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# Experimental Study of Polymethyl Methacrylate (PMMA) and Polyvinyl Alcohol (PVA) Coating of Taper Microfiber for Sodium Hypochlorite Liquid Sensing

***Abstract**. The research explained the effect of coating polymethyl methacrylate (PMMA) and polyvinyl alcohol (PVA) of tapered microfiber as sodium hypochlorite liquid sensors. The taper microfiber was designated using a technique known as "flame brushing" from SMF-28 silica fiber. The parameter for the size of taper microfiber is named as a middle diameter $D_m$ and length diameter $D_l$. The taper microfiber was then coated with PMMA and PVA, respectively. The sodium hypochlorite concentration ranges from 1% ppm to 6% ppm. The liquid was then used with coating and non-coating taper microfiber as sodium hypochlorite sensors for analysis purposes. The coating and non-coating taper microfiber's performance as a sensor is defined by sensitivity, linearity stability, and repeatability results. The results show that the taper microfiber's sensitivity and linearity achieve >1.0 dB/% ppm and linearity >90%, respectively. The stability and repeatability showed promising performance of all taper microfiber conditions.*

***Streszczenie.** Badania wyjaśniły wpływ powlekania polimetakrylanu metylu (PMMA) i alkoholu poliwinylowego (PVA) stożkowej mikrofibry jako czujników cieczy podchlorynu sodu. Mikrofibra stożkowa została wyznaczona przy użyciu techniki znanej jako "szczotkowanie płomieniowe" z włókna krzemionkowego SMF-28. Parametr wielkości mikrofibry stożkowej jest nazywany jako średnica średniej średnicy $D_m$ i średnica długości $D_l$. Mikrofibra stożkowa została następnie pokryta odpowiednio PMMA i PVA. Stężenie podchlorynu sodu waha się od 1% ppm do 6% ppm. Ciecz została następnie użyta z powłoką i niepowlekającą mikrofibrą stożkową jako czujniki podchlorynu sodu do celów analitycznych. Wydajność mikrofibry stożkowej powłoki i stożka niepowłokowego jako czujnika zależy od czułości, stabilności liniowości i powtarzalności wyników. Wyniki pokazują, że czułość i liniowość mikrofibry stożkowej osiągają odpowiednio >1,0 dB / % ppm, a liniowość >90%. Stabilność i powtarzalność wykazały obiecującą wydajność wszystkich warunków stożkowej mikrofibry. (**Badania eksperymentalne powłoki polimetakrylanu metylu (PMMA) i polialkoholu winylowego (PVA) stożkowej mikrofibry do wykrywania cieczy podchlorynem sodu**)*

**Keywords:** Taper Microfiber, PMMA, PVA, Sodium Hypochlorite Liquid Sensing, microfiber sensor
**Słowa kluczowe:** Mikrofibra stożkowa, PMMA, PVA, czujnik cieczy podchlorynu sodu, czujnik z mikrofibry

## Introduction

Microfiber recently captured interest due to promising performance in applications such as sensors, laser, amplifier and plasmonic devices [1-4]. Small in sizes, flexible structural, least electromagnetic interference and ability to perform well in high temperature become a reason to be used in recent technology [5-7]. Hence, it has been used with micro optical resonators as part of experimental procedures such as microbottle, microloop and microring resonator [8-12]. High insensitivity and almost perfect performance percentage are shown by taper microfiber as a sensor as an additional reason to keep this fiber structure used until today [13, 14]. Taper microfiber works depend on transmitted light inside the fiber core, leading to an evanescence field and sensing mechanism [11, 15]. The evanescence field disperses around the tapered area and senses every molecule in the particular area [16]. Therefore, it may produce different transmitted output power by tapered microfiber on the final stage and be sensing results [17].

