Multilayer Barrier Film of Biaxially Oriented PA6／EVOH by Double Bubble Tubular Film Process

M.Takashige[(a)], T.Kanai[(b)]
(a) Idemitsu Unitech Co, Hyogo, Japan
(b) Idemitsu Kosan Co, Chiba, Japan

Abstract

A biaxially oriented PA6 film produced by the double bubble tubular film process has high strength, but does not have enough gas barrier property compared with K-coated PA6. A multilayer film having gas barrier layer is studied. High gas barrier layer of EVOH is added in center layer to PA6 films in the outer layers. The gas barrier ability increases with increasing the content of EVOH and decreasing ethylene content of EVOH, but at the same time the mechanical properties and processability get worse. From this point of view, it is found that the optimum content of EVOH is between 20% and 43%.

A biaxially oriented multilayer film composed of PA6 layers and EVOH one keeps high strength and high gas barrier. The material and production technology of a PA6 film can solve environmental and barrier problems.

Introduction

As there has been a strong needs of long life food packaging in the market, a high oxygen barrier film is desired. An ethylene-vinylalcohol copolymer（EVOH）which has high gas barrier property was developed by Kuraray Co., Ltd. and it has been applied for food packaging and gas barrier end-usage〔1〕.PA6 film has inferior oxygen gas barrier performance.

The development of the film with compatible performance of toughness and high barrier is the goal. A polymer blend of PA6 and EVOH has been discussed by Tae [2].

This study was carried out to clarify the relationship among multilayer composition, gas barrier property and physical properties of stretched film. It should aim at the development of a high oxygen barrier film keeping the toughness of biaxial stretching PA6 film by using multilayer film including EVOH layer. The influence of EVOH content in multilayer film and ethylene content of EVOH on stretchability, stretching stress and physical properties of biaxially oriented film including gas permeability is studied by using the double bubble tubular multilayer film machine [3,4]. Outer layers are composed of PA6 and center layer is EVOH as a gas barrier layer.

Experimental

Three layer thickness ratio is changed 2/1/2, 2/2/2 and 2/3/2 for outer layer /center layer /outer layer. EVOH grade in the center layer was changed. PA6 was used for outer layers from these compositions. Five different EVOH grades were used. EVOH is produced by Kuraray and EVOH ethylene contents were 27- 47 mole% with different MI. The maximum stress at the end point of stretching was obtained. The evaluation of gas barrier and toughness was carried out.

Results and Discussion

The stretching stress decreases with increasing EVOH ratio. The stretching stress decreases with increasing stretching temperature. It is found that multilayer film shows higher temperature dependence of stretching stress than PA6. As a result, stretching process window of EVOH is narrower than one of PA6.

The stretching stress increases with decreasing ethylene content of EVOH, which means films with low ethylene EVOH contents is difficult to be stretched（Fig.1）. As ethylene content of EVOH increases, hydrogen bond formation of EVOH decreases and as a result the stretching stress decreases. Fig. 2 shows the relationship between oxygen gas permeability of multilayer film and ethylene content of EVOH. In spite of the same EVOH layer thickness, oxygen gas

permeability decreases with decreasing EVOH ethylene content. From the above results, it is concluded that the grade which has ethylene content between 32mole% and 38mole% is optimum one having wide process windows. And high oxygen barrier.

A blend material of PA6 / EVOH 80/20 was stretched by using double bubble tubular film machine. Three layer multilayer film PA6/EVOH/PA6 2/1/2 was also stretched in order to compare with blend material including 20% EVOH (Table1). In spite of same EVOH content, oxygen gas permeability of multilayer film is superior to the blend film. The blend of EVOH and PA6 is possible to be stretched, but it forms a gel. Because both PA6 and EVOH have polar groups such as OH functional group and amide one, they are reactive and produce crosslinking structure.

The PA6/EVOH multilayer film has high interface adhesion without any adhesive. The surface color of multilayer film turns white in hot boiling water, so its application in hot boiling water over 100℃ is restricted. As a high strength film using non-halogen material can be produced, the waste and environmental problems are cut down.

Table 1 Physical properties of biaxially oriented PA6／EVOH film

Multilayer film v.s. Blend film (outside / center / inside = 2 / 1 / 2)

Properties			Multi layer film	Blend film
Structure		Outside	PA6 100%	PA6 80%
		Center	EVOH 100%	+
		Inside	PA6 100%	EVOH 20%
Processability			Good	Good
Oxygen gas permeability	(cc/m^2・day)		2	50
Film impact strength	(J/m)		61,000	70,000
Gelation			Good	Bad (Gelation)
Laminate strength			Good	—
Hot water resistance	90℃		Good (Clear)	—
	100℃		Bad（White）	—

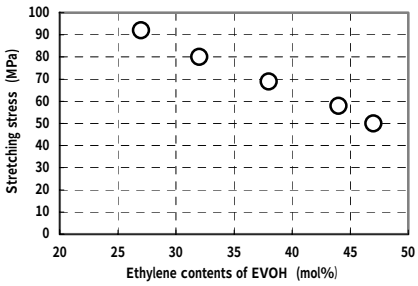

Fig. 1 Relationship between ethylene contents of EVOH and stretching stress

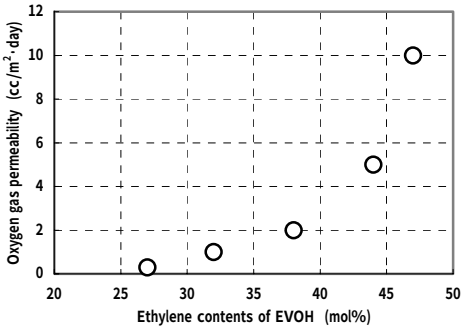

Fig. 2 Relationship between ethylene contents of EVOH and oxygen gas permeability

References

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