금속-고분자 계면에서의 전하의 거동

윤주호, 최용성, 안성수, 문종대, 이경섭
동신대학교

Charge Carrier Behaviour of Metal-Polymer Interface

Ju-Ho Yun, Yong-Sung Choi, Seong-Soo Ahn, Jong-Dae Moon and Kyung-Sup Lee
Dongshin University

Abstract : Insulating polymers and their composites have been widely used in various electric apparatus or cables. Recently, the effects of interfaces (metal/insulator or insulator/insulator interfaces) on electrical insulation have attracted much attention. However, interfacial phenomena in actual insulation systems and their physical backgrounds are not well understood yet. In this paper, the behaviour of charge carriers near the metal/polymer interface and its effects on conduction and breakdown phenomena are discussed. The metal/polymer interface strongly affects carrier injection, space charge formation and breakdown phenomena. Based on their experimental results, the physical backgrounds of the interfacial phenomena are explained.

Key Words : Insulating polymers, composites, electric apparatus, cables, metal/insulator

1. Introduction

Organic polymers have been widely used as insulating materials for electrical apparatus, electronic parts, cables, printed-circuit boars and so on. Sometimes their composites are used. Moreover, in practical uses, insulating systems have various interfaces such as polymer/ metal(electrode), polymer/polymer, polymer/ filler, polymer/oil and polymer/air. Such interfaces sometimes strongly affect the performance of insulation systems. Recenly, nano-composites have also attracted much attention as new insulating materials and the role of interface becomes more and more important. However, the properties of such interfaces have not well understood yet. Their understanding are strongly requited to improve practical insulating systems.

In this paper, we will focus mainly on the metal/polymer interface. At first, typical experimental results associated with interfacial phenomena are reviewed. They include carrier *injection, high field conduction, space charge* and pre-breakdown phenomena. Their physical backgrounds are discussed based on these experimental results.

2. Carrier Injection

2.1 Electrode dependence of high-field current

Figure 1 shows the J-F characteristics of EVA (ethylene-vinylacetate copolymer) with Al/Al, Al/Au and Au/Au electrodes). In Fig.1, The Au anode shows much higher current than the Al cathode. These results are qualitatively understandable because Au has a higher work function than Al. Polymers which show electron or hole injection are listed up in Table 1 [1].

For further explanation, we have to know the energy diagram for the metal/polymer interface including the barrier height for carrier injection. However, the energy diagram is not clear for the metal/polymer interface.

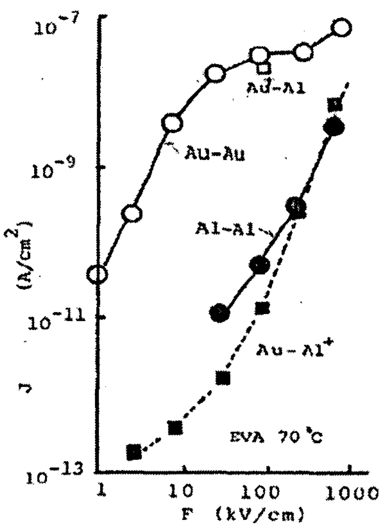


Fig. 1. J-F characteristics of EVA (25mm) at 70℃.

Table 1. Polymers which show electron or hole injection..

Electron injection	PE	PET	PEN	
Hole injection	EVA	PPX	PTEF	FEP

2.2 Energy diagram of metal/polymer interface

There are very few papers which treat with the energy diagram of the metal/polymer interface. We estimated the injection barrier heights of PPX (poly p-xylylene) and PET from photoinjection currents [2, 3].

Figure 2 shows the barrier height as a function of photon energy for PPX, together with that for PET. The barrier height ϕh of PPX (hole injection) obeys the equation, ϕh = 6.84 - ϕm [eV], where ϕm is the work function of electrode metal and 6.84 eV is the ionization energy of PPX Therefore, we obtain the energy diagram of the metal/PPX interface of Fig. 3.

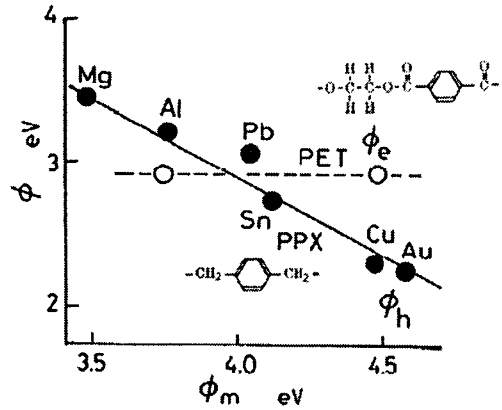
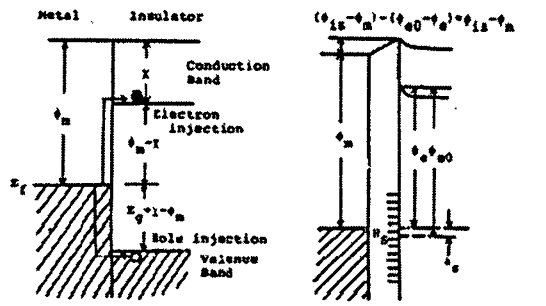


Fig. 2. Barrier heights for hole injection to PPX and electron injection to PET.



(a) PPX (b) PET

Fig. 3. Energy diagrams of metal/PPX and metal/PET interface. (Ns: Surface states).

2.3 Effect of electrode condition

Current or carrier injection depends upon the type of electrode. Figure 4 shows currents in 25-μm LDPE (low-density polyethylene) with evaporated metal electrodes (Al and Au) and plasma electrode. In the plasma electrode, DC 10 kV is applied to the needle electrode and the surface potential of LDPE is kept at 1000 V by the mesh electrode. The plasma electrode shows much higher current than evaporated metal electrode. The kinetic energy of carriers may assist the injection to LDPE. It suggests that the existence of air gap at the metal polymer interface or the exposure to corona discharge can enhance the carrier injection in a practical insulation system. The Al electrode has higher current than Au electrode, which suggests that electron injection is dominant in LDPE. Electron injection is also dominant in the plasma electrode.

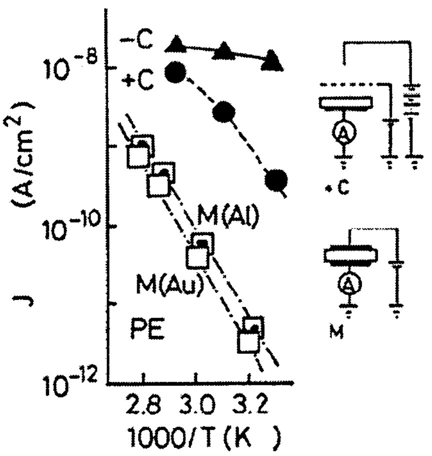


Fig. 4. Currents in LDPE with evaporated metal electrodes and plasma electrode. (F=4x10^5V/cm)

3. Conclusions

As mentioned above, the metal/polymer interface is closely related to high-field conduction, breakdown and degradation phenomena in practical insulation systems. However, the interfacial phenomena seem complicated because many factors such as surface states, additives, the chemical/physical structures of polymers and so on affect them in complicated ways. Experimental results sometimes seem to be different among researchers partly because of different material or experimental conditions. However, modern measurement techniques and well-characterized polymeric specimens enable us to reveal gradually the complicated interfacial phenomena. For further understanding of the behavior of the metal/polymer interface and its physical background, systematic research works on the following items are required.

Acknowledgement

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