Separation of Copper and Polyvinyl Chloride from Electric Cables by Means of Plasticizer Extraction and Ball Milling

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Introduction
About 10% polyvinyl chloride (PVC) resin is used for production of electric cables in Japan¹, which mainly consists of covering flexible PVC and Cu wires. Both PVC and Cu are relied heavily on foreign resources. However, most fraction of waste PVC which is not recycled in Japan, is exported to other countries. Therefore, domestic recycling of that is important for the sake of future resource security.

Recycling methods for electric cables are mainly categorized into three methods². First one is stripping of covering PVC from cables by hand, which is inefficient and cannot treat large amount of cables while the quality of recovered PVC and Cu are very high. Second one is granulation of cables into millimetre-sized particles by blenders, which is efficient while the separation accuracy is limited. The third one is incineration of electric wires. However, it can recover only Cu. Thus, there is no effective way to recover both PVC and Cu from electric cables.

PVC covering Cu wire includes plasticizers to obtain flexibility³. In the present work, we focused on the plasticizer extraction from covering PVC to produce brittle cables. We expected that the brittle PVC will be easily crushed by physical impacts such as ball milling, which makes them possible to recover both PVC and Cu with high purity. In this work, plasticizers in the electric cables were extracted by using diethyl ether. The pretreated samples were crushed by using a ball-mill. The influence of plasticizer extraction rate and the morphology change of PVC before and after the extraction on the separation were investigated.

Experimental
Materials
Commercial electric wires (2.1 mm in diameter) were cut into 1 cm length, which was used for all experiments. The sample consisted of 63 wt% of Cu and 37 wt% of covering PVC. The covering PVC included 18 wt% of diisononyl phthalate (DINP) as plasticizer.

Soxhlet and dipping extraction
DINP in the cables were extracted by soxhlet or dipping extraction using diethyl ether. By changing the extraction time in both methods, different extraction rates’ samples such as 20%, 49%, 57%, 82%, and 100% were achieved. The scanning electron microscopy (SEM) analysis and crush resistance test of the prepared samples were carried out.

Ball milling
The ball milling of the prepared samples was carried out using a stainless steel pot (15 cm in diameter) with 20 balls made from tungsten carbide (1 cm in diameter, 7.8 g/ball) at 240 rpm for 6 hours. The crushed cables were separated into 12 fractions between 100 μm and 4.75 mm by using an electromagnetic sieve shaker to determine the size distribution of the crushed samples.

Results and discussion
Characterization of pretreated PVC cables
The results of the crush resistance test are summarized in Fig.1. The crush

![Fig.1 Results of the crush resistance tests of different extracted samples.](image-url)

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force is increased with increasing extraction rate while the 60% extracted sample exceeds measurable limit. The SEM images of the cables before and after the extraction are summarized in Fig. 2. The original PVC has homogeneously distributed pores while those of the 100% extracted sample are inhomogeneous. Thickness of the covering PVC shrank from 0.58 mm to 0.45mm after the DINP extraction. These morphology changes might influence on the hardness and resistance of covering PVC. Thus, we confirmed that the de-plasticized PVC becomes brittle with increasing extraction rate.

Influence of plasticizer extraction on the PVC and Cu separation

No separation was observed at the samples with the extraction rate with 0%, 20%, 49%, and 57% while it was drastically enhanced to 57% at 82% extracted sample (Fig. 3(a)). The maximum separation rate of 77% was achieved at 100% extracted sample. The picture of the crushed sample is shown in Fig. 4. The particle size distribution obtained from the 100% extracted sample is summarized in Fig. 3(b). The particle size of Cu is concentrated into <600 μm and crushed PVC is concentrated into >710 μm. Therefore, the purity of separated Cu between 150 μm and 600 μm size reached to >99%.

Conclusions

Maximum 77% separation ratio with the highest Cu (150-600 μm) purity >99% can be achieved from the 100% extracted sample. PVC was simultaneously recovered with Cu. Thus, the present work revealed that the effectiveness of the combination of plasticizer extraction and ball milling processes.

References