# A tilted fiber Bragg grating pH sensor coated with polyaniline

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## Introduction

Potential of hydrogen (pH) value is an important index to measure the degree of acidity and alkalinity of a solution. It plays a very important role in many biochemical and chemical reactions. Polyaniline (PANI) is a widely used conductive polymer, which is easy to synthesize and has excellent chemical stability, unique optical and electrical properties. At different external pH value, PANI presents different oxidizing and reducing properties. TFBG is a short period fiber grating. Compared with FBGs, the grating planes of the TFBGs is tilted respect to the fiber axis. As a result, they cannot only couple the light from forward propagating core mode to backward propagating core mode as normal FBGs do, but also couple the forward propagating core mode to backward propagating cladding modes. This makes them more advantageous than normal FBGs in sensing applications as the exited cladding mode resonances in TFBGs are sensitive to surrounding refractive index. In this work, a pH sensor combined with polyaniline is proposed and experimentally demonstrated. As a result, the external pH value measurement is successfully achieved within a range from 2 to 11.2 by monitoring extinction ratio of cladding mode resonance. PANI-TFBG pH sensors can be used in a variety of fields, such as medical[5], biological monitoring, and pipeline corrosion monitoring.

## Experiment

In the experiment, the TFBGs was manufactured by using phase mask method in standard single mode fiber (SMF-28 Corning telecom fiber, with high-pressure hydrogen loading for two weeks) with a 248 nm UV excimer laser (BraggStar200, Tuilaser Corp. Munich, Germany). Light in the C+L band(1510nm-1610nm) from a broadband source (BBS, A0002 from HaoYuan Photoelectric Corp. Shenzhen. China) is launched into the sensing TFBG and its transmission spectrum is monitored by an optical spectrum analyzer (OSA, AQ6370 from Tokogawa, Tokyo, Japan) with a wavelength resolution of 0.02 nm and an amplitude resolution of 0.02 dB. A linear polarizer and polarization controller (PC) are placed upstream of the TFBG to control and orient the state of polarization of the light launched into the fiber grating.

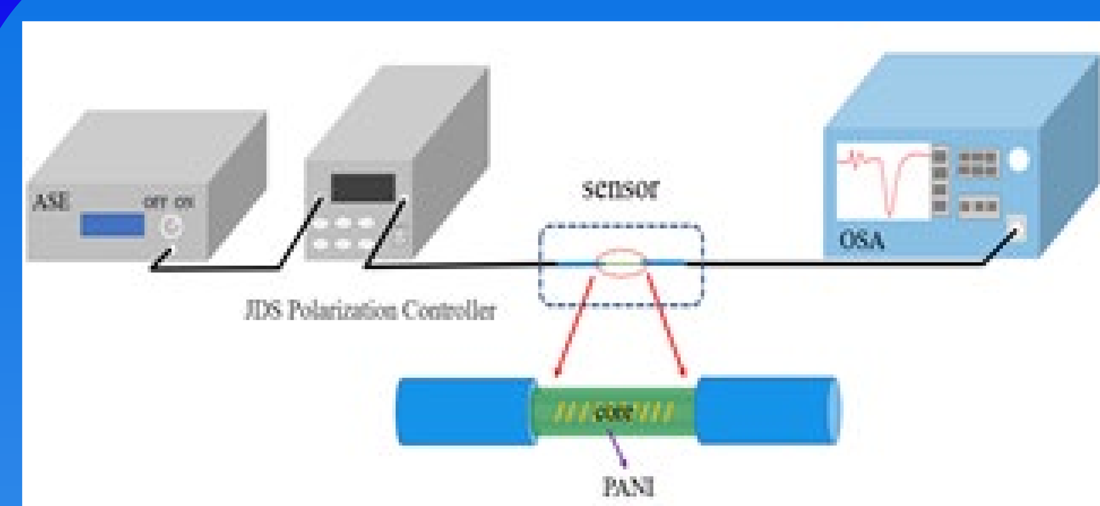


Figure 1. Schematic diagram of the experimental set-up of fiber optic pH sensor.

## Result and Discussion

The optical fiber coating process was monitored by the OSA. With the increase of deposition time, the thickness of PANI grows gradually. Thus the external refractive index of the TFBG becomes higher, resulting in more resonant cladding modes coupled to the external medium. The spectral comb decreased significantly and has a red drift.

In the process of pH detecting, we found that the thickness of PANI deposition is the most important parameter affecting the sensitivity. So, we used different thickness of PANI (different deposition time） coated onto 6° TFBG and the test result is shown in Fig.2 (a). It demonstrates that the thicker the PANI (about 20 dB of spectral compression when depositing), the higher the sensitivity of the sensor.

