Correlation of light-electron interactions and structural changes in fused regions of polymer optical fibers for optical sensing applications

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Source LASER PHYSICS

View Journal Impact

Volume: 36 Issue: 2

DOI: 10.1088/1555-6611/ae4194

Article Number 025104

Published FEB 27 2026

Indexed 2026-02-17

Document Type Article

Abstract

Polymer optical fibers (POFs) are increasingly utilized in optical sensing due to their mechanical flexibility and low fabrication cost. However, the effect of thermal fusion on their photophysical properties remains inadequately understood. This study investigates the correlation between fusion-induced structural modifications and light-electron interactions in step-index POFs fabricated from polymethyl methacrylate (PMMA). Fiber segments were subjected to controlled thermal fusion. Comprehensive optical characterization was performed on fused and non-fused fibers, including UV-VIS absorbance, transmission, and reflection spectroscopy, fluorescence emission analysis, and optical band gap estimation via Tauc plots employing the Kubelka-Munk function. Fused fibers exhibited significantly increased absorbance, decreased transmission, and enhanced reflection relative to controls, indicative of refractive index modulation and defect formation at the fused interface. Fluorescence spectra revealed a pronounced red shift from approximately 632 nm to 651 nm, accompanied by a strong enhancement in emission intensity, indicative of defect-assisted radiative recombination pathways formed during fusion. These fusion-induced optical responses enable the fused region to function as a localized sensing element in multiple configurations. Intensity-modulated sensing can be realized through fusion-induced absorption and scattering changes that respond to external perturbations such as mechanical deformation or refractive index variations. Fluorescence-based sensing modes may exploit defect-assisted emission intensity and wavelength shifts under fixed optical excitation, while enhanced reflectance at the fused junction supports reflectometric sensing schemes sensitive to surface or interfacial changes. These findings establish a direct relationship between thermal processing and photonic behavior in PMMA-based POFs, providing a physically grounded framework for the development of tunable POF sensing platforms.

Keywords

Author Keywords: polymer optical fiber (POF); fused region characterization; light-electron interactions; optical band gap narrowing; Tauc plot (Kubelka-Munk method); defect state formation; optical sensing

Keywords Plus: MECHANICAL-PROPERTIES; HEAT-TREATMENT; FABRICATION

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Categories/ Classification

Research Areas: Optics; Physics

Citation Topics: 5 Physics › 5.38 Optical Electronics & Engineering › 5.38.232 Fiber Optic Sensors

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Optics; Physics, Applied

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