Material Recycling of Silane Cross-linked Polyethylene Insulated Cable Using Supercritical Alcohol

Introduction

Silane cross-linked polyethylene (Si-XLPE) is widely used for insulation of wires and cables. Most of industrial waste of the cross-linked polyethylene is burned as fuel. But material recycling is more favorable for environment.

Material recycling of Si-XLPE is hardly to be accelerated because it is not thermoplastic. If the cross-linking element will be decomposed selectively, we will get the thermoplastic polyethylene (recycled PE) from the Si-XLPE waste.

In this article, we show the new technology to get recycled PE from Si-XLPE by chemical reaction in supercritical alcohol. Moreover, the new continuous process of supercritical fluid for polymer which use extruder was developed. Mechanical and electrical properties of recycled polyethylene were good enough for insulation of 600V rating XLPE cable.

Chemical Reaction

Chemical reaction in the supercritical alcohol is shown in Fig.1[1]. Siloxane bond (Si-O-Si) can be decomposed to alkoxide group (-OR) or hydroxyl group (-OH) by supercritical alcohol selectively. The schematic phase diagram is shown in Fig.2. It is called supercritical fluid that the temperature and the pressure of the materials are higher than critical points. Critical points of water and alcohol are shown in Table 1. Critical temperatures of the alcohol are lower than that of water.

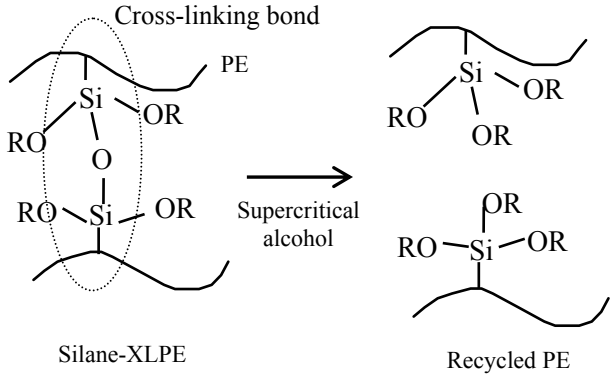


Fig.1 Chemical reaction of crosslinking bond in supercritical alcohol

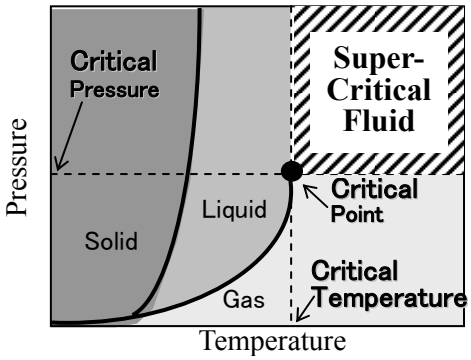


Fig.2 Schematic phase diagram

Table 1 Critical points

Material	Methanol	1-propanol	Water
Temperature(℃)	240	264	374
Pressure(MPa)	8.0	5.1	21.8

Process Development

One of the most important subjects of the supercritical fluid technology is development of the industrial process for the solid material. In the general process for the supercritical fluid, the solid material was crushed into the small particle and dispersed in the solvent to make a slurry. Then, liquid pump is used to feed the slurry but this kind of process has the problem for the industrialization as follows. It is required much cost to crush the materials into particle to make powder for slurry. Moreover, the process requires much solvent more than solid material itself.

To solve this problem, we developed the new continuous process for the supercritical fluid using extruder. Extruder was used as the processing machine for polymers. Pressure and heat can be applied to the polymer with the extruder. The polyethylene which is crushed into 2 to 3mm in diameter can be fed to the new process. It means that the new process does not require to make powder of solid material. Furthermore, minimum amount of supercritical fluid is required for the chemical reaction into pressurized polymer.

The schematic diagram of the new continuous process using extruder for supercritical alcohol is shown in fig.3.

It is used here that the crushed Si-XLPE waste which come out from the process making cross-linked PE cable. The gel fraction of Si-XLPE waste was 31%. Si-XLPE was fed to the hopper of continuous process. Twin screw extruder made by Japan Steel Works was used as equipment for chemical reaction (Ext-Chem) and degas (Ext-Degas). One-way valve was attached to the cylinder of the Ext-Chem to inject the supercritical

1-propanol. The 1-propanol was pressurized by high pressure liquid pump and heated to the supercritical state to be 10phr per 100phr of Si-XLPE before it was injected to the cylinder.

