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DEVELOPMENT OF FIBER BRAGG GRATING AS A HYDROGEN SENSOR: A REVIEW

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ABSTRACT
Hydrogen is a very useful but dangerous gas. Therefore, to use hydrogen gas, an accurate and reliable sensor is required to prevent accidents. The use of chemical fiber-optic sensors is the answer. Fiber Braggs Grating (FBG) type are sensors that are sold in bulk but have some drawbacks that are not moisture resistant and less sensitive. The development of FBG is based on these weaknesses.

KEYWORDS: Fiber-Optic, Bragg, Grating, Hydrogen, Sensor

1. INTRODUCTION
Hydrogen is a gas that can be fueled in fuel cells and can be produced from the reshaping of natural gas (Silva, Ferreira, Noronha, & Hori, 2017; Ahn, Park, Lee, Noh, & Chang, 2018; Bang, Park, Han, Yoo, Song, Choi, ... & Song, 2016). The waste from the fuel cell is very environmentally friendly, namely water (H2O). In the fuel cell working scheme (Figure 1), the carbon dioxide is output from the inlet air.

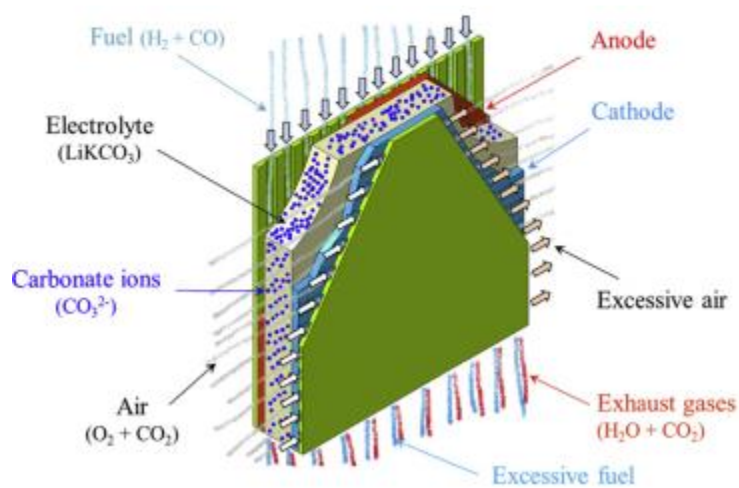


Figure 1. Fuel cell working scheme (Ahn, Park, Lee, Noh, & Chang, 2018)

Despite its large and easy-to-carry strength, hydrogen has a drawback. It is very reactive to the air (Wang, & Wolfbeis, 2016; Wang, & Wolfbeis, 2019). If there is a leak in storage, the danger level will be much higher than other fuels. Therefore, accurate and reliable sensors are required to ensure they do not leak.

Fiber-optic chemical sensors are a low-cost bulk product that provides high accuracy that can perform measurements in hard-to-reach places, at long distances, in places with the high electromagnetic force, and in hard-to-reach places (Wang, & Wolfbeis, 2019). This makes the development of fiber-optics as interferometric chemical sensors, or which can be referred to as Fiber-Optics Chemical Sensors (FOCS).

2. DISCUSSION

This interferometric sensor for hydrogen uses Palladium (Pd) material because it interacts strongly up to nine hundred times its volume with hydrogen (Wang, & Wolfbeis, 2016; Wang, & Wolfbeis, 2019). This material must interact strongly with hydrogen because hydrogen is a gas with a very small density and is very reactive to the air, so there will be no spark. Since this is an interferometric sensor, the reverse response is a wave change. One example of a sensor is one made by Fiber Sensing S.A. in Portugal (Figure 2). This signal uses a broadband light source signal and provides a signal in realtime.