(a)

(b)

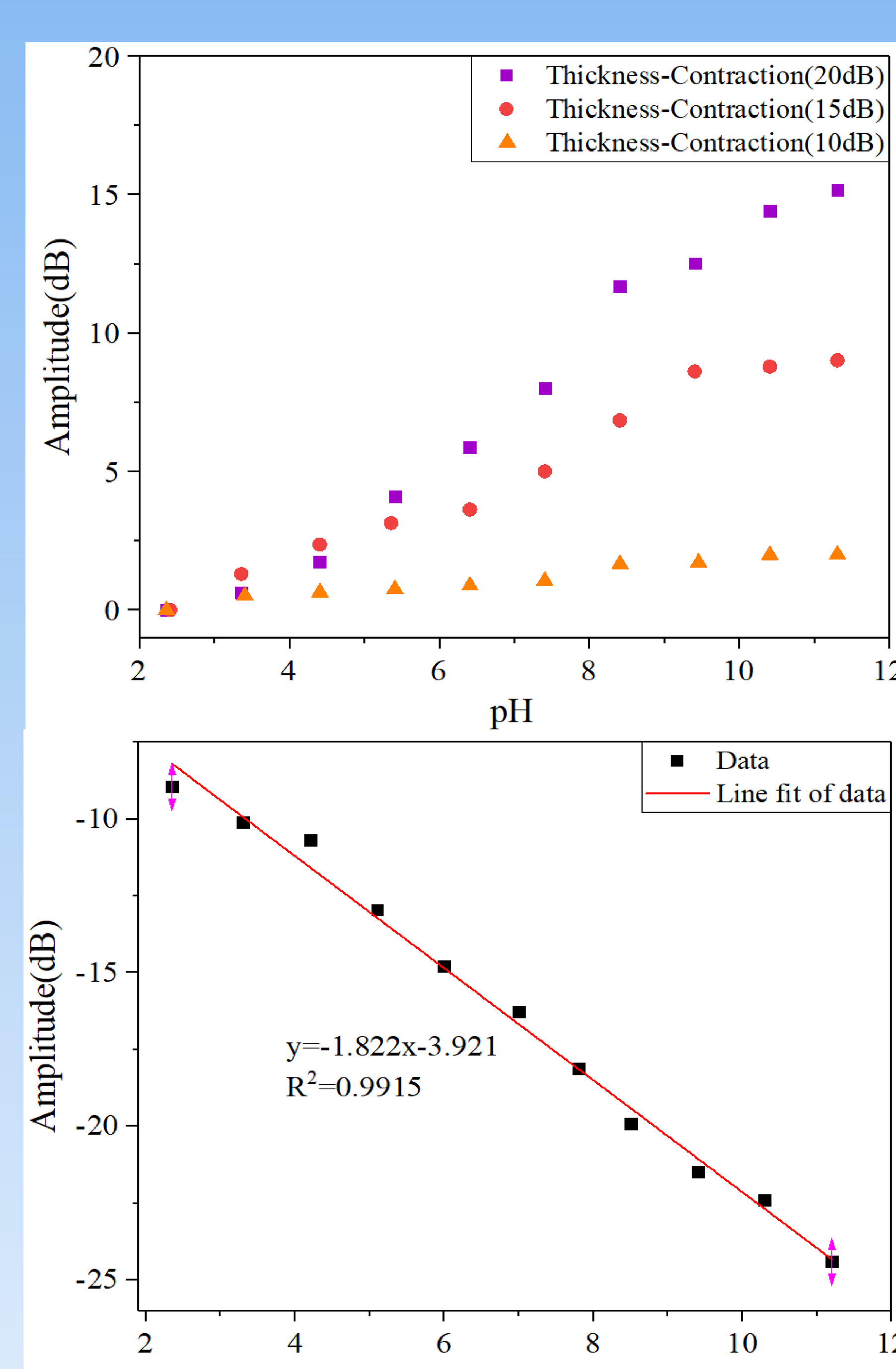


Figure 2(a). Results of pH measurement by TFBG at different thickness. (6° TFBG) (b) The refraction index of the pH sensor. (6° TFBG)

In general, a 6° TFBG with approximately 20 dB decrease when coating has the best performance.

As shown in Fig.2 (b), the sensitivity is up to 1.82 dB/pH with a very small lag. Fig.3 show the pH hysteresis and the cycling characteristics of the above sensor. As can be seen from the figures, the response intensity is almost constant for each cycle, which indicates that the sensor has good repeatability and can accurately monitor pH changes over long periods of time.

