Formic Acid-Assisted Sustainable Recycling of Ni, Cd, and Co from Spent Li-Cd batteries

Masud Rana[1], **Young-Tae Jo**[1,2], Jeong-Hun Park[1*]

[1]Department of Environment & Energy Engineering, Chonnam National University,
77 Yongbong ro, Bukgu, Gwangju 61186, Republic of Korea
[2]Soil Technology and Research Institute, Chonnam National Univeristy, Gwangju 61186, Republic of Korea

Introduction

Ni-Cd batteries and Component metals

◎ Ni-Cd batteries have been banned in several countries and replaced with LIBs in various applications because of their severe toxic components.
◎ Cadmium in spent Ni-Cd batteries, which is a heavy metal and a potential carcinogen.
◎ Nickel and Cobalt : significant amounts in Ni-Cd batteries
◎ Lack of recycling technology & Cost problem: Ni-Cd batteries are discarded as Landfills instead of being recycled.
➔ Therefore, a low cost, environmentally-friendly technology is urgently required to recycle spent Ni-Cd batteries

Reaching with Organic Acid and H_2O_2

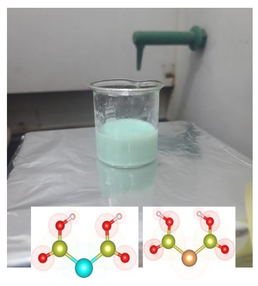
◎ In Ni-Cd batteries, metallic nickel (Ni◦) and Ni (II) oxidation states, while Cd and Co remain as Cd (II) and Co (II) oxidation states.
◎ need oxidized to Ni (II) before being it leached out.
→ oxidizing agent is required to oxidize metallic Ni to Ni (II).
→ Hydrogen peroxide (H_2O_2)
◎ Take the advantages of both organic acid and oxidizing agent into account to explore an effective leaching and recovery method of Ni, Co and Cd from spent N-Cd batteries under mild leaching.
◎ Formic acid was used as a leachate and a precipitant, and H_2O_2 was used as an oxidizing agent.
◎ The effects of different variables, such as temperature, time, and the liquid/solid ratio were carefully investigated.

Result and Discussion

Experiment Method (summary)

Dead Ni-Cd batteries

This work
+ Formic acid
(HCOOH)
(25 °C < T < 90 °C)
+ Hydrogen peroxide
(H_2 O_2)

