A REVIEW ON THE HUMIDITY SENSORS

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Abstract

A wide variety of uses, including hygiene, comfortability, farming, food storage and processing, and electronic technology, demand rapid and precise humidity measurements. There are many benefits to sensors based on optical fibres over electronic sensors and good research attempts have been made in this area in recent years. The latest patterns of optical fibre humidity sensors are recorded in the current article. Along with the new technologies used by this aim, the evolution of optical structures built for humidity sensors will be studied. Excellently optical frameworks are also being researched to boost their sensitivity, such as long-period fibre gratings or fibre Bragg gratings. Sensors based on resonances based on lossy mode constitute a platform mixing high sensitivity with low complexity, both in respect of their manufacturing process and the appropriate materials. To boost the sensitivity of humidity sensors, innovative mechanisms, like resonators, are now being tested. Besides that, current findings on polymer optical fibres shows that this type of sensor's sensitivity has not yet surpassed its maximum. Therefore, in terms of resolution and sensitivity, there's still some potential for growth.

Keywords: *Fiber Bragg Gratings, Humidity, Optical, Sensors.*

I. INTRODUCTION

Humidity has a major effect on many manufacturing activities, such as the production of electronics, food or pharmaceutical products, food storage, etc. Continuous monitoring of air humidity is needed for all these processes that can be influenced by humidity. Furthermore, appropriate humidity levels can be crucial to the product's consistency and getting the correct humidity level can lead to a reduction in energy usage[1].

Compared to electronic humidity sensors, optical fibre humidity sensors (OFHSs) offer many benefits, such as miniature size, reliability, the ability to operate in flammable conditions and at higher pressure and temperature levels, and, most notably, their electromagnetic immunity. They can also tolerate a certain kind of rough and challenging circumstances used in manufacturing processes[2].

There's a few evidence, nevertheless, that have kept OFHSs from being a popular commercial commodity. Optical fibre sensor processing is not yet an adequately continuous procedure to become a product of serial manufacturing. There is a certain amount of complexity implicit in the production process for some optical structures. The biggest inconvenience, however, is related to optical equipment prices. It is possible to find halogen white light sources and regular optical fibres on the market at reasonable prices, however spectrometers, optical spectrum analyzers (OSA) and other optical instruments have restricted OFHSs to unique applications where no other alternative exists[3].

More potential applications could be identified, some of which have been connected to the control of structural health, which is an important case where sensors of relative humidity (RH) can be used. OFHSs provide the ability for civil engineering systems to be tracked using, for example, fibre Bragg gratings (FBG) or even dispersed measurements for large structures integrating Optical Time Domain Reflectometry (OTDR) with chemically sensitive water swelling polymers (hydrogels). Moreover, the above-mentioned FBG sensors have the ability to serve as sensors for road parameters (humidity, ice, temperature, etc.)

For tunnel leakage detection, another application found for distributed measurement is. One of the greatest benefits of OFHS is the probability of making distributed measurements. Food preparation and storage is another field where this sort of sensor is useful. In addition, for the proper preservation of precious artwork, such as in museums or libraries, humidity management is important.

Continuous RH calculation and regulation, in addition to the above applications, is essential for human comfort, such as controlling air conditioning and achieving controlled hygienic conditions. Furthermore, owing to the need for humidification of the inspired gases in essential respiratory care, OFHSs have found new uses in clinical treatment.

The latest patterns of optical fibre humidity sensors are recorded in the current article. Novel optical systems will be explored and reflected on, as well as materials recently tested. A thorough study of OFHSs based on resonances in the lossy mode will then be carried out. Thanks to its comparatively straightforward manufacturing process and high sensitivity to the surrounding medium refractive index, this type of sensor occupies a unique role next to optical fibre sensors (SMRI). Finally, some concluding remarks will be given on the sensing efficiency of all these sensors[4].

II. LITERATURE REVIEW

A. Recent Trends in Optical Fiber Humidity Sensors: -

Here, a short overview will be given of the most recently produced OFHSs. In compliance with their operating theory, the OFHS are categorised. The first group contains OFHS based on the optical absorption of the first class of OFHS formed by the materials. The next category encompasses fibre Bragg gratings (FBG)-based OFHS and long-term fibre gratings (LPFG). Interference, which can be split into several types of interferometers, like Fabry-Pérot, Sagnac, Mach-Zehnder, Michelson, and modal interferometers, is another possibility for OFHS development. OFHS based on micro-tapers, micro-ring, and micro-knot resonators (MKR) and other sensors based on whispering gallery modes are included in the next group (WGM). Finally, there will be a review of OFHS dependent on electromagnetic resonances, especially lossy mode resonances (LMRs)[5].

B. **Optical Absorption Sensors**

These sensors are based on the evanescent field's contact with the coating used as the sensitive material, producing improvements in the optical power emitted across the entire spectrum. Plastic-cladding silica (PCS) optical fibre or plastic optical fibre (POF) is widely used for this type of sensor, but other alternatives such as side-polished optical fibre are possible (D-shape). There are benefits of some of these optical fibres, such as low processing costs, the ability to calculate with a quick setup, and good durability, but they have some drawbacks. The key drawbacks are due to the measurement process, which detects only changes in the transmitted optical power; unfavourable variables such as variations in the light source may influence these changes.

The study of materials that are becoming popular in the production of optical fibre sensors has been the subject of most recent studies. These products, such as reaction time or sensitivity, are being tested for their ability to enhance certain OFHS characteristics. Tungsten disulfide, reduced graphene oxide (rGO), and zinc oxide are the studied components[6].

