

Effect of Tapered Fiber Diameter and MoS₂ Coating Concentration on Sensitivity of Humidity Sensor

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Abstract

This study investigates the influence of tapered optical fiber diameter and MoS₂ concentration on the sensitivity of optical humidity sensors fabricated using the heat-and-pull method. Optical fibers with tapered diameters of 3 μm , 5 μm , and 7 μm were analyzed under varying humidity levels (40%, 50%, and 60%). Additionally, the effect of different MoS₂ concentrations 2 μL , and 4 μL coated on the fiber surface was examined for each diameter. Experimental results demonstrate that smaller fiber diameters yield significantly higher sensitivity, with the 3 μm fiber showing the greatest power response at all humidity levels, with up to 35.07% more sensitivity at 40% humidity compared to 7 μm fibers. Furthermore, increasing MoS₂ concentration enhances the sensor response across all diameters, with the 4 μL concentration consistently delivering the highest power output. For example, at 40% humidity, a 4 μL concentration on a 7 μm fiber produced an 18.89% increase in sensitivity compared to an uncoated fiber.

1. Introduction

Optical fibers have a wide range of applications across various fields due to their unique ability to transmit light with minimal loss. In telecommunications, optical fibers are extensively used for long-distance data transmission, offering high bandwidth and low signal attenuation [1], [2]. Beyond telecommunications, optical fibers play a crucial role in the medical and healthcare sectors, where they are integrated into devices such as endoscopes and laparoscopes. These instruments enable minimally invasive procedures and real-time diagnosis, thereby enhancing patient care and reducing recovery time [3].

In addition to data transmission and medical imaging, optical fibers are increasingly employed in sensing applications, including temperature, pressure, and humidity monitoring. Their small size, flexibility, and high sensitivity make them ideal candidates for integration into compact sensing systems used in healthcare, environmental monitoring, and industrial diagnostics. A key feature of optical fiber sensors is their ability to detect changes in the surrounding medium through variations in the refractive index. In biosensing, for instance, optical fibers serve as transducers that detect the binding of specific biomolecules such as proteins or DNA to the fiber surface. These interactions alter the refractive index near the fiber, which in turn affects the propagation of light, allowing detection of biological events with high precision.

To further enhance the sensitivity of optical fiber sensors, modifications to the fiber's geometry and the application of nanomaterial coatings have been widely studied [4]. Coating materials with tailored refractive indices can reduce reflection losses at the fiber-medium interface and increase the depth of the evanescent field, thereby improving the interaction between the guided light and the surrounding environment. This leads to more responsive and accurate sensing capabilities [4].

2. Results and Discussion

Figure 1 presents the output power measured at different humidity levels (40%–60%) for three tapered fiber diameters: 3 μm , 5 μm , and 7 μm . As observed, the 3 μm diameter fiber exhibits the highest output power across all humidity conditions, indicating superior sensitivity. The 5 μm and 7 μm fibers show progressively



lower responses, highlighting the effect of reduced diameter on enhancing the evanescent field interaction. The sensitivity of tapered optical fiber increased 8.67% for 5 and 7 μm tapered optical fiber (TOF) size diameter. By reducing the size diameter TOF, 3 μm has 35.07% increase in sensitivity.

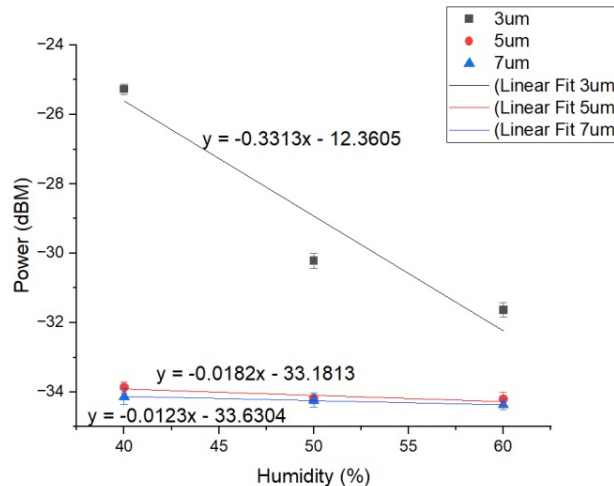


Figure 1. Output power for various diameter sizes of tapered optical fiber.

Next, the experiment will compare the performance different size diameter of TOF (3, 5 and 7 μm) for non-coated and coated with MoS_2 . For all tapered diameters tested (3 μm , 5 μm , and 7 μm), the application of MoS_2 coatings enhanced the optical fiber's sensitivity to humidity. At every humidity level (40%, 50%, and 60%), fibers coated with 4 μL of MoS_2 exhibited the highest output power (dBm) compared to 2 μL and uncoated fibers. While output power (dBm) itself may not directly indicate sensing accuracy, in this study, increased output power corresponds with enhanced signal variation in response to humidity, which reflects improved sensitivity. Specifically, at 60% humidity, the sensitivity increased by 0.56%, 2.73%, and 4.34% for 4 μL concentration compared to uncoated fibers of 7 μm , 3 μm , and 5 μm diameter, respectively. Similarly, at 50% humidity, sensitivity gains reached 10.69%, 5.77%, and 5.96% for the respective diameters, while at 40% humidity, the enhancements were most pronounced up to 18.89% for the 5 μm fiber. While 4 μL MoS_2 coating generally improves sensor performance, the results indicate that 2 μL does not always outperform uncoated fibers, particularly for 3 μm and 7 μm diameters. Therefore, the effect of MoS_2 concentration on sensitivity is also influenced by the tapered fiber diameter as shown in Figure 2.

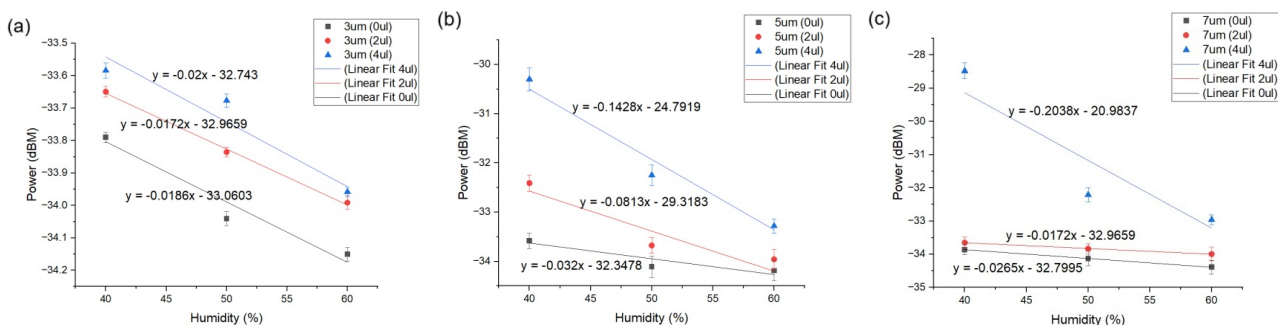


Figure 2. TOF performance for uncoated and coated with MoS_2 for various size diameters. (a) 3 μm TOF, (b) 5 μm TOF, and (c) 7 μm TOF

Smaller tapered fiber diameters, especially 3 μm , significantly enhance humidity sensitivity. MoS_2 coating improves performance, though its effect depends on fiber size. Optimizing both diameter and coating is key for high-efficiency optical sensors.

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