Degradation Mechanisms of Organic Solar Cells

Efe Çetin YILMAZ[1*], İlhan Volkan ÖNER[2], Muhammet Kaan YEŞİLYURT[3]

Atatürk University, Pasinler Vocational School, Erzurum 25300, TURKEY
Email: *efe.yilmaz@atauni.edu.tr, ivoner@atauni.edu.tr, kaan.yesilyurt@atauni.edu.tr

***Abstract*—** *Organic solar cells are of majority concern for future electrical power generation because of low-cost, lightweight and flexible production. Stability and degradation is of paramount importance in organic solar cells. Depending on the significance of air exposure, the degradation of organic solar cells can be divided into extrinsic and intrinsic degradation. Organic solar cells often suffer from degradation in oxygen and water. Intrusion of oxygen and water are the principal causes of extrinsic degradation. In this study, we discuss the recent developments of organic solar cell materials and summarize recent improve of organic solar cells with emphasis on the extrinsic degradation that specially related to oxygen and water.*

Keywords*— Degradation, Organic Solar Cell, Stability.*

I. INTRODUCTION

Organic solar cells (OSCs) are considered to be a green solar energy technology. OSCs are attractive mainly because they can be fabricated from various organic compounds with modifiable structures and exhibit excellent flexibility, high power conversion efficiency (PCE) under low light irradiation, and promising see-through power-generation windows. Over the course of the past few years, various aspects of organic solar cells have been extensively studied, including synthesis and application of new materials, modeling of physical processes, large-scale manufacturing, stability improvement, etc. [1]. The research trajectories of OSCs have been described in various reviews [2-6]. The ultimate aim of organic solar cell research is to realize efficient solar energy conversion. In the past two decades, OSC efficiency has been remarkably improved through new approaches such as using fullerene electron acceptors [7,8], and broadening OSC absorption bands within the solar spectra [9]. The total energy output of a fabricated solar cell equals the product of its efficiency and lifetime. Therefore, stability is an important OSC property that impacts the value (yield over cost) of an OSC system as current energy production is largely limited by the low durability [10]. Thanks to persistent efforts, our understanding of the degradation of OSCs has been significantly deepened. Numerous structures have been developed to protect OSCs from degradation and the shelf lives of unencapsulated organic solar cells have been improved to thousands of hours. In addition, the working lifetime, of encapsulated organic solar cells under continuous irradiation, has improved. [6]

II. WORKING PRINCIPLE

A single-junction OSC comprises five or six layers stacked on the surface of a supporting substrate, which is normally a piece of glass or transparent plastic. These five or six layers include a transparent conductive electrode (normally indium-tin-oxide, ITO), a hole-transport layer (HTL), one or two photoactive layers (PALs) composed of an electron donor and an electron acceptor, an electron-transport layer (ETL), and a top metal electrode (normally Al or Ag). The HTL also functions as an electron-blocking layer, or an exciton-blocking layer. Similarly, the ETL also functions as a hole-blocking layer. For simplicity, buffer layers are denoted HTL and ETL as shown in Fig. 1. An extra encapsulation film is sometimes employed. In some cases, the PALs are doped or modified with functional dopants. Over 200 small-molecular or oligomer organic semiconductors used in OSCs were recently reviewed. [5].

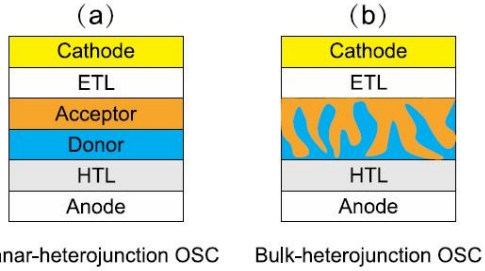

FIGURE 1: SCHEMATIC DIAGRAMS OF A PLANAR-HETEROJUNCTION OSC AND (B) A BULK HETEROJUNCTION OSC [10].

III. DEGRADATION MECHANISM OF ORGANIC SOLAR CELLS

Degradation of Organic solar cells refers to the deterioration (especially in the PCE layer) in their operational capacity. This deterioration does not necessarily occur always in the chemical structure of the OSC's.[10] The degradations of OSC's can be subdivided into two groups, degradation under the effects of internal structure and induced of external factors. The significant part of the degradation is caused by the ambient air. Mass transfer (diffusion) is a concern in both degradation types. For example, OSCs having metal-organic intermediates stored under inert atmosphere environment has been shown to suffer significant degradation. Illustrated in Fig 1 are chemical structures of four different organic solar cells manufactured from commonly used semi-conductors [10].