C. **Fiber Bragg Gratings**

A Bragg grating is an optical device consisting of a periodic disturbance of a waveguide's refractive index. A FBG is created by exposure to an extreme optical interference pattern of ultraviolet light from the centre of the optical fibre. The exposure induces a permanent rise in the refractive index of the fibre centre, generating a modulation of the fixed index according to the exposure pattern. A small amount of light is reflected at each intermittent refraction shift as light is launched into the optical fibre. All the reflected light signals converge coherently at a given wavelength into one broad reflection while the grating period is roughly half the wavelength of the input light. Light perpetuating at wavelengths varying from the Bragg wavelength that satisfies Equation does not impact the grating:

$\lambda_B = 2\eta\Lambda$ (1)

where λ_B is the Bragg wavelength, η is the effective refractive index of the grating in the fiber core, and Λ is the grating period. Bragg wavelength is typically located in the infrared spectrum due to the mask measurements and the properties of normal single mode optical fibre (SMF) communications. More recent study includes the use of decreased core diameter micro-structured plastic optical fibres (POFs) or SMF to be able to operate in the visible-near-infrared spectrum[7].

D. **Long-Period Fiber Gratings**

Long-term fibre gratings (LPG) consist of a periodic change in the central refractive index of a single-mode optical fibre optic fibre (SMF). In comparison to FBG, which has a sub-micron duration and a couple of lights from the optical fibre forward-propagating mode to a counter-propagating backward mode, LPGs usually have a period of 100 m to 1 mm. This induces a coupling of light between the directed core mode and separate co-propagating cladding modes in LPGs.

In the optical fibre transmission spectrum, this coupling produces a series of attenuation bands, each centred at a different resonant wavelength. In the shape of an evanescent pulse, a part of the cladding mode's electromagnetic field penetrates the surrounding medium. While LPGs were initially developed as filters for the rejection band, they also offer interesting sensing characteristics[8].

E. Modal Interferometers

For the generation of modal interferometers, fibre optics technology provides several degrees of independence. Several systems have therefore been tested, many of them offering benefits such as stability, compactness, small scale, lightness, etc. The interferometric phase difference is constructed by considering the difference between various fibre modes in the effective refractive indices. Alternative topological structures exist, such as Michelson or Mach-Zehnder interferometers, which can be applied in a composite structure or by other approaches by splicing various types of fibres[9].

F. Optical Fiber Humidity Sensors Based on Lossy Mode Resonances

These are all mistaken with surface plasmon resonance (SPR) for the first time in interacting with lossy mode resonances (LMR), but major distinctions can be distinguished between the phenomenon regarding their similarity. What makes them similar is that both are electromagnetic resonances that on the broadcast spectrum produce an attenuation band. In SPRs, however, there is energy conversion from light to the noble metal's free electrons, while in LMRs the light is combined with the coating. Another distinction is the potential for transverse magnetic (TM) and transverse electric (TE) modes to be observed, which may minimise the required configuration and the amount of materials accessible for the generation of LMR, thus extending the usage of sensors based on LMR. A further gain of LMRs is the prospect of producing multiple attenuation bands at tunable wavelengths. However, their capacity to produce an optical phenomenon that can be observed by the wavelength measurement system using the same material that serves as the sensitive layer to the variable to be measured is one of the most significant factors that makes LMRs a good option for the production of optical fibre sensors. The structure of an LMR-based system consists of a waveguide coated with a thin film of the necessary material, enabling access to the evanescent field. The criterion for the generation of LMR is that the actual portion of thin film permittivity is positive and greater in magnitude than both its own imaginary portion and the actual portion of the thin film material. When there is a resonant coupling of light to modes directed by the external coating, LMRs are produced. There are many ways in which optical configurations and OFHS can measure relative humidity and several areas of use where this type of sensor can be used, like radiation conditions or waterproof packaging, or, for example, vacuum packaged foods, where other sensors can change the atmosphere and distort the measurement. While there are mechanisms that have not been studied, it is possible to extract some interesting findings from those explained here[10].

III. CONCLUSION

Novel technologies, recognized as innovative nanostructures (nanotubes, quantum dots), are still present and exhibit encouraging moisture sensing ability. Nonlinear activity can occur with polymeric coatings and inorganic salts, particularly at high relative humidity values where they have their greatest sensitivity. Metal oxides and semiconductor oxides appear to be a good option for the 20 percent-90 percent RH range to achieve linear responses and good sensitivity. Their reaction times are normally slower than those of products that swell with water. With respect to optical structures, there ought to be a consensus between the attenuation band's target spectral width and its dynamic range. The sophistication of the needed fabrication process is another significant aspect that must be taken into consideration. In recent years, modal interferometers produced by splicing various types of fibres together display the significant amount of literature. Furthermore, polymeric optical fibres and photonic crystal fibres have shown their power in the production of optical fibre sensors.

Special equipment for inscribing the grating to the optical fibre is required by FBGs and LPFGs. In their own, they are not too sensitive to external parameters and require an external coating in addition to the grating. However, recent research has shown that with these optical systems, increased sensitivities can be achieved. Moreover, with their high resolution, they compensate for their limited dynamical range.

To enter the evanescent region, a previous procedure is needed for LMRs. This procedure is easier than that needed for a grating to be written and typically consists of a chemical system to extract the cladding partially or entirely. LMRs enable an attenuation band to be produced from the same substance that acts as a sensitive layer, simplifying the process of receiving a sensor for optical fibre humidity.

Finally, because of their good efficiency and the relative simplicity of obtaining them, Fabry-Pérot interferometers, produced by coating the tip of an optical fibre, seem to be a good option for obtaining optical fibre humidity sensors. They are also a less invasive method of measuring optical fibre dimensions. This optical structure dealing with hygroscopic materials matches the highest sensitivity found in this study.

IV. REFERENCES

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