This paper advocated using PVA and PMMA coating with tapered microfiber for sodium hypochlorite sensors. The PMMA is a transparent thermoplastic that happens to be used as a shatter-resistant alternative to glass. The PVA is commonly used in medical applications based on the low tendency for protein adhesion and low toxicity. Based on previous research, these two materials have the potential to increase taper microfiber performance as sodium hypochlorite liquid sensors [10, 18]. Sodium hypochlorite is a chemical compound widely used as a bleaching liquid [19]. It is known as hypochlorous acid with a chemical formula of NaOCl or NaClO. Hence, it was the oldest and most popular bleach liquid with chlorine-based [20]. However, in solution form, the corrosive properties were high and may increase a safety risk while handling. The potential of the bleaching performance is based on the concentration percentage. Due to this reason, taper microfiber seems to have the most suitable to be used as a sodium hypochlorite sensor. Hence, non-other previous research used fiber optic as sodium hypochlorite sensor to be found.

The taper microfiber is structured using a well-known "flame brushing" technique and coated with PMMA and PVA using the "drop-casting" procedure, as shown in **Fig. 1**. The sodium hypochlorite concentration was used from 1% ppm to 6% ppm for entire microfiber conditions. Furthermore, sensitivity, linearity, stability and repeatability is measured. The measurement is used to evaluate the performance of non-coating, PVA-coating and PMMA-coating microfiber as sodium hypochlorite concentration sensors.

The taper microfiber is obtained from SMF-28 standard silica fiber using a "flame brushing" technique [21]. The silica fiber holds on both the left and right sides, where the flame heats the middle area of fiber [22]. The fiber was pulled backwards, and the heating area slowly decreased to the dimeter of 3μm. Fig. 2 show the taper microfiber structure with three parameter named as middle diameter $D_m$ and length diameterr $D_l$.

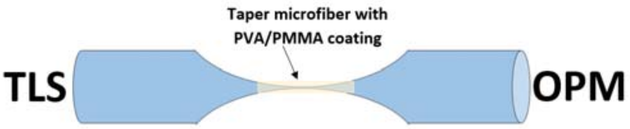

Fig. 1: The taper microfiber coating with PVA and PMMA.

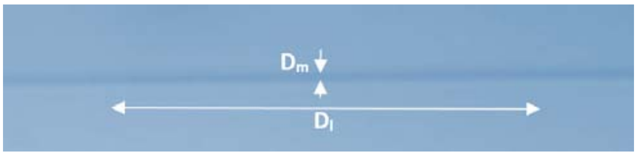

Fig. 2: Sample fabricated taper microfiber of Dm = 3.0 µm and Dl = 240 µm

**Performance of taper microfiber as sodium hypochlorite sensor**

Fig. 3 showed an experiment setup using non-coating, PVA-coating and PMMA-coating for sodium hypochlorite concentrations sensor. The taper microfiber soaked inside sodium hypochlorite liquid with one end of fiber connected to tunable laser source (TLS) and another connected to the optical power meter (OPM) for wavelength supplied and power measurement. The TLS was set a wavelength at 1550 nm for all conditions of taper microfiber. The liquid concentration of sodium hypochlorite then changed from 1% ppm to 6% ppm, and transmitted output power is then examined for every concentrations level. Fig 4 show the wavelength shift and repeatability of three conditions of taper microfiber. Every concentration produced a different wave peak and led to wavelength shift for non-coating, PVA-coating and PMMA-coating. The non-coating taper microfiber manages to have shifted from 1550.5 nm to 1551 nm, while PVA-coating is from 1550.4 nm to 1551.3 nm and PMMA-coating is from 1550.3 nm to 1551.8 nm. The results are obtained because of the adsorption concept, where the microfiber interaction with the liquid particle is always different on every liquid concentration percentage. It is proved that the microfiber, either coating or non-coating excellent to be sodium hypochlorite concentration sensor.

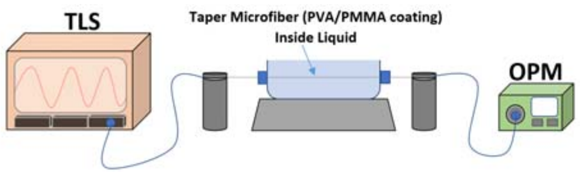

Fig 3: The non-coating, PVA-coating and PMMA-coating taper microfiber for sodium hypochlorite sensing. The tunable laser source and optical power meter were used to supply wavelength and collected output transmitted power.