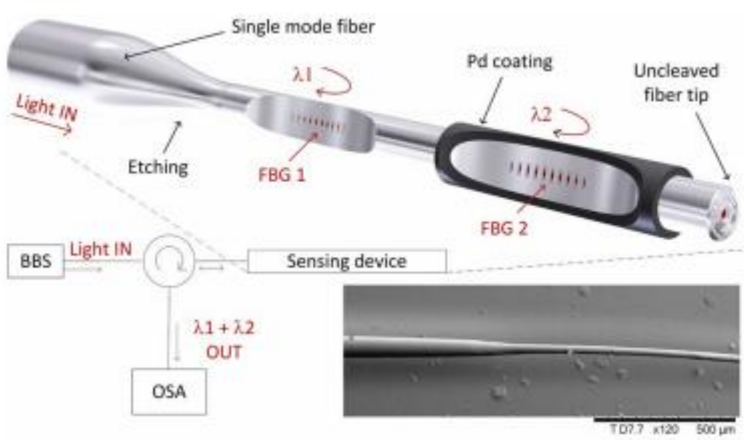
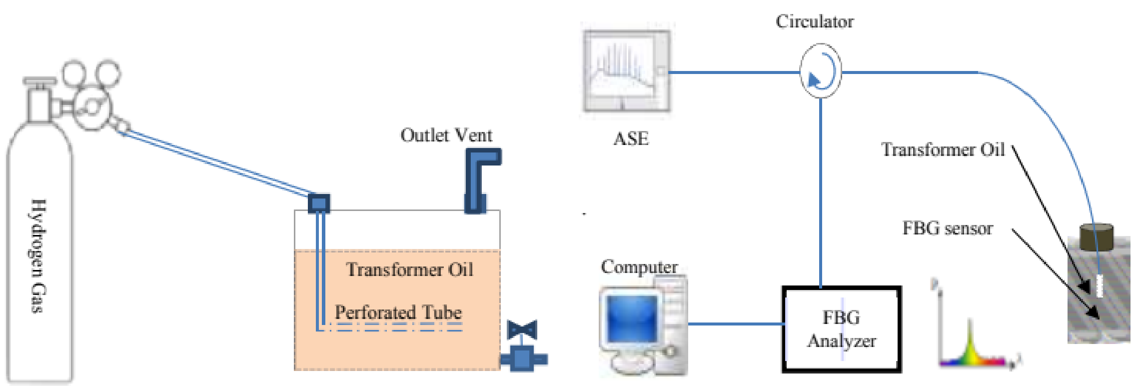


Figure 2. Sample tool of FOCS: BraggMeter FS2200SA (FiberSensing S.A., Portugal) inserted into Scanning Electron Microscopy (SEM)

In the sensors above, there will be a difference between wavelength one (λ_1) and wavelength two (λ_2) if palladium reacts with hydrogen thus forming palladium hydroxide which certainly changes the shape of palladium crystals (Coelho, De Almeida, Santos, & Viegas, 2015). This method is also referred to as Inline

Fiber Bragg Gratings (FBG), and this small signal can be amplified using fiber-optics. Coelho (Coelho, De Almeida, Santos, & Viegas, 2015) states that this tool has a weakness of not being able to be included in a humid place for a long time because it can make the sensor output unstable.

The development of sensors carried out by Samsudin, et al., by coating the sensor with a thin layer of titanium dioxide (TiO_2) before being recoated using Palladium (Samsudin, Shee, Adikan, Razak, & Dahari, 2016). The application of this sensor was to check the amount of hydrogen during petroleum filtering (Figure 3). The sensor will be at a high humidity level. The results showed that the instability in the coating tool ranged only between 0-1% and the wavelength difference between the coated and uncoated TiO_2 was around 20 pm.



(a) (b)

Figure 3. Scheme (a) petroleum filtration, (b) research (Samsudin, Shee, Adikan, Razak, & Dahari, 2016)

Jiang et al., were etching the FBG sensor so that the sensor becomes more sensitive to hydrogen (Jiang, Song, Ma, Luo, & Wang, 2015). He used this new tool to measure hydrogen in very small levels, which is 0.060 pm/µL/L or more than 30% sensor sensitive than without etching. However, this makes the error even bigger. The sensor scheme can be seen in Figure 4. Etching used is 49% HF acid.

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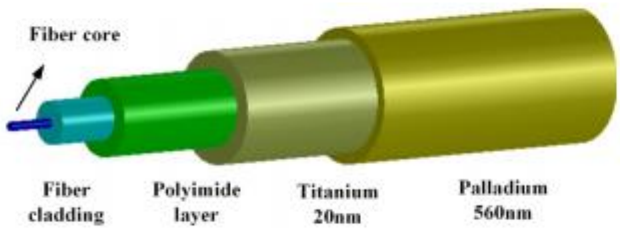
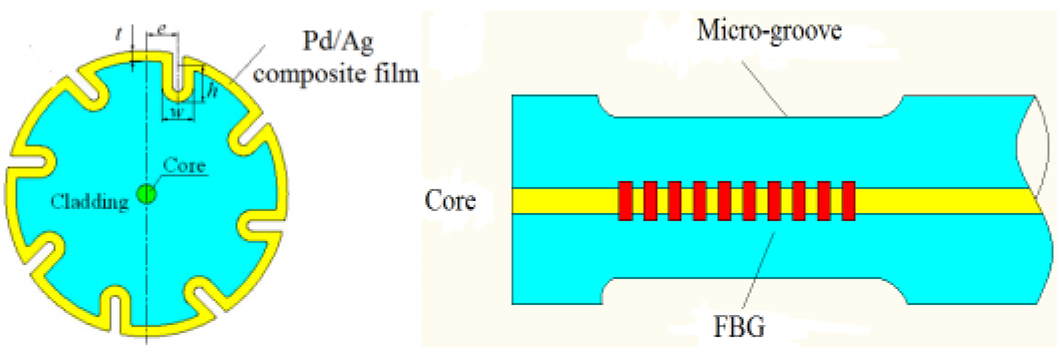
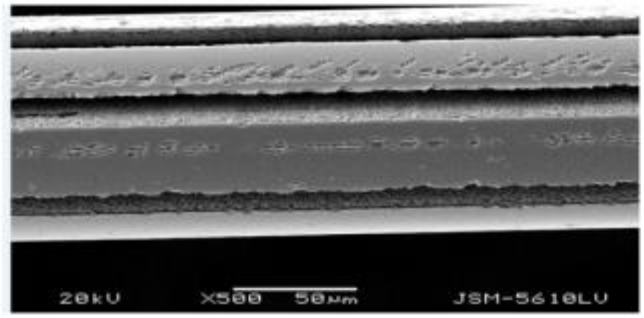


