Differential Fresnel Reflection Based Fiber-optic Relative Humidity Sensor

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Introduction

Humidity, commonly expressed by relative humidity (RH), is a physical quantity describing how dry the air is. It refers to the ratio of the water vapor density to the saturation water vapor density. A wide range of industrial fields, such as food production and storage, electronic manufacturing, agriculture, require a fast and accurate monitoring of RH [1-2]. Additionally, excessively low ambient RH will reduce the resistance of human respiratory system and even aggravate respiratory diseases, so RH also has a great influence on human health. So far, the reported measure schemes for humidity sensing can be generally categorized into electrical resistance and capacity measure [3-5], optical-fiber-based intensity [14-17] and specific wavelength tracking [6-13]. Compared with electrical based sensors, optical fiber based sensors have been paid much attention relying on their intrinsic properties, including miniature design, electromagnetic immunity, corrosion resistant, real-time and remote sensing [18]. Optical-fiber-based humidity sensors can be designed by employing fiber gratings [6-7], fiber interferometers or fiber-in-line modal interferometers [8-13], optical microresonators (OMRs) [17] and evanescent wave [14-16], etc.

In this paper, a simple fiber-optic humidity sensor based on differential Fresnel reflection (DFR) and cellulose acetate butyrate (CAB) is proposed and investigated both in theory and experiment. The water-vapor sorption of the CAB induces the permittivity change and further changes the Fresnel reflection intensity. Besides, the proposed DFR technique can eliminate the fluctuations in light source and exhibits high stability. Such a humidity sensor has the advantages of wide measure range (~10% to ~100%), low cost, simple instrument, high stability and good reversibility.

Principle of Operation

The overall sensing structure is sketched is Fig. 1, which is mainly composed of a C-band broad band source (Lightcomm Technology), three 50:50 optical couplers (T&S Communications), two photodetectors (Lightcomm Technology), two fiber sensing terminals placed into standard telecommunication ferrules with diameter of 2.5mm for protection and vertically planar surface.

Furthermore, one of the sensing terminals is further coated with CAB polymer and is immersed in a saturated-solution-oriented humidity environment whose humidity is also monitored by commercial humidity meter Center 313.

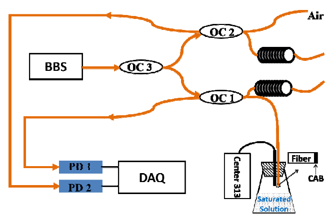

Fig. 1 The overall differential Fresnel reflection based humidity sensing system.

The sensing mechanism of the CAB is similarly to other cellulose-based humidity sensors [4]. Initially, CAB tends to absorb free volume water to form a weak water/polymer interaction, resulting in a monolayer of bonded water molecule. After that, more layers are formed by adjacent hydroxyl groups in line with the Grotthuss chain reaction mechanism [3-4]. Therefore, within the physical water absorption process, different volumes of water are absorbed, leading to different permittivity of the composite and different differential Fresnel reflections such that the RH can be obtained.

Experimental Results and Discussion

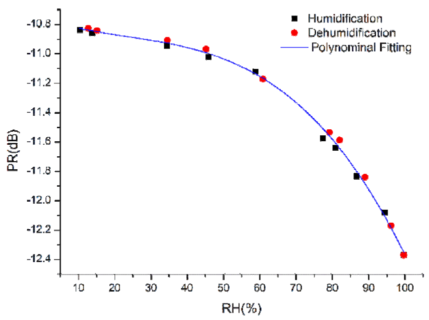

Fig. 2 Plot of the PR versus the RH roughly ranging from 10% to 100% in the humidification and dehumidification process

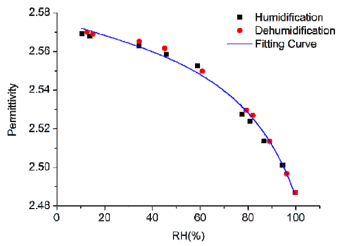

Fig. 3 Plot of the calculated permittivity of the composite versus RH

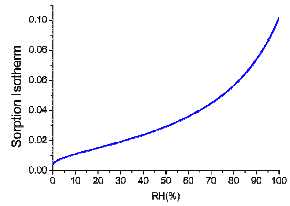

Fig. 4 Theoretic sorption isotherm when g equals to 0.84 kJ/mol

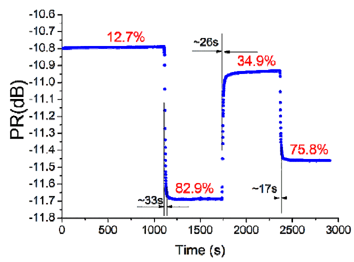

Fig. 5 Real-time response of the proposed differential Fresnel reflection based humidity sensor

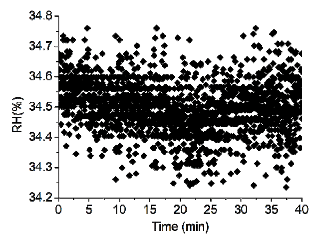

Fig. 6 Graph of the calculated RH versus the time over 40 minutes when RH's fixed at 34.5%.

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