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INVESTAGATION OF POLYESTER REMOVAL MECHANISM FOR RECYCLING Cu WIRE THROUGH APPLICATION OF VOLTAGE

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ABSTRACT

In this research, we have found out very easy, low cost and highly efficient technique for recycling copper materials from polymer coated copper wire wastes as voltages are applied through Induction heating furnace. Different voltages were applied to find out optimum condition for removal technique of polymer materials which are coated on Cu wires. Different voltages such as 562V, 689V, 793V, 887V and 969V onto polymer coated copper wires, were applied to find out the optimum voltage to obtain pure copper materials from polymer coated copper wires. We have used FT-IR, SEM, XRD and optical images to find out the exact removal temperature of polymers and its removal mechanism. As a result, FT-IR analysis confirmed that the polymer that was coated on the Cu waste, to be polyester. Moreover, we also confirmed that polyester was successfully removed at applying voltage at 969V.

KEYWORDS: Recycling, Polyester, Induction Heating Furnace.

1. INTRODUCTION

Waste metal recycling is one of the most recyclable products. Most metals only have to be melted down and then reformed into other products, making its life cycle potentially endless. Recycling makes a substantial saving on landfill space requirements and it helps conserve the world’s resources.

Metals should not be dumped or burnt in fires, but should be collected and recycled or reused as storage containers. There are many scrap metal collectors operating across the Pacific, as it is generally the most viable recycling commodity. Scrap metal recycling is one of the most valuable recycling markets in the South Pacific (and the world). Unlike some other recyclables, metal can be recycled endlessly. Waste metal recycling is one of the most recyclable products. Most metals only have to be melted down and then reformed into other products, making its life cycle potentially endless. Recycling makes a substantial saving on landfill space requirements and it helps conserve the world’s resources.

Recycling of metal has gained significant importance for many years. Exploitation of large quantities of ores by metallurgical industries produces enormous amount of industrial wastes. Recycling of metals reduces waste generation and therefore pollution of the environment.Production of metals from scrap requires much less energy compared to the production from their ores [1].

High consumption levels of certain mineral resources pose a threat to their continued availability in future. Recycling can slow down the depletion of natural mineral resources and enable their conservation. Copper plays a valuable role in manufacturing and construction due to its high thermal properties and electrical conductivity. Good properties and infinite recyclability of Cu make the value of scrap copper nearly equal to the value of newly mined copper.

The importance of waste Cu wire (WCW) recycling has become more evident than before over the last two decades. It is expected that quantities of waste electrical device will increase rapidly in the near future. Due to their hazardous material contents, WCW may cause environmental problems during waste management phase if it is not properly treated. Many countries in the world have drafted legislation to improve the reuse, recycling and other forms of recovery of such wastes to reduce disposal. Recycling of WCW is an important subject not only from the point of waste treatment but also from the recovery of valuable materials.

In order to develop a cost effective and environmental friendly recycling system, it is important to identify and quantify valuable materials and hazardous substances to understand the physical characteristic of this waste stream [2]. Pyrolysis of synthetic and natural polymers is usually conducted in the temperature region of 400-900°C [3-5]. It is believed that the most favorable conditions for heat exchange between polyester film and Cu wire are created in pyrolyzers of the filament type (due to direct contact, small film thickness, etc.), which restricts the possible occurrence of uncontrollable secondary reactions and thus ensures high reproducibility of the results of pyrolysis in comparison to pyrolyzers of the tubular furnace type.

Therefore, pyrolysis of polyester film is very important to recycle pure Cu metal from polyester coated waste Cu wire.

In this study, different voltages onto polyester coated WCW are applied to find optimum condition to fully remove polyester from polyester coated WCW. FT-IR analysis is conducted to identify the polymer.

2. MATERIALS AND METHODS

2.1 Materials

The WCW samples were supplied by Dae Sung Metal Corporation. Supplied samples were cut into 100 mm in length approximately and bunch of WCWs was placed in the furnace chamber.

2.1. Voltage Application

Voltage treatment of the polyester coated WCW carried out under normal pressure and air atmosphere in an induction heating furnace, manufactured by IAE, Korea.