Fig. 4 likewise showed repeatability results for all microfiber conditions where the sensitivity and linearity are defined in every repetition cycle. All taper microfiber experienced three times repetition cycle to reduce random error during data collection. The transmitted power was reduced over the liquid concentration percentage. It is due to the taper microfiber's adsorption, which increased power losses per unit and increased liquid concentration level. The PMMA-coating manages to have the highest sensitivity and linearity results, with sensitivity >2.0 dB/%ppm and linearity >97%, respectively. In contrast, non-coating and PVA-coating taper microfiber have sensitivity >1.2 dB/%ppm and >1.9 dB/%ppm, where overall linearity is>90%.

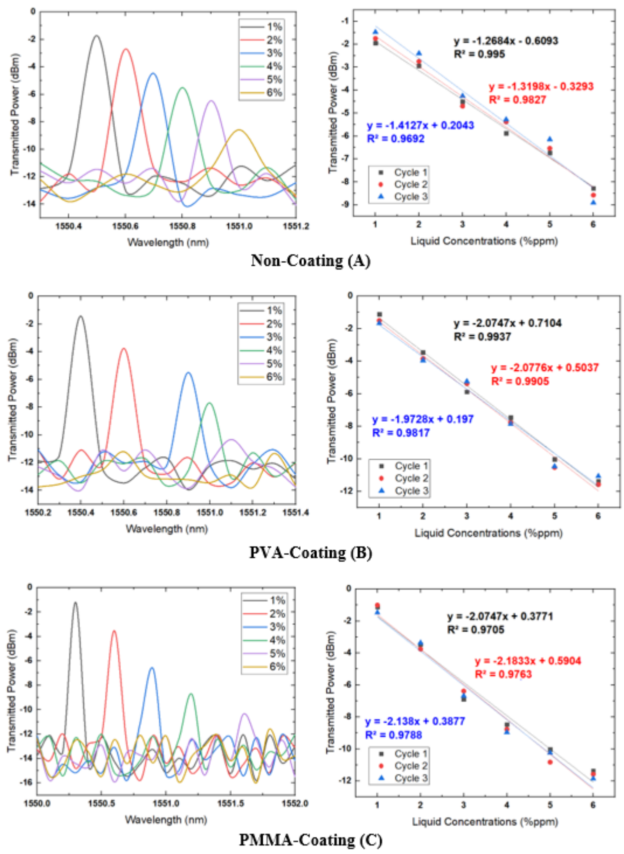

Fig. 4: The wavelength shifts and repeatability for non-coating, PVA-coating and PMMA-coating taper microfiber for sodium hypochlorite sensing.

Fig. 5 below shows the averaging value from the repeatability test by non-coating, PVA-coating and PMMA-coating taper microfiber for sodium hypochlorite sensing. The transmitted power decreased per unit increased of liquid concentration percentage. The PMMA-coating taper microfiber (C) managed to have higher sensitivity of 2.132 dB/%ppm than PVA-coating (B) with 2.0417 dB/%ppm and non-coating (A) with 1.3336 dB/%ppm. B's linearity is 98.32%, higher than A, 97.25% and C, with 95.62%. It is due to the tabulated data shown on every cycle. However, to ensure the PMMA-coating performed better than the others, the sensitivity and linearity results should be considered from the wavelength shift graph shown in Fig. 6. The wavelength shift increased when the liquid concentration changed to a high percentage. The sensitivity and linearity define from the slope value of wavelength shift with different percentages of liquid concentration. The PMMA-coating (A) remained higher in sensitivity of 3.0 pm/%ppm and linearity 99.16%, which is more than PVA-coating and non-coating taper microfiber. PVA-coating manages to have 1.7 pm/%ppm with 93.97% for sensitivity and linearity. Compared with non-coating, only have 1.0 pm/%ppm with 81.25%.

Fig. 7 showed the stability test of non-coating, PVA-coating and PMMA-coating taper microfiber for sodium hypochlorite sensing. The data was taken for 60 minutes, 3% ppm of sodium hypochlorite, where 60 different transmitted power were recorded. The stability test is conducted to optimize the performance of all taper microfiber as a sensor. Based on the tubulated date in Fig. 7, all taper microfiber showed slightly similar performance in 60 minutes. It is because the microfiber's size is less than 5µm which acquire more intention on handling.