The condition of reactor zone was kept the supercritical state for 20min. Pressure control valve was connected to the front of the reactor.

Ext-Degas was mounted to the outlet of the intermediary pipe to separate recycled PE and 1-propanol. In Ext-Degas, the recycled PE was send to the die by screw but the gas of 1-propanol was retrieved by the vacuum pump of the vent of the extruder.

Then the strand of the recycled PE was extruded and cooled in the strand cooler. Finally, strand is cut into the pellet.

As it was explained, this process make it possible to get the recycled PE from Si-XLPE automatically.

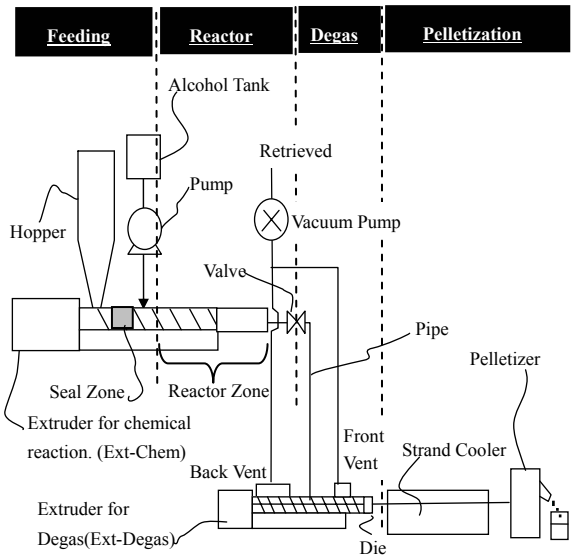


Fig.3 Schematic diagram of continuous process for silane-XLPE using supercritical alcohol.[2)]

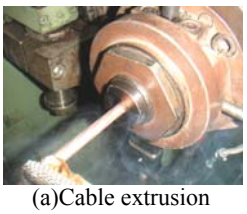
The properties of the recycled PE was shown in table 2[3)]. The gel fraction of recycled PE is 0%. This means that cross-linking is completely decomposed. The mechanical properties of the recycled PE satisfy the JIS C3605(Japan Industrial Standard for the 600V rating XLPE cable).

Table 2 Properties of recycled PE

Tensile strength at break (MPa)	18.3
Elongation (%)	660
Gel Fraction (%)	0

XLPE cable made by recycled PE

Apearance of Cable extrusion of recycled PE and the 600V rating XLPE cable(Cross section of conductor 38mm^2, Thickness of insulation:1.2mm) was shown in fig.4. The proccessability of recycled PE was good enough to be used as the insulation of cable.



(a)Cable extrusion

(b) Recycled 600V rating XLPE cable

Fig.4 Trial for cable recycling

The properties of the recycled cable was shown in table 3. The initial mechanical and electrical properties of the cable satisfied the JIS C3605.

Table 3 Properties of the recycled cable

Items	Recycled Cable	Required
Tensile Strength at break(MPa)	20	>10
Elongation(%)	500	>200
Insulation Resistance(MΩ・km)	1.0×10^5	$>1.5\times10^3$
Breakdown Voltage(kV)	28	>2.5
Heat Deformation(%)*	0.9	<40

* : At 120℃ under the force of 20N.

Conclusion

Recycling technique of Si-XLPE of the wire and cable was investigated. Cross-linking element can be decomposed selectively by supercritical alcohol. The new continuous process using extruder for supercritical fluid is useful for the recycling of Si-XLPE. The properties of the recycled PE indicated that the recycled PE can be used as the insulation of wire and cable. These results suggest that the recycling from cable to cable will soon be available.

References

1) T. Goto etc. Japanese J. Polym. Sci. and Tech. Vol.58, No.12 pp.703-709 (2001).
2) T. Goto etc., Kagaku Kogaku Ronbunsyu,Vol.31,No.6, pp.411-416(2005)
3) T.Goto etc. J. of the insititute of Elec. Eng. of Japan-Vol.126B, No.4, pp.400-406(2006)

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