

論文 / 著書情報  
Article / Book Information

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著者(和文)	CaoHuanqi
Author(English)	Huanqi Cao
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種別(和文)	論文要旨
Type(English)	Summary

(博士課程)  
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## 論文要旨

THESIS SUMMARY

専攻： 有機・高分子物質 専攻  
Department of  
学籍番号：  
Student ID Number  
学生氏名： Cao Huanqi  
Student's Name

申請学位 (専攻分野)： 博士 (工学)  
Academic Degree Requested Doctor of  
指導教員 (主)： 石川 謙  
Academic Advisor(main)  
指導教員 (副)：  
Academic Advisor(sub)

要旨 (英文 800 語程度)  
Thesis Summary (approx.800 English Words)

This thesis focuses on the stability of organic solar cells based on CuPc and C<sub>60</sub>. The content is composed of six chapters. The first chapter describes the background, and the second chapter describes the experimental. The 3<sup>rd</sup> chapter describes the experimental results, and the 4<sup>th</sup> chapter discusses several models for fitting the experimentally observed degradation curves. The 5<sup>th</sup> chapter discusses a novel Ti-Al bilayer cathode, which improves the stability of organic solar cells. The 6<sup>th</sup> chapter is the conclusion chapter. The following explains the main contents discussed in each chapter.

### Chapter 1. Introduction

This chapter includes the motivation and aim of this study, general principles of photovoltaic, milestones in the history and core terms widely used in organic solar cells. Important factors influencing the stability of unencapsulated organic solar cells, including oxygen, water and light, are also discussed.

### Chapter 2. Experiments

Functionality, purification of materials, vacuum equipment used in this study are discussed. Fabrication procedures of devices with a structure of ITO/PEDOT:PSS (or MoO<sub>3</sub>)/CuPc/C<sub>60</sub>/BCP (or LiF)/Al are explained in detail. Several important techniques used for characterizing organic solar cells are demonstrated, including sheet resistivity, crystalline form, UV-visible absorption, surface morphology, and elemental depth profiles, etc. We also comment on the aperture method which is considered as the accurate performance measurement method of organic solar cells.

### Chapter 3. Light-induced degradation

In this chapter, we show the effects of light irradiation on the degradation of unencapsulated organic solar cells in different degradation stages in air or in vacuum. In air, for devices fabricated in one batch, those stored in a dark box degrade relatively slowly than those stored under fluorescent lamps. In vacuum, organic solar cells reach equilibrium after consuming adsorbed oxygen under light irradiation, and such equilibrium will be broken by air exposure. The synergistic effect of oxygen and light irradiation on the degradation of organic solar cells is therefore evidenced. Detailed experimental results show that the light-induced degradation of small-molecular organic solar cells is related with the photo-aging of the fullerene layer.

### Chapter 4. Modeling of degradation curves

In this chapter, we propose several models to explain the degradation curves of unencapsulated organic solar cells. When oxygen is considered as the major cause of the extrinsic degradation, a lateral oxygen diffusion model agrees the best with experimental

observations. According to simulations, microscopic pinholes in the aluminum cathodes are insufficient to cause the rapid degradation of unencapsulated OSCs in the initial few hours. Instead, we hypothesize that oxygen can also pass part of the cathode grain-boundaries that are wide enough. Based on experimental observations, we conclude that the diffusion constant of oxygen in fullerene is increased by approximately seven times under fluorescent lamps.

#### Chapter 5. Titanium-aluminum bilayer cathode

In this chapter, we systematically examine novel cathodes, i.e. AlTi bilayer cathodes, which can significantly improve the stability of organic solar cells in air. As discussed in previous chapters, the intrusion of air from pinholes and grain-boundaries in the cathodes causes the main short-term degradation. To eliminate the intrusion of air, we replace the aluminum cathodes with titanium-aluminum bilayer cathodes. Such bilayer cathodes dramatically improve the life stability of an unencapsulated organic solar cells stored in air by three orders of magnitude, i.e. from a few hours to thousands of hours.

We compare the effects of different buffer layers on the stability of both aluminum and aluminum-titanium devices. Bilayer-cathode devices with BCP as electron transport layers and PEDOT:PSS as hole transport layers perform the best. The effects of humidity on the stability of devices with different cathodes and buffer layers are discussed. Aluminum devices cannot resist RH > 50%. On the contrary, aluminum-titanium devices are highly resistant to ordinary humidity, although they can still be ruptured under RH > 90%.

In order to investigate the stabilization mechanisms of the bilayer cathodes, we check the surface morphology with AFM and elemental depth profiles with TOF-SIMS in different devices. According to the experimental results, the stabilization mechanisms of the bilayer cathodes are proposed as following.

- Titanium eliminates the microscopic pinholes in the cathodes;
- Titanium hinders the interdiffusion between the aluminum cathodes (as well as LiF) and the organic layers;
- Aluminum sustains the oxygen scavenging of titanium, during which aluminum gets passivated, suppressing further oxygen intrusion.

Besides, we speculate that titanium protects aluminum from corrosion.

#### Chapter 6: Conclusions

In this chapter, we summarize our experimental observations and proposed theories.

To conclude, we have studied the extrinsic degradation of small-molecular organic solar cells from different perspectives. A simple and versatile diffusion model has been built to explain various degradation curves of organic solar cells. To overcome the degradation, we have designed a bilayer cathode which improves the shelf-life of an unencapsulated OSC by at least three orders of magnitude. These findings will hopefully advance the current understanding and development of organic solar cells.

備考：論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 2 部提出してください。

Note: Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 2 copies of 800 Words (English).