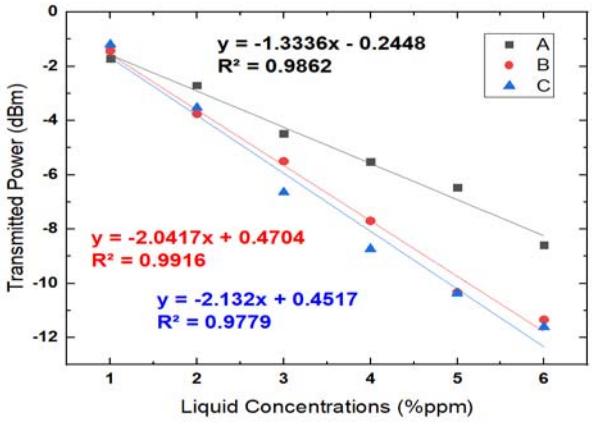


Fig. 5: The sensitivity and linearity of non-coating (A), PVA-coating (B) and PMMA-coating (C) taper microfiber for sodium hypochlorite sensing.

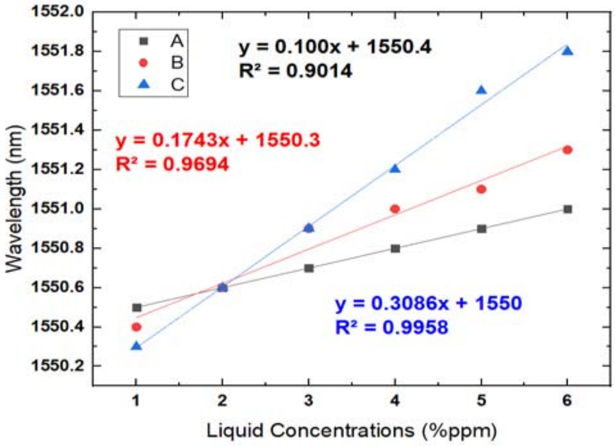


Fig. 6: The sensitivity and linearity from wavelength shifts for all taper microfiber

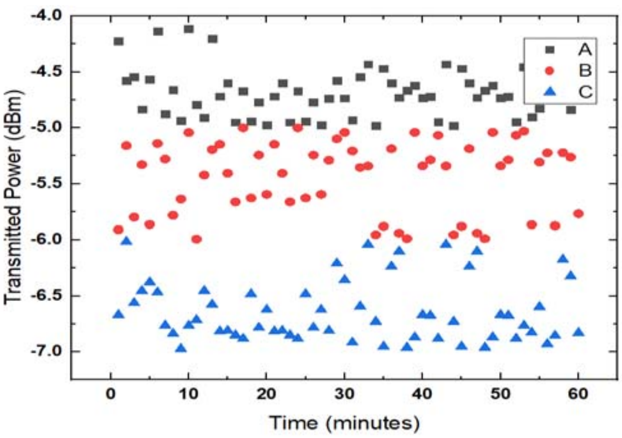


Fig. 7: The stability results of all taper microfiber for sodium hypochlorite sensor.

## Conclusion

This research paper studied the effect of PVA and PMMA coating on taper microfiber for sodium hypochlorite concentration sensors. The taper microfiber was formed using a method known as "flame brushing" from SMF-28 silica fiber with parameters as middle diameter $D_m$ and length diameter $D_l$. The taper microfiber is then coated with PVA and PMMA using a method known as "drop-casting". The sodium hypochlorite concentration used is from 1% to 6% ppm and tasted for non-coating, PVA-coating and PMMA-coating taper microfiber. The sensitivity, linearity, stability and repeatability results are compared for all taper microfiber. The PMMA-coating microfiber is more excellent than PVA-coating and non-coating taper microfiber. To optimize the performance and reduce random error, non-coating, PVA-coating, and PMMA-coating taper microfiber experienced three-time repetition and stability tests.

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