Fig 1. Induction heating furnace

Table 1: Different experimental conditions

Condition Exp. No.	Power (kW)	Current (A)	Current (A)	Temperature (K)
1	2.4	562	120	593
2	3.6	689	147	680
3	4.8	793	170	753
4	6.0	887	190	778
5	7.2	969	207	1207

2.2 Infrared Spectra

The infrared spectra of before and after heat treated WCW were taken on a Thermo scientific Nicoret 6700 / Bruker IFS-66s spectrophotometer with co-addition of 64 scans at a resolution 4 cm^{-1} to observe any change in the polyester film before and after heat treatment.

2.3 Wide-Angle X-Ray Diffraction

The heat treated polyester coated WCW samples were characterized for its change in crystalline behavior after heat treatment by wide-angle X-ray diffraction technique. The experiment was carried out using Rigaku D/MAX-2500/PC diffracto meter.

The XRD pattern was obtained using CuKα radiation that was monochromatized with a curved Graphite crystal monochromator and nickel filter. Samples were scanned at a scanning speed of 4°/min in the 2θ range of 40° to 80°.

2.4 Scanning Electron Microscopy

The morphology of the WCW before and after heat treatment was observed using Scanning Electron Microscope (TESCAN VEGA 3 SB). The average thickness of polyester film was determined using SEM micrographs. The microscope was normally operated in the secondary emission mode at 20kV. Large area of the sample was observed initially at a low magnification and then the selected areas were examined at increasing magnifications (MAG. = X 300, 500).

3. RESULT AND DISCUSSION

3.1. FT IR Analysis Of Polyester Coated WCW Before And After Heat Treatment

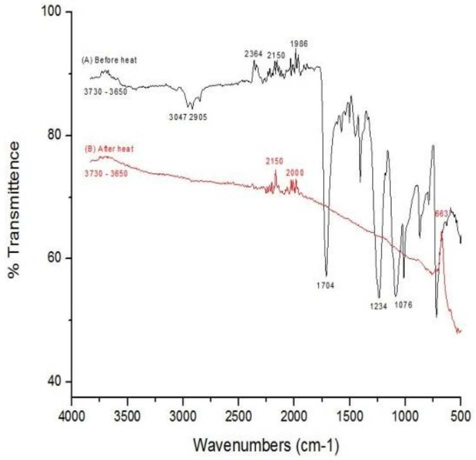


Fig 2. FT-IR spectra of polymer coated WCW before and after applying different voltages

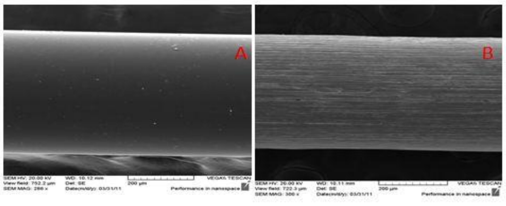
Figure 1 shows FT-IR spectra of polymer coated WCW before (A) and after heat treatment (B).To identify the polymer coated WCW was indeed polyester-based film, FT-IR spectra was performed. The film prepared for examination was thermally heated gradually with voltage increase. As illustrated in figure 1A, the resulting spectra for the polyester film before heat treatment was compared with a reference infrared spectrum found to be for polyester film. Strong absorption peaks marked on the spectrum (see fig. 1A) at are the characteristic peaks for the polyester film. Therefore, the polymer that was coated WCW was confirmed to be polyester. A typical FT-IR spectrum of polymer of WCW coated is shown in Figure 1. Spectrum of Polyester has the characteristic absorption peaks at 1704 cm^{-1} (C=O bonds), 1410 cm^{-1}, 1018 cm^{-1}, and 863 cm^{-1} (vibration of aromatic ring), The band at 1410 cm^{-1} resulting from phenylene ring vibrations (C-H bend coupled with ring C-C stretch) has usually been considered to be insensitive to orientation and conformation and is a reference band [6-8]. The peaks at 1234cm^{-1} and 1076cm^{-1} are symmetrical and unsymmetrical stretching band respectively.

On the other hand peaks at 3047cm^{-1} and 2950 cm^{-1} are stretching band for –CH=CH- of polyester and stretching band for –CH_2-CH_2- of polyester, respectively [9]. The peaks at 3650-3730 cm^{-1} are present due to absorbed water and around 2150 cm^{-1} may be the strong ketene carbonyl Stretch absorption band of polyester. Another absorption band at peaks 1986 cm^{-1} and 663 cm^{-1} may be due to C=C torsion and deformation for aromatic and aliphatic respectively [10].