Figure 4. Fiber-optic chemical sensor etching (FOCS) etching scheme (Jiang, Song, Ma, Luo, & Wang, 2015)

Karanja et al., were micro-machining the FBG sensor so that the cores of the FOCS get more light. The treatment scheme can be seen in Figure 5. Micro-machining is done using lasers and recoated using a 520 nm-thick Pd/Ag film. When hydrogen reacts with palladium, the thickness will increase, and the readings can be done. This developed sensor has a sensitivity up 6.6 times greater than usual with a wavelength increase of 2.5 pm/%,H2 (Karanja, Dai, Zhou, Liu, & Yang, 2015).



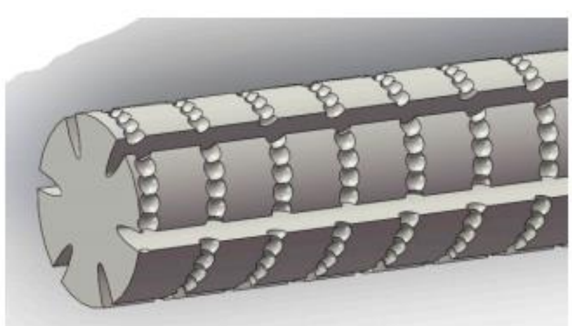
(a) (b)



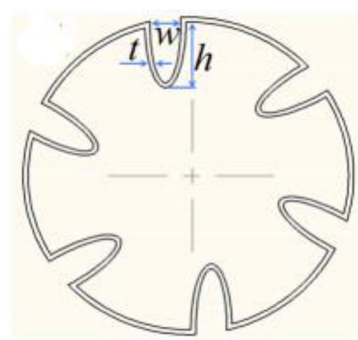
(c)

Figure 5. Micro-machining form on FBG sensors (a) front view, (b) side view, (c) appears on Scanning Electron Microscopy (SEM) after being coated Pd/Ag (Karanja, Dai, Zhou, Liu, & Yang, 2015)

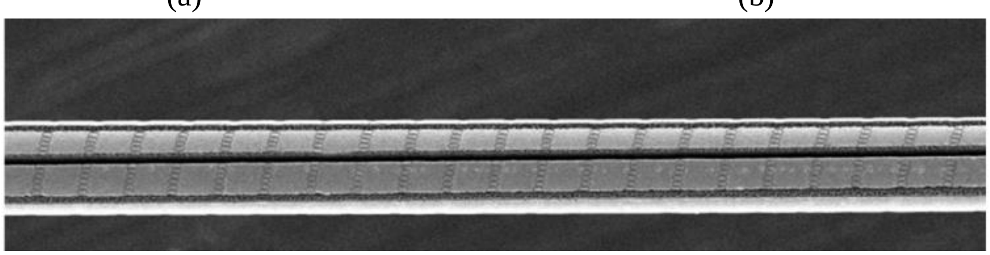
Zou, et al., redeveloped from the micro-machining above so that sensitivity rises again with a wavelength increase of 21 pm/%,H_2 (Zou, Dai, Zhou, Dong, & Yang, 2016). This was due to the re-granting of a thread-shaped hole around the body of the FBGs sensor (Figure 6).



(a)



(b)



(c)

Figure 5. Micro-machining form on FBG sensors (a) thread a new hole, (b) front view, (c) appears on Scanning Electron Microscopy (SEM) after being threaded (Zou, Dai, Zhou, Dong, & Yang, 2016)

3. CONCLUSION

Research on the development of these sensors has been done. FbG sensors with the best moisture resistance are coated by Titanium, while Zou makes FBG sensors that have the best sensitivity. The development of possible sensors is to combine both types of research so that the sensors obtained will become moisture resistant and high sensitivity.

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