

UNIVERSITI TEKNOLOGI MARA

**PMMA POLYMER MICROFIBER
DOPED WITH POLYANILINE AND
MULTI-WALLED CARBON
NANOTUBES FOR SENSING
APPLICATION**

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ABSTRACT

Microfiber sensors have gained significant attention in research activities owing to their distinctive properties and broad applicability across various applications. Among the many types of microfiber sensors, polymer-based microfibers present numerous advantages, including biodegradability. This thesis focus on the exploration of functionalized polymer microfibers, with an aim on employing polymethyl methacrylate (PMMA) as the polymer host for incorporating functional materials such as Polyaniline (PANI) and Multi-Walled Carbon Nanotubes (MWCNT). The primary objectives encompass the fabrication of PMMA polymer-based microfibers through direct drawing techniques and the investigation of the influence of incorporated materials on the performance of PMMA microfiber sensors. Specifically, the study aims to assess the sensors' efficacy in detecting changes in environmental conditions, namely humidity, temperature, and alcohol solutions. The fabrication process involves the direct drawing technique to produce PMMA polymer-based microfibers with diameters below 10 μm . Functionalization of PMMA with PANi and MWCNTs is achieved through doping techniques. The evaluation procedures include exposing the fabricated sensors to varying concentrations of alcohol solutions from 2% to 10% for methanol, ethanol, and propanol. Meanwhile, for humidity levels, the range is from 45% to 80% of relative humidity (RH), and the temperature range is from 30 $^{\circ}\text{C}$ to 75 $^{\circ}\text{C}$. The changes in spectrum power are measured using an Optical Spectrum Analyzer to evaluate sensor response. The findings show that PANI-doped PMMA microfibers exhibit the most sensitivity to changes in alcohol solution concentrations compared to undoped PMMA and MWCNTs-doped PMMA counterparts. Field emission scanning electron microscopy (FESEM) confirms successful PANI doping, revealing its role in enhancing sensor performance. In humidity sensing, MWCNTs-doped PMMA microfibers demonstrate superior sensitivity, surpassing both PANI-doped and undoped PMMA microfiber sensors. Similarly, MWCNTs-doped PMMA polymer microfiber performs the best sensitivity in temperature sensing. However, the maximum limit of temperature sensing is up to 75 $^{\circ}\text{C}$ as the PMMA polymer microfiber starts to swell when exposed to higher temperatures. The findings highlight the ability of PANI to be incorporated in PMMA microfiber and applied in alcohol sensing applications and the potential of MWCNTs for increasing the potential of PMMA microfiber in humidity and temperature sensing. The successful fabrication of sensors through direct drawing techniques highlights the feasibility of incorporating functional materials into PMMA microfibers for enhanced sensing capabilities. These results indicate promising avenues for the development of advanced microfiber sensors tailored for ambient environmental monitoring.

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CHAPTER 1

INTRODUCTION

1.1 Research Background

The advancement of optical technology has transformed various aspects of modern life, including communication, data transmission, and internet speeds, ultimately enhancing connectivity and information exchange. This progress in optical technology has revolutionized the way we communicate, access information, and connect with the world. Additionally, optical technology, such as optical fiber sensors, is widely applied in various fields, including healthcare, industry, and daily life, contributing to improved quality of life by enabling better health monitoring, advanced industrial systems, and enhanced everyday experiences [1]–[3]. Optical fiber sensors offer inherent benefits including their lightweight and compact nature, chemical stability, and resistance to electromagnetic interference.

Prior research has found that reducing the diameter of an optical sensing probe is typically necessary to produce a faster response, higher sensitivity, reduced power consumption, and improved spatial resolution [4]. This type of microscale waveguide guides light with low optical loss, exceptional mechanical flexibilities, tight optical confinement, and large fractional evanescent fields, making it a novel miniaturized platform for optical sensing with special advantages including faster response, higher sensitivity, and low power consumption [5]. This is due to the high-index contrast between the microfiber material and the surroundings.

Due to their chemical specificities, low cost, mechanical flexibility, adjustable properties and ease of fabrication and integration, polymer-based optical microfibers have higher opportunities in the development and advancement of optical sensors in the fast-growing sectors [6]. Polymer-based microfibers have been fabricated using a variety of methods [7], including chemical synthesis, nanolithography, electrospinning, and mechanical drawing. Nanolithography and chemical synthesis are very complex processes that require expensive equipment. Unfortunately, electrospinning cannot be used to make a single microfiber structure and is only suitable for making microfiber