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# 聚合物光波导薄膜的制备和改性研究

# Development and Modification Study of Polymer Optical Waveguide Thin Films

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# Development and Modification Study of Polymer Optical waveguide thin films

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# 摘　要

近年来，随着光通信和集成光学研究的飞速发展，薄膜光波导被广泛应用于光无源器件和集成光路中，利用它可以完成开关、调制、复接等许多光作用,各种光集成结构都是围绕光波导而展开的，光波导制备的技术也由于薄膜光波导的广泛应用而飞速发展。聚合物波导因为制作工艺简单、价格低廉、容易和半导体器件和光纤集成等优点，将在上述领域发挥巨大的作用。因此，研制成本低且性能优良的聚合物薄膜及其光波导，对于聚合物薄膜光波导及其器件的研究和实用化有着重要的理论意义和实践意义。

本文简述了平面光波导理论和平面光波导材料的研究现况，并比较了各种平面光波导制备工艺的特性，特别详细地介绍了溶胶－凝胶法制备薄膜的特点及其工艺流程。论文工作主要研究利用无机纳米颗粒改性甲基丙烯酸甲酯预聚物（PMMA）的制备工艺以及聚合物光波导薄膜的各种物化和光学性能。采用纳米颗粒掺杂和旋涂技术，旨在提高 PMMA 薄膜材料的热稳定性，并通过优化实验工艺条件使光波导薄膜达到透明、均匀、致密及无气孔的要求，从而降低其光损耗。实际利用两种聚合物合成改性手段，采用不同的工艺条件和材料配比，制备了纳米 $SiO_2$ 和 $TiO_2$ 颗粒掺杂改性的 PMMA 溶胶，并利用旋涂法在基片上甩制了纳米改性的 PMMA 光波导薄膜。利用各种先进的测试手段对其进行了性能测量和表征分析，结果表明，纳米 $SiO_2$ 颗粒能够大幅度地提高 PMMA 光波导层的热稳定性和 Tg，使其有望在更高的工作温度下正常使用。而纳米 $TiO_2$ 颗粒使其折射率有显著的提高，为聚合物光波导选择折射率匹配的包层材料提供更多的灵活性。同时，对拟作为波导芯层的 PMMA 和包层的硅橡胶（PDMS）薄膜的单层和多层制备进行了实验研究和理论分析，在表面形貌、薄膜折射率和厚度、热稳定性和透

光率等各方面展开了一系列深入的探讨，将宏观结果与微观分析结合起来，从而得到了许多有一定实际意义和参考价值的结论。

**关键词：**聚合物光波导;薄膜;纳米改性;热稳定性;折射率;光损耗

# Abstract

Recently, with the great development of research in optical communication and integrated-optics, optical waveguide thin films are applied widely in the optical passive device and optical integrated-circuit, which can implement many optical functions including switching, modulating and compound-meeing etc.. Various optical integrated configurations are made of optical waveguides, and the preparation technology of optical waveguides develops very quickly with the wide use of thin film optical waveguides. Polymer waveguides will play a important role in the above-mentioned realm, because the manufacture process is very simple, the price is low and the coupling with semi-conductor devices and optical fibers is more easy etc. Therefore, it is very important, not only in theory but in practice to develop thin film optical waveguides that prepare optical thin film with low cost and good performance.

In this paper, the theory of planar optical waveguides was represented briefly and various preparation techniques of planar optical waveguides are compared, specially introducing in detail the characteristic and process of thin films preparated by Sol-Gel. The modification process of PMMA with inorganic nano-particles and various physical chemistry and optical performance of polymer optical waveguide thin films are mainly studied here. By taking the film spinning technology and the mechanic-mixing modification process with nano-particals, the paper work aims at improving the thermal stability and the refractive index of PMMA, and making its optical waveguide thin-films with well-distributed compact and less-blister for the light loss will be reduced. We have utilized two kinds of compound modification process of polymer materials, and have prepared PMMA complex material mixed by sol nano-silicon dioxide as well as sol nano-titanium dioxide with different processes and material formula. The polymer optical waveguide thin-films which mixed by inorganic

nano-particles have been prepared, and their configuration and properties are observed and analyzed by various advanced measurement technologies. The results show that nano-silicon dioxide can improve PMMA's thermal stability as well as Tg greatly, as we expected, the polymer thin-films will be used in more higher temperature of operation. Nano-titanium dioxide can increase the refractive index of PMMA, so we can take more choices of clad materials which matched with polymer optical waveguide in refractive index. At same time, we engaged in the research and theoretic analysis on preparation of single and multi-layer polymer thin films. Further study on the thin-films' surface appearance, refractive index, thickness, thermal stability and light transmission rate etc. under different spinning conditions and preparation processes of polymer materials has been done. Thus, lots of practical and referenced results are concluded by combining the macroscopical results with microcosmic analysis.

**Keywords:** Polymer Optical waveguides; thin-films; Nano-modification; Thermal Stability; Refractive index; light loss

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