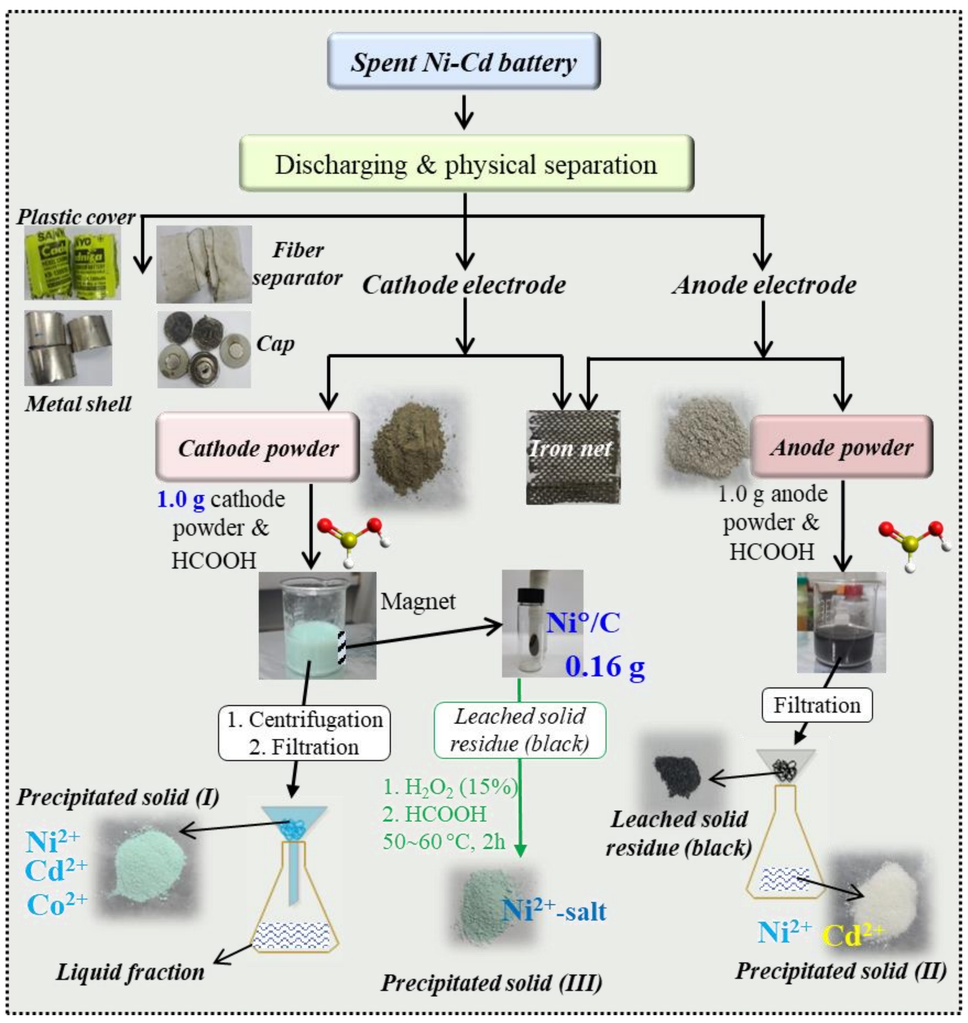


$Ni(COOH)_2$ $Cd(COOH)_2$
Extracted metals in leaching solution

Temperature (℃)

Time (min)

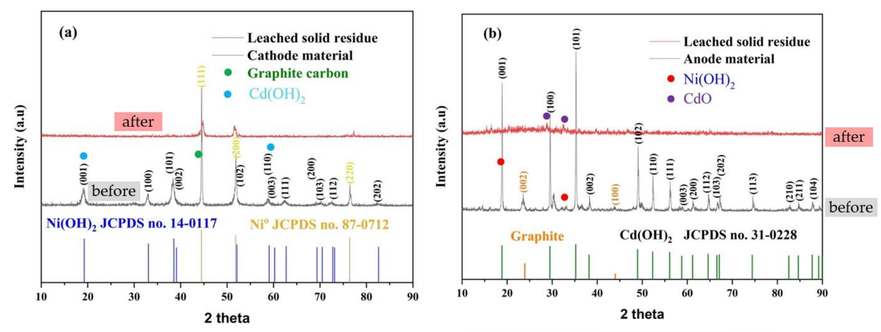
L/S ratio (mL/g)

