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Case Report

Surface Modification of Thermoplastic Polymers for Oligonucleotide Dip-Pen Nanolithography

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ABSTRACT

Dip-Pen Nanolithography (DPN) has revolutionized the precise patterning of biomolecules at the nanoscale, offering unprecedented opportunities in biotechnology and nanomedicine. However, the application of DPN on thermoplastic polymer surfaces has been hindered by challenges such as poor wetting properties and inefficient ink transfer. Surface modification techniques have emerged as a promising solution to enhance the compatibility of thermoplastic polymers with DPN, enabling precise deposition of oligonucleotides for various biotechnological applications. This review provides an overview of surface modification strategies tailored for thermoplastic polymer substrates, including chemical functionalization, physical modification, and the use of self-assembled monolayers and polymer brushes. Furthermore, we discuss the applications of oligonucleotide DPN on surface-modified thermoplastic polymers, such as DNA microarray fabrication, biosensing, and single-molecule studies. Challenges and future perspectives in optimizing surface modification strategies and advancing oligonucleotide DPN on thermoplastic polymer surfaces are also highlighted. Overall, surface modification of thermoplastic polymers holds great promise for expanding the capabilities of DPN, paving the way for new discoveries in biotechnology and nanomedicine.

Keywords: Dip-pen nanolithography (dpn), Thermoplastic polymers, Surface modification, Oligonucleotides, Biomolecular patterning, Nanoscale precision

INTRODUCTION

Dip-Pen Nanolithography (DPN) has emerged as a powerful technique for precisely patterning biomolecules, including oligonucleotides, onto surfaces with nanoscale resolution. However, the application of DPN on thermoplastic polymer surfaces has been limited due to challenges such as poor wetting properties and inefficient ink transfer. Surface modification techniques offer a promising avenue to enhance the compatibility of thermoplastic polymers with DPN, facilitating precise deposition of oligonucleotides for various biotechnological applications [1]. Dip-Pen Nanolithography (DPN) has emerged as a groundbreaking technique for precisely patterning biomolecules at the nanoscale, offering unparalleled potential in various fields such as biotechnology, nanomedicine, and materials science. This innovative method enables the direct deposition of molecules onto surfaces with sub-micrometer resolution, facilitating the creation of intricate patterns and structures for a wide range of applications [2, 3]. However, the application of DPN on thermoplastic polymer surfaces has been met with significant challenges, primarily due to the inherently hydrophobic nature of these materials, which leads to poor wetting properties and inefficient ink transfer [4]. Thermoplastic polymers, such as polystyrene, polyethylene, and polypropylene, are widely used in numerous industrial and biomedical applications due to their desirable mechanical properties, chemical resistance, and cost-effectiveness. However, their hydrophobic surfaces pose obstacles to the precise deposition of biomolecules via DPN, limiting their utility in biotechnological applications requiring nanoscale patterning. To overcome these challenges, researchers have focused on developing surface modification strategies tailored specifically for thermoplastic polymer substrates. By modifying the surface properties of these polymers, such as enhancing surface wettability and promoting ink adhesion, it becomes possible to achieve precise and reliable deposition of biomolecules, including oligonucleotides, via DPN [5, 6].

Surface modification strategies

A range of surface modification strategies has been developed to improve the wettability and ink transfer properties of thermoplastic polymer surfaces for DPN. Chemical functionalization methods

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involve the covalent attachment of functional groups, such as hydroxyl, amino, or carboxyl groups, onto the polymer surface through techniques like grafting or plasma treatment [7]. Physical modification approaches, including laser ablation and ion beam irradiation, alter the surface morphology and roughness to promote ink adhesion and transfer. Additionally, the use of self-assembled monolayers (SAMs) and polymer brushes provides a versatile platform for controlling surface chemistry and enhancing molecular immobilization.

Applications in oligonucleotide dpn

Surface-modified thermoplastic polymer substrates enable precise patterning of oligonucleotides via DPN for various biotechnological applications. These include the fabrication of DNA microarrays, biosensors, and biochips for genomics, proteomics, and diagnostic purposes [8, 9]. Oligonucleotide DPN on thermoplastic polymer surfaces offers advantages such as scalability, reproducibility, and compatibility with multiplexed assays. Moreover, the ability to pattern oligonucleotides with nanoscale precision facilitates the study of biomolecular interactions and cellular processes at the single-molecule level [10].

CONCLUSION

Through chemical functionalization, physical modification, and the use of self-assembled monolayers (SAMs) and polymer brushes, researchers have successfully tailored the surface properties of thermoplastic polymers to enhance surface wettability, promote ink adhesion, and improve ink transfer efficiency. These surface modification strategies have paved the way for the fabrication of DNA microarrays, biosensors, and biochips for genomics, proteomics, and diagnostic applications. Additionally, the ability to pattern oligonucleotides with nanoscale precision has enabled the study of biomolecular interactions, cellular processes, and disease mechanisms at the single-molecule level, offering unprecedented insights into biological systems. Despite the significant advancements achieved in surface modification and oligonucleotide DPN on thermoplastic polymer surfaces, several challenges and opportunities for future research remain. Challenges include optimizing surface modification techniques to achieve uniform and reproducible surface functionalization, minimizing nonspecific adsorption, and improving ink stability and transfer efficiency. Furthermore, the development of novel surface modification approaches, such as gradient patterning and nanoparticle functionalization, may further enhance the performance and versatility of thermoplastic polymer substrates for oligonucleotide DPN.

DISCUSSION

The surface modification of thermoplastic polymers for oligonucleotide Dip-Pen Nanolithography (DPN) represents a crucial step towards enabling precise and reliable biomolecular patterning on hydrophobic substrates. In this discussion, we delve into the significance of surface modification techniques, their impact on DPN performance, current challenges, and future directions in the field.

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