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INCREASING THE ADAPTABILITY OF ORGANIC PHOTOCELLS

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Annotation: discusses methods for improving the excellent mechanical flexibility of organic photovoltaics . Current strategies aimed at improving the mechanical stability of film-based polymer photovoltaic systems are presented, as demonstrated by a selection of relevant examples using PM6-based systems. General methods for introducing third components, including novel polymer donors/acceptors and isolated polymers, to improve the stretchability are explored .

Keywords: polymer, PM6, donor, acceptor, insulation, photovoltaic, mechanical flexibility.

V state osnovnoe vnimanie udelyaetsya metodam povysheniya prevoskhodnoy mekhanicheskoy gibkosti organicheskikh photoelementov (OSC). V etoy state predstavleno polnoe issledovanie tekushchih strategic, napravlennyx na povyshenie mekhanicheskoi stabilizati tonkoplenochnyx polymernyx photoelementnyx system, o chem svidetelstvuet vybor sootvetstvuyushchix primer s usepolzovaniem sistem na osnove pm6. First, we will examine tertiary components for increased elasticity, including new donor/acceptor polymers and general strategies for the introduction of isolated polymers. (50)

Key words: polymer, PM6, donor, acceptor, insulation, photovoltaic, mechanical flexibility.

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In the rapidly developing field of wearable electronics, flexible organic solar cells (OSCs) have emerged as promising candidates for portable power sources that require materials with excellent mechanical flexibility, which in turn requires materials with high mechanical flexibility. However, the inherent stiffness of the configured backbones of high-performance photovoltaic polymers such as PM6 is a problem, as it makes the photovoltaic films prone to failure under mechanical stress. Therefore, improving the mechanical properties of these films is an important research direction for the development of stretchable photovoltaic technologies. Improving the mechanical properties is usually achieved by modulating the micromorphology of the photoactive composite films or increasing the intrinsic stretchability of the materials. Understanding the relationship between structural features and material properties is crucial for optimizing these mechanical properties and achieving a balance between device stretchability and efficiency. To this end, researchers have

developed various strategies to create photovoltaic films with high electrical and mechanical properties.

Material and methods

Energy and environmental concerns are major challenges in modern society, driving the rapid development of solar cell technologies to meet the demand for renewable energy sources. Organic photovoltaic cells (OSCs) are a revolutionary technology in this field, offering important advantages such as light weight, transparency, environmental friendliness, flexibility and even plasticity [1]. Flexible and portable (Fig. 1c, d). The charging process is essential for photovoltaics . Despite significant growth, most flexible electronic devices still rely on non-flexible power sources, primarily due to the difficulties in developing flexible alternatives . Recent advances have increased the power conversion efficiency (PCE) of OSCs by approximately 20% [2 . P. 114].

Results and their analysis

The photovoltaic cells used today often exhibit poor elongation, with separation strain typically below 8% and high modulus. The reason for this growing problem is that the polymer donors (PDs) and acceptors in the active layer typically have alternating chains of donor-acceptor units [3]. This structure enhances the charge transport within the molecule and broadens the absorption spectrum, which is important for high photovoltaic efficiency. However, the rigidity of the configured backbone chain leads to brittleness of the material, which limits the mechanical flexibility of thin films during stretching. The active layer is prone to high stress concentrations during stretching, especially at the site of defects that occur at the donor-acceptor interface [4]. In addition, the physical properties of the film with respect to stretching depend on its degree of crystallization and how the molecules are arranged. Excessive crystallization and unsatisfactory molecular arrangement can cause the film to crack and crack rapidly [5]. The mechanical properties of organic solar cells (OSCs), including the elastic modulus and the elongation at break (COS) or full elongation, are important factors determining their suitability for flexible electronics. High mechanical strength allows photovoltaic films to withstand significant deformations, which increases the device lifetime and reliability. To address these issues, there is an urgent need to develop stretchable photovoltaic films that match the elastic modulus of human skin and can withstand bending and stretching under large deformations [6]. To this end, researchers have developed various strategies to obtain photovoltaic films with high electrical and mechanical properties. These strategies typically involve physical mixing and structural modification. The improvement of mechanical properties is achieved by modulating the microscopic morphology of the photoactive composite films or by increasing the intrinsic stretchability of the materials. Understanding the relationship between structural structure and material properties is crucial for optimizing these mechanical properties and achieving a balance between device stretchability and efficiency. Among the various materials studied, PM6, also known as PBDB-TF, stands out as a promising donor polymer [7].

