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Polysiloxanes for optoelectronic applications

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ABSTRACT

During the past few years, polysiloxanes have been extensively researched on optimizing the physical and electronic properties of organic polymer semiconductors. Polysiloxanes display their advantages including good solubility in common organic solvents, good film-forming ability, fair adhesion to various substrates and excellent resistance to thermal, chemical and irradiation degradations. In this review, we focus on the fundamental design and synthesis strategies of bonding polysiloxanes with organoelectronic groups. The characterization of polysiloxanes will be briefly introduced. Specifically, we summarize the recent advances of the utilization of polysiloxanes as organic light-emitting diodes (OLEDs), solar cells, electrical memories and liquid crystalline materials. Finally, several perspectives related to polysiloxanes materials for organoelectronic applications are proposed based on the reported progress and our own opinion.

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1. Introduction

Organoelectronic materials and devices have attracted much attention as an area of intense interest in both the academic and industrial communities, e.g. organic light emitting diodes (OLEDs) [1,2], photovoltaics (OPVs) [3], electrical memories [4,5] and liquid crystal display [6,7]. In the past years, numerous publications have appeared on the topic of organoelectronics. One of the aims for the extensive research is achieving high efficiency device for practical applications. Taking OLEDs for example, the ongoing study lies in high efficiencies, enhanced brightness, and longer lifetimes [8]. Many approaches have been used in attempts to improve the performance of organoelectronic devices, including improving the electronic and physical properties of the active materials [9], developing new deposition techniques [10], interfacial microstructure modification of multilayer-structured devices [11] and so on. Among them, it is a facile way to modify the electronic and physical properties of the active materials by rationally designing their chemical structures. As we known, tuning chemical structure can change its molecular interactions, energy levels, chemical stability and some other properties and can therefore optimize the electronic properties of the materials. Considerable efforts have been devoted to developing new organoelectronic materials, especially the polymeric ones, because of their advantages of low cost, light weight, solution-processability and in particular the flexibility.

Polysiloxanes are a fascinating class of organosilicon polymers possessing desirable properties, such as excellent heat, radiation or chemical resistance, good solubility in common organic solvents and film-forming ability, fair adhesion to various substrates, rather good nontoxic characteristic as well as fair mechanical properties [12]. In addition, generally polysiloxanes are known for their low dielectric constants. Taking these into account, the polysiloxane, when used as macromolecular skeleton for hanging functional groups, has the negligible impact on the electronic properties of the semiconductors. They can be used only to modulate the physical attributes of the final materials. Therefore, incorporation of active electronic materials onto or into polysiloxane main chains has been frequently applied to tune the solubility, intermolecular interactions, physical states, thermal and mechanical properties of organic semiconductors [13]. For examples, Strohriegl et al. [14] synthesized a side-chain carbazole polymer with a siloxane main chain (PSX), which displays the better performance than polyvinylcabazole, including greater conformational freedom, good solution processability and minimized excimer formation upon photoexcitation. Heeger et al. [15] have synthesized the polyhedral oligomeric silsesquioxanes (POSS)-anchored semiconducting MEH-PPV-POSS and PFO-POSS polymers. Comparing with the corresponding parent MEH-PPV and PFO polymers, the MEH-PPV-POSS and PFO-POSS have higher thermal stability and improved blue electroluminescent efficiency. Theato et al. [16] introduced poly(methylsilsesquioxane)-poly(N,N-di-4-methylphenylamino styrene) (PMSSQ-PTPA) as a potential hole-injection layer forming material. Spin-coating and thermally induced cross-linking resulted in an effective planarization of the anode interface. The obtained hole-injection material features a HOMO level of −5.6 eV and a hole mobility of 1×10^{-6} cm^2 V^{-1} s^{-1}. Donnio et al. [17] reported that various linear siloxane oligomers containing main-chain polymers liquid crystalline elastomers via direct hydrosilylation reaction. The mesomorphic properties of liquid crystal were nearly unchanged upon the replacement of a small ratio of the siloxane spacers by cross-linking segments to produce the elastomers. However, the length of siloxane spacer turns out to be an efficient and essential parameter to change the properties of elastomers.

In this review, the use of polysiloxanes or oligosiloxanes in organic electronic materials will be discussed and explored. The methods of incorporating siloxanes into the existing classes of organic semiconducting materials will be briefly covered. This will include popular and efficient coupling strategies to attach siloxanes to organic semiconductors as monomers and the subsequent polymerizations as well as some post-functionality of polysiloxanes. Specifically, examples about the application of polysiloxanes will be discussed in detail with a focus on OLEDs, solar cells, electrical memories and liquid crystals.

2. General synthetic methods and characterizations of polysiloxanes

There are several methods for synthesizing functional polysiloxanes, including post-functionalization of polysiloxanes and polymerization of siloxanes incorporated in organoelectronic groups as monomers. The post-functionalization of polysiloxanes is easy to realize. However, this strategy usually result in many defects because of incomplete functionality.