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Composite engineering – direct bonding of plastic PET films by plasma irradiation

Tamio Endo[a,b,*], Lakshmi Reddy[c], Hiroaki Nishikawa[d], Satoru Kaneko[e], Yoshinobu Nakamura[f], Kazuhiro Endo[g]

[a]*Faculty of Engineering, Mie University, Japan*
[b]*Faculty of Engineering, Gifu University, Gifu 5011193, Japan*
[c]*S.V.D. College, Cuddapah, India*
[d]*Faculty of Biology-Oriented Science and Technology, Kinki University, Japan*
[e]*Kanagawa Industrial Technology Center, Japan*
[f]*Graduate School of Engineering, University of Tokyo, Japan*
[g]*Kanazawa Institute of Technology, Japan*

Abstract

This article reviews “plasma bonding” of plastic films. Polyethylene terephthalate (PET) films can be bonded directly by oxygen plasma irradiation and heat-press at low temperatures of 100-160°C. Functional groups of COOH and OH were detected on the irradiated surface. The irradiated films were kept in the atmosphere for six years, yet they can be bonded tightly. The irradiated surface is extremely active just after the irradiation, and it is still considerably active after five years. Dry- and wet-peel tests on the bonded films suggest that there are two elements, hydrogen bonding and chemical bonding. The films are bonded weakly by these two elements at lower press temperatures due to low densities of bonds, while they are bonded strongly by high density of the pure chemical bonds at higher temperatures. The hydrogen bonding is broken by water penetration into the interface, causing smaller peel strength under the wet-peel test. FTIR results on the non-irradiated, irradiated and bonded samples indicate that COOH and OH groups are created at the surface, they are responsible for the both bondings. The OH is consumed during the heat-press bonding, then dehydrated condensation reaction can be proposed for the chemical bonding. Cross-linking layer may be the origin for the long lifetime of the irradiated active surface.

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* Corresponding author. Tel.: +81-90-4084-0075.
E-mail address: endotamio@yahoo.co.jp

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1. Introduction

1.1. Utility of PET films

Biaxially oriented polyester polymer (PolyEthylene Terephthalate :PET) films have strong merits such as high mechanical strength, high electrical insulation, high transparency, high heat resistance and low-temperature durability. Then they are used for various applications, for example, magnetic tape bases, liquid crystal display touch panels, food packages[1], and back-sheets in solar cell panels [2,3].

In most of important utilities, low cost PET is mainly used in laminates with various plastic films. A biaxially oriented PET film possesses high performance, it has oriented molecular chains and crystallized structure. A graphic formulae of PET molecule is shown in Fig. 1, composed of C, H, O, and benzene ring. Then the biaxial oriented PET (we call this simply as PET henceforth) cannot be bonded with each other at temperatures lower than melting point (258°C). That is, it has no heat-sealing nature. For this reason PET films are coated with layers having the heat-sealing nature using glues and organic solvents when they are used for the food packages [1].

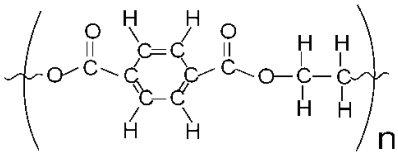

Figure 1. Graphic formulae of PET. It is feasible that the left end is terminated by H and the right by OH.

1.2. Solar cell back-sheets and issues of glue

A clean energy is urgently necessary in the world. One of essential technologies is the solar cell electric generation. It is important to further improve power generation efficiency, weight and durability for wider applications. A cost performance is also an important factor. Usually laminated PET film is used for the back-sheet of solar cell panel, as shown in Fig. 2. Alternatively a PVF/PET/PVF trilayer structure using fluoropolymer PVF (polyvinyl fluoride) was proposed by DeBergalis [4]. It is expected by this lamination that electrical isolation is increased, moisture permeation is decreased and cost is minimized. The other types of trilayer back-sheets also consist of PET films, and these are laminated using glues and organic solvents as well. But the organic solvents cause environmental and health issues, then we should withdraw the organic solvents during the coating process. Further the glues cause performance deterioration of devices in a long term use.

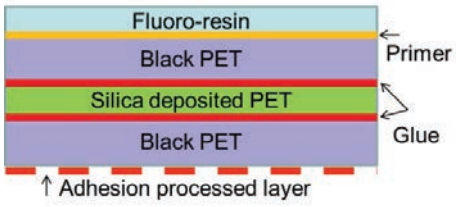

Figure 2. An example of back-sheet of solar cell panel.

1.3. Short lifetime of irradiated surface

To solve such problems, we developed a technique of plasma irradiation-induced direct bonding of plastic films without using any glues [5]. Normally the plasma irradiation effects on the plastic surfaces have very short lifetime,