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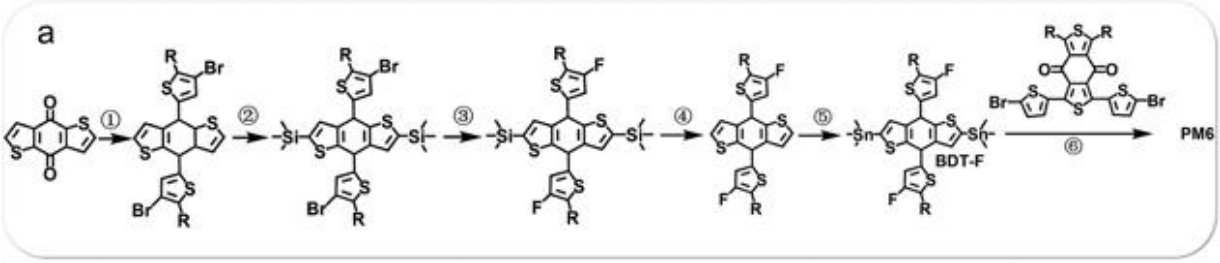
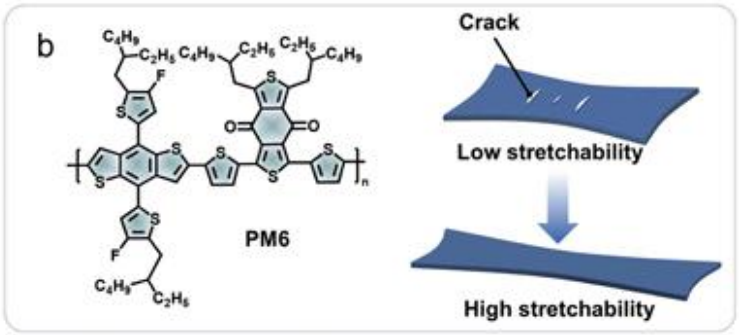
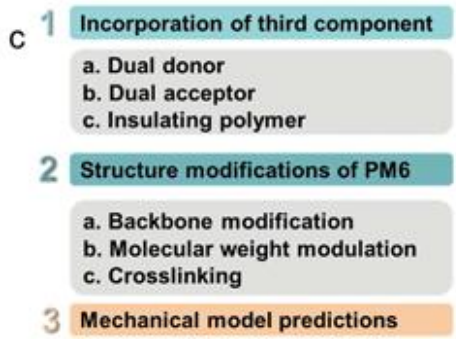


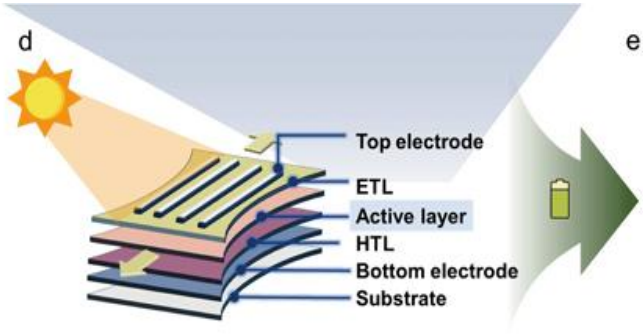
Figure 1. (a) Synthesis routes of BDT-F and PM6 monomers are presented.





1-rasm. (b) PM6 ning kimyoviy formulasi va uni ichki cho‘zilish qobiliyati bilan ta’minlash muammosining murakkabligi, PM6 qattiq plyonkasi uchun kiyiladigan quyosh batareyalarida qo‘llash uchun.

1-rasm. (c) PM6 asosidagi fotofaol qatlamning mexanik xususiyatlarini yaxshilash strategiyalari.





1-rasm. (d) Is-OSC ning sxematik diagrammasi.

1-rasm. (e) Is-OSCs dastur imkoniyatlari

Its excellent optoelectronic properties and high compatibility with various small molecule acceptors (SMAs) and polymer acceptors (PAs) make PM6 a promising candidate for organic solar cells (OQEs). PM6 is a donor-acceptor polymer donor (PD) in which benzodithiophene (BDT) serves as the donor component, thiophene as the π- bridged element, and benzodithiophene-4,8-dione (BDD) as the acceptor unit (Fig. 1a) [7]. Fluorination of the PM6 polymer effectively lowers both of its energy levels, while leaving the optical bandgap largely unaffected. Compared to unfluorinated derivatives, PM6 deepens the highest occupied molecular orbital (HOMO) to −5.45 eV, which is favorable for high open circuit voltage (V_{OC}). Since its initial synthesis by Hou's group in 2015 [8], PM6 has attracted much attention due to its high crystallinity and flat molecular arrangement, which significantly improve its photovoltaic properties. The number average molecular weight of PM6 batches, which are widely used in high-efficiency organic solar cells (OQEs), is typically below 60 kg/mol. The fused aromatic rings (i.e., core bonds) in PM6 not only provide high mobility of charge carriers, but also impart rigidity to the material, which limits the ability of the polymer chains to deform under mechanical stress. As a result, the material becomes brittle and the elongation at break (COS) does not exceed 10%. In light of these issues, this review article focuses on recent advances in PM6-based photovoltaic films and provides a detailed analysis of the strategies and challenges related to their mechanical properties in the thin film state (Fig. 1b)[9]. We have reviewed the available polymer physics data on the mechanical behavior of photovoltaic polymers.