(a)

(b)

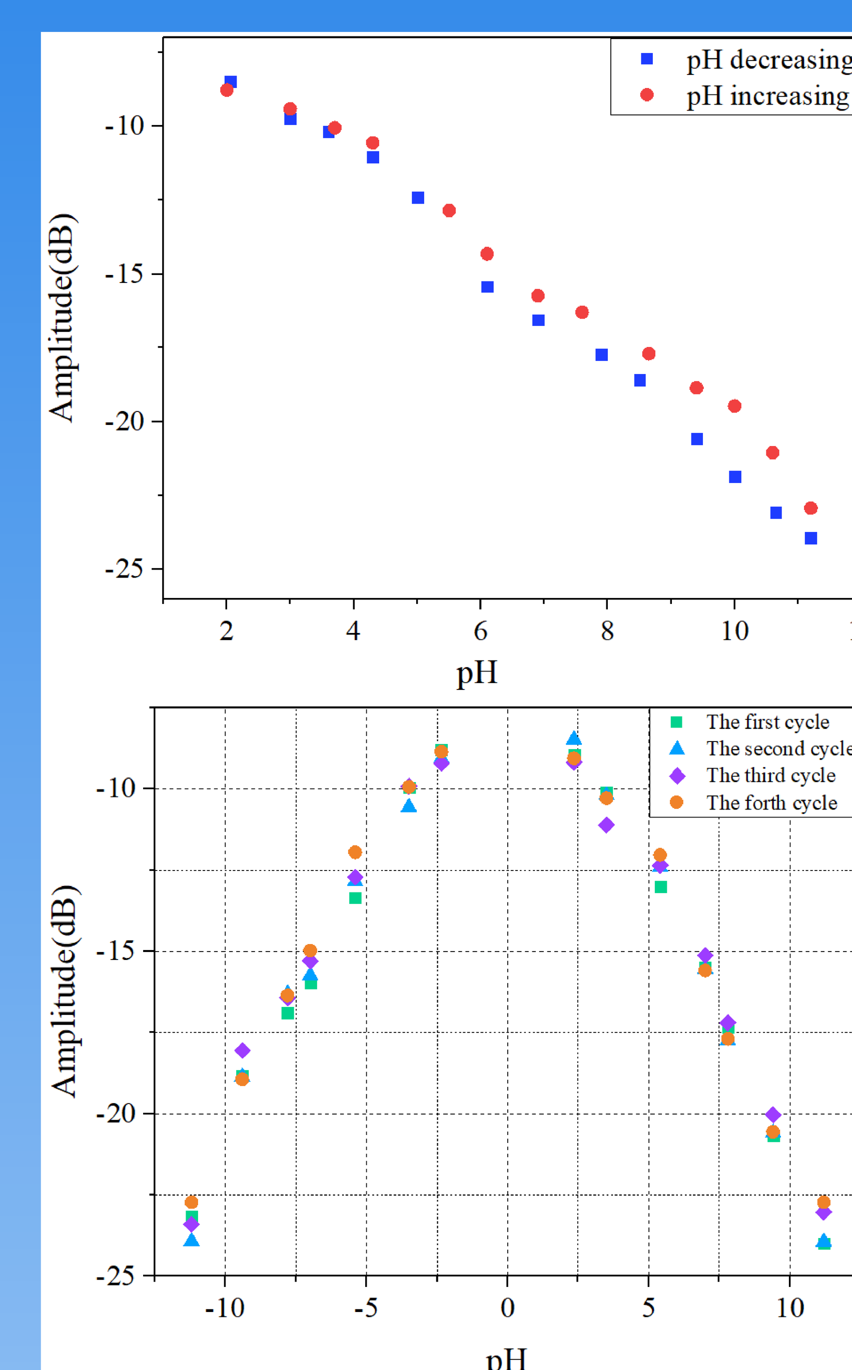


Figure.3 (a)Response to pH evolution of the sensor coated with contraction 20dB by PANI. (6° TFBG) (b) Repetitive response to pH sensor coated with contraction 20dB by PANI. (6° TFBG)

## Conclusion

In this paper, a tilted fiber grating sensor based on polyaniline is proposed to detect pH in solution. The polyaniline was deposited on the surface of TFBG by in situ chemical oxidation synthesis. By measuring the sensors with different PANI thicknesses, the 6° TFBG sensor had the maximum sensitivity of 1.82 dB/pH when the spectrum was compressed by 20 dB during the deposition of polyaniline. The pH hysteresis of the sensor was also examined, and it was found that the hysteresis was regular, indicating that the sensor was still accurate during the pH change. Finally, the cycling characteristics of the sensor were investigated, and the experimental results showed that the sensor has good repeatability and can be used for long-term pH monitoring.