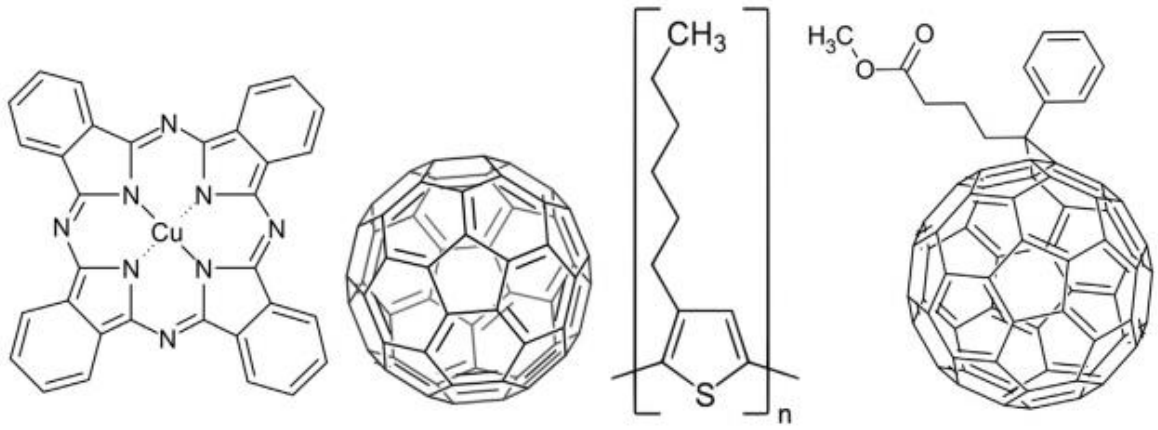

FIGURE 2: CHEMICAL STRUCTURES OF FOUR COMMON ORGANIC SEMICONDUCTORS USED IN OSCS. LEFT TO RIGHT: CUPC, C60, P3HT, AND PCBM [10].

IV. OXYGEN DEGRADATION

oxygen-induced degradation in Organic solar cells are of external environment based degradations. This parameter is often discussed in the literature. Oxygen is dominant parameter in organic solar cells because of the factors given below:

- While allotrope materials do not react with water, they can easily react with the oxygen in the atmosphere. For example, while aluminum exhibits high strength in aqueous media this behavior is not possible with oxygen in the atmosphere.
- In allotrope materials oxygen can enter the electron transport layer very easily and lowers the operational efficiency of this layer.
- Improvements made on surface of metallic materials to cause formation of pitting on these surfaces and cause damage as a result of reaction with oxygen.

V. DEGRADATION WITH WATER

In the literature, it has been explained in many studies that this parameter cause degradation to a lesser extent when compared to oxygen. While surface of Aluminum is observed to exhibit a good passivity in dry air, degradation on the surface is observed in a humid environment, however the degradation is shown to be quite small when compared to the degradation rate of oxygen.

VI. CONCLUSION

In this study, degradation of organic solar cells induced by oxygen and water is discussed and literature survey has shown that oxygen is more dominant as a parameter of degradation. In future studies it is necessary to determine how these parameters affect the efficiency of solar cells and how long does it take newly developed coatings to display activity.

REFERENCES

[1] R. Søndergaard, M. Hösel, D. Angmo, T.T. Larsen-Olsen, F.C. Krebs, Mater. Today 15 (2012) 36.
[2] G.A. Chamberlain, Sol. Cells 8 (1983) 47.
[3] H. Spanggaard, F.C. Krebs, Sol. Energy Mater. Sol. Cells 83 (2004) 125.

[4] B.C. Thompson, J.M.J. Fréchet, Angew. Chem. Int. Ed. 47 (2008) 58.

[5] A. Mishra, P. Bäuerle, Angew. Chem. Int. Ed. 51 (2012) 2020.

[6] N. Yeh, P. Yeh, Renew. Sustain. Energy Rev. 21 (2013) 421.

[7] S.H. Park, A. Roy, S. Beaupre, S. Cho, N. Coates, J.S. Moon, D. Moses, M. Leclerc, K. Lee, A.J. Heeger, Nat. Photonics 3 (2009) 297.

[8] G. Yu, J. Gao, J.C. Hummelen, F. Wudl, A.J. Heeger, Science 270 (1995) 1789.

[9] J. You, L. Dou, K. Yoshimura, T. Kato, K. Ohya, T. Moriarty, K. Emery, C.- C. Chen, J. Gao, G. Li, Y. Yang, Nat. Commun. 4 (2013) 1446

[10] Cao, H.Q., et al., Recent progress in degradation and stabilization of organic solar cells. Journal of Power Sources, 2014. 264: p. 168-183.