The introduction of various inorganic components into the three-dimensional structure of an organometallic perovskite allows to change its electronic properties, the contribution of organic cations to the electronic functionality of organometallic systems remains indirect. The diversity of combinations of organic and inorganic components opens up broad prospects for the creation of materials with tunable semiconducting properties, providing new opportunities for molecular functionalization and improving the level and excitation of charge carriers. Targeted control of the spatial distribution, characteristics of electron carriers and optical excitations allows to tailor the properties of materials for use in a wide range of applications. In addition, the development of layered structures with different sizes and two-dimensional perovskites helps to improve the tunable properties[10].

We begin our analysis with a physical blending strategy, which involves the integration of a third component, such as a configured or insulating polymer, into PM6-based blends. The goal of this approach is to enhance the intrinsic stretchability of photovoltaic films by fine-tuning the morphology. We investigate how these third components interact with PM6, how they affect the overall properties of the films, and how they contribute to the enhancement of stretchability and mechanical stress tolerance. We also consider examples of various structural modifications aimed at overcoming the inherent stiffness problem of the PM6 polymer backbone. Here, we review in detail the results of recent studies and specific examples that have shown that changes in the structure of PM6-based films can lead to significant improvements in mechanical properties. This expands the potential of these materials as stretchable materials. We also provide a detailed analysis of the predictive models developed to evaluate the mechanical properties of composite films with different compositions. By understanding the capabilities and limitations of these models, researchers can more accurately tailor materials and design strategies to achieve optimal elongation and device performance [11].

Finally, we identify key unresolved issues and propose possible solutions to overcome these obstacles to achieving intrinsic stretchability and high efficiency. By choosing PM6 as the main

model system, this analytical review serves as an excellent reference for researchers seeking to advance the field of wearable photovoltaics by integrating knowledge from materials science, structural design, and predictive modeling [12].

The incorporation of a third component that increases the bending ability to enhance the wear or flexibility of photovoltaic cells is one of the effective and widely used strategies to improve both the mechanical and photovoltaic properties of the active layer film. As mentioned in the introduction, advances in the field of small molecule acceptors (SMAs) have allowed the photoelectric conversion efficiency (PCE) of PM6-based organic solar cells (OSCs) to be increased by up to 20%. However, SMAs are typically planar, which enhances π-π interactions—which is beneficial for charge transport but detrimental for stretchability [9,10]. For example, the E group of configured polymers [13] demonstrated that a PEC of 16.7% and a COS of 9.3% were achieved by adding PC71BM to a PM6 blend. These results were achieved by modulating the molecular order, orientational texture, and phase separation. However, the mechanical properties of the blend are not promising due to the rigidity of the small molecules. Recently, donor polymers (PD) and acceptor polymers (PA) have been gaining much attention [14]. PD or PA-based photovoltaic films exhibit excellent stretchability due to their twisted molecular chains, which helps to enhance their mechanical strength.

The incorporation of configured polymers is highly effective as a third compound that increases the flexibility of photovoltaic cells, allowing the production of wearable and portable photovoltaic bags, photovoltaic shirts for deserts, and other products[14].

Despite their many advantages, organometallic perovskites face challenges related to their instability under conditions of humidity, heat, oxidation, and strong light. Water molecules easily penetrate the perovskite structure, forming intermediate hydrates and interacting with organic cations, which increases their vulnerability to heat and electric fields. Organometallic perovskites are also prone to decomposition under the influence of oxygen, and strong light promotes the release of ions, negatively affecting the stability of the structure. Problems related to the mobility and stability of ions under heat require further research and development of stabilization methods [15].

Conclusion

To move IS-OSC technology from the laboratory to commercialization, it is necessary to develop large-scale and cost-effective production technologies. Research should focus on optimizing solution processing methods, including technologies such as roll-to-roll printing and spray coating, which will allow for reduced production costs while maintaining high production efficiency. Addressing the issues of ensuring uniformity and reproducibility of these large-scale processes will be crucial for industrial implementation.

Looking ahead, ongoing research should continue to refine these strategies and explore new materials and methodologies. The balance between superior electrical properties and mechanical robustness is crucial for the development of PM6 and other advanced IS-OSCs, paving the way for more reliable and versatile applications in flexible and wearable electronics.

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