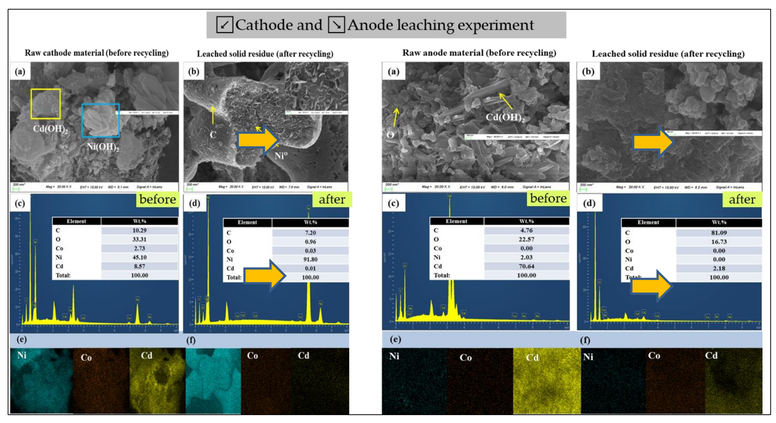


XRD pattern Before & After

(a) : ~Cd

(b) : ~Ni

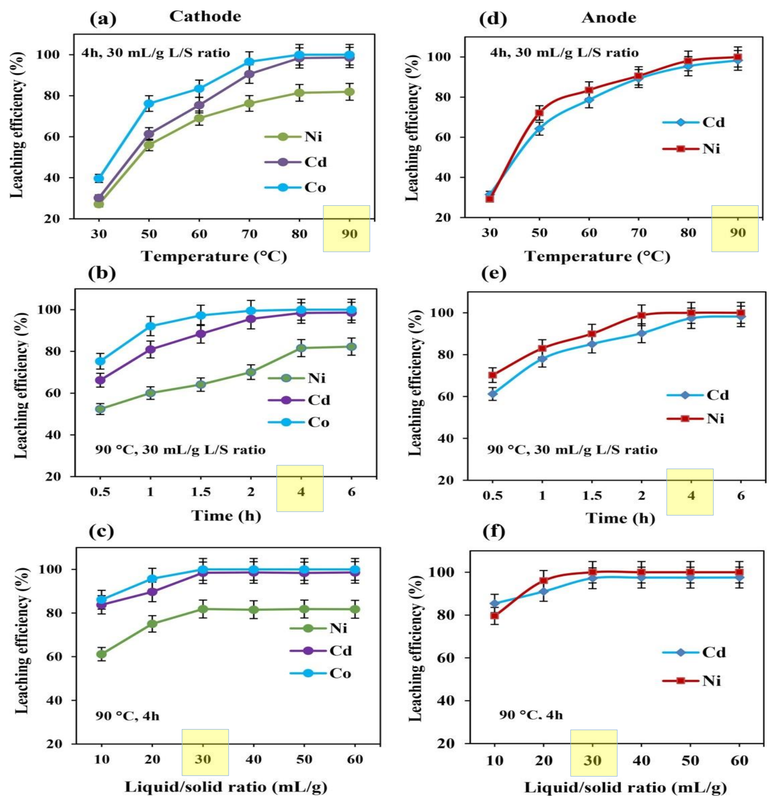




SEM image
Before ↔ After
(a) ↔ (b)

SEM-EDS component(wt%)
(c) ↔ (d)

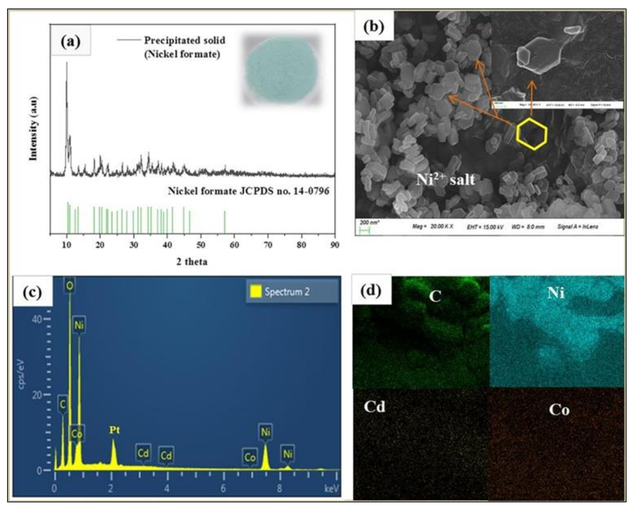
EDS image: Ni, Co, Cd



Optimum conditions:

82.0 % Ni,
98.50 % Cd,
100 % Co
were leached out

@ 90 ˚C for 4 h.



(a)XRD pattern (b)SEM
(c),(d) SEM-EDS analysis

Ni from the leaching solution through **recrystallization.**

● The process's results showed that
→ over 95% of Cd and Co could be leached at 80 ˚C in 2.5 hours,
→ up to 81% of Ni leached in formic acid at 90 ℃ over 4 hrs with a 30 mL/g liquid/solid ratio.

● Temperature and time were found to significantly impact Ni and Cd leaching.

● While metallic Ni in the cathode was initially resistant due to its inertness, using H2O2 as an oxidizing agent
→ resulted in 99.70% conversion of Ni at 60 ˚C in 2 hours.

The authors would like to express appreciation for the support of the sponsors:
National Research Fund (NRF) of Korea : project no.#2202R1A2B501002469.