the conditions of wastes as well as packaging materials. Some examples require second distillation process to illuminate carbons.

The outlet gases are mainly hydrogen and carbon monoxide, which are all burnable gases and can be used as the heat source for the distillation reactor. By using the outlet gases, we can also minimize the energy for the distillation process.

One issue upon the distillation process is that some packaging materials, such as PVC, contain chlorine, which becomes dioxin during the distillation process, because of the low process temperature. Usually commercial incinerators burn the waste at higher temperature (800 C) to prevent the forming of dioxin, whereas our distillation process is around 600 C. Therefore, the distillation reactor requires other measure to illuminate dioxin, such as chemical trap at the gas outlet.

If we process plastic-based aluminum-covered waste materials, we can obtain recovered aluminum, burnable outlet gases as well as residual oil inside the reactor. The residual oil, which has the similar heat quantity as heavy oil, is also usable for heating the distillation reactor (Fig. 7).

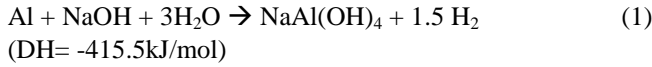


Fig. 7 Residual oil at the dry distillation reactor

IV. HYDROGEN GENERATION CARTRIDGE SYSTEM

Recovered aluminum cannot be used as the secondary bare aluminum, because of its thinness. (the commercial aluminum recycle companies use melting process, where thin aluminum slices are soon oxidized and cannot be refined.)

In order to use recovered aluminum, the authors and our research team have been working on the development of hydrogen generation cartridge by using the reaction (1):



This reaction can be simply controlled by the rate of dropping of NaOH solution onto recovered aluminum powder. From our investigation, the concentration should be around 20-30% to promote the reaction. Our prototype hydrogen generation cartridge is rather large, and currently we are working on the second prototype (Fig 8). This cartridge is designed to operate at ambient temperature and pressure.

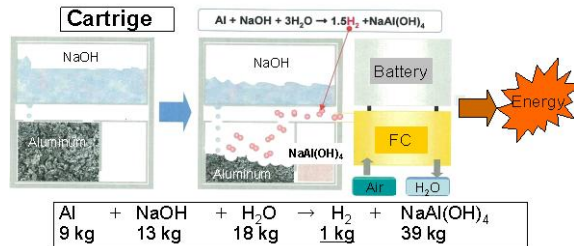


Fig. 8 Concept of hydrogen generation cartridge

Fig. 9 shows the H₂ generation rate dependence on temperature and pressure. The reaction temperature strongly affects the generation rate, but the pressure does not have any effects on the rate. This means the operator should not care about the pressure, resulting in the simplification of the system.

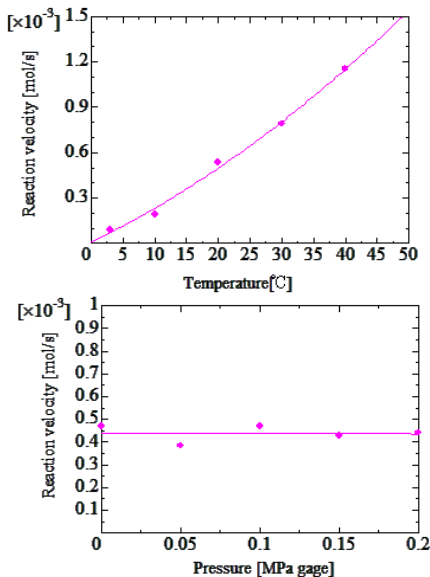


Fig. 9 H₂ generation rate dependence on temperature and pressure

With this reaction, aluminum is converted to sodium aluminate (NaAl(OH)₄), which can be used for water industry (coagulant of water softening system), for paper industry (sizing agent), and for alumina production. Therefore, the byproduct is also industrially valuable.

The system is using NaOH as the key agent to generate hydrogen, but it is also considered dangerous material. Therefore, the cartridge is designed to be an almost closed system, and only hydrogen can be flowed from the cartridge.

Fig 10 shows the overall material flow of aluminum. Currently nearly 2 mil tons of aluminum (as aluminum-coated packaging waste) is simply burned and buried (conventional “burn and bury” process).

We propose that such aluminum can be collected and recovered by dry distillation process, and be used for hydrogen generation (“recover for hydrogen” process). Sodium aluminate, by-product, can also be used as the industrial material, so that recovered aluminum can be returned into the aluminum material flow. Therefore, CO₂ emission and energy consumption at aluminum production can be cancelled.

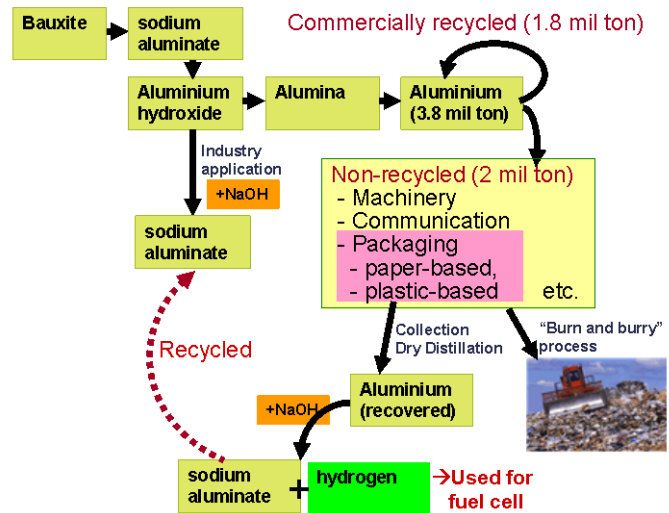


Fig. 10 Aluminum material flow

V. DEMONSTRATIONS

The cartridge can be cost-competitive, because this system does not require any high pressure system and metal hydrides. The cartridge can be used for home applications (lighting, electric appliances, CHP, UPS, and backup power), as well as mobile applications.

The Authors concluded the R&D contract with Japanese Government for the next three years, and also have organized “Hokuriku Green Energy Society”, the public-private partnership at Hokuriku district of Japan. The Society conducted several demonstrations using the prototype cartridge (Fig 11-12).



Fig. 11 Demonstrations using the system
(LED lighting, summer 2010)



Fig. 12 Demonstrations using the system
(Heating carpet, winter 2010)

VI. CONCLUSION

Authors are working on an innovative Aluminum-hydrogen system, using Aluminum from the wastes. The system is innovative and unique process which converts negative value (waste) into positive value (energy). We believe our system can be beneficial to any places in the world.

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