Figure 1B shows the FTIR spectra of heat treated polymer at 969V. This spectrum shows characteristic peak 3650-3730 cm^{-1} due to absorbed water [11]. Another absorption band around 2000 cm^{-1} and 663 cm^{-1} may be due to C=C torsion and deformation for aliphatic and aromatic respectively [8]. And other peaks were removed to indicate that polyester has been removed successfully. Therefore, voltages applied at 562V, 689V, 793V, and 887V were not enough to remove polyester completely. WCW coated by polymer was identified to be polyester figure1(A) and figure 1 (B) showed disappearance of peaks for polyester, indicating that polyester on WCW was fully decomposed after applied at 969V.

3.2 Scanning Electron Microscopy

SEM images were observed to understand the change in surface morphology of the polyester coated Cu wires before heat treatment and after heat treatment as shown in figure 2. Figure 2A shows the SEM image of untreated polyester coated Cu wire. It is observed that the thickness of polyester coated layer was around 20µm, while Figure 2B shows the SEM image of polyester coated WCW after applied voltage. After heat treatment, the surface was rough as shown in figure 2(B). It could be attributed to the ablation effect caused by the bombardment of the voltage treated species on the fabric surface. The results have proved that the voltage treatment could degrade the surface of polyester coated Cu wire and the burnt polyester layer could be etched. Finally, Figure 2C shows the SEM image of the heat treated polyester coated Cu wire (Exp. No. 5) after washing. It was observed that there has no trace of polyester on Cu wire surfaces. Therefore, polyester coating materials with 20 µm in thickness was successfully removed by applying 969V.



Cu wire before heating

Cu wire after heating and washing

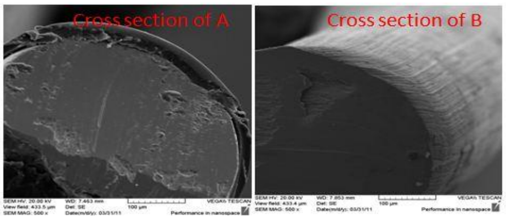


Fig 3 (A). polyester coated waste Cu wire before heat treatment and
(B). after heat treatment and washing (Exp. no. 5)

3.3 XRD Analysis Of The Heat Treated Cu Wires

XRD analysis of the heat treated (Exp. No. 5) Cu wire after washing, showed metallic copper as the final product as shown in Figure. 3. [12]. Therefore, polyester was completely removed after applying at 969Vand pure Cu was detected.

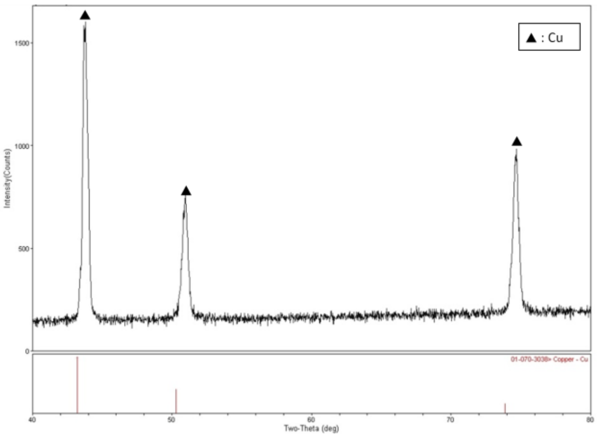


Fig 4. XRD spectra of heat treated Cu wire

4. CONCLUSIONS

The mechanism for the recycling process of Cu from polyester coated WCW has been investigated. The surface of WCW coated polymer was characterized WCW using FTIR, DSC and DTA. The polymer coated on the WCW was found to be polyester. Different voltages (Exp. no 1 to 5) were applied and it is observed that FT-IR spectra shows same characteristic peaks for the samples with applied at voltages at 562-887 V (320-505°C) and those voltages are not enough to completely break the bond for polyester. However, the bond for polyester was broken at applied voltage of 969 V. We observed very clean WCW surface after voltage applied at 969V and washing, indicating successful remove all of polyester layer from polyester coated WCW.

Therefore, recycling of Cu from WCW by applying voltage was demonstrated successfully and this technique can be applied in large scale of Cu recycling or any metal recycling for industrial purpose.

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