Development of cholesterol liquid crystal sensors for VOCs detection in atmospheric environment-Effects of the thinness of liquid crystal layer

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The Volatile Organic Compounds (VOCs) are the most typical pollutants in the atmospheric environment, some of the VOCs are hazardous to human health. The concentrations of VOCs in the atmospheric were typically determined by a Gas Chromatography (GC) in the laboratory, however, this method is complicated and the equipment is expensive. Recently, the Liquid Crystal (LC) was innovatively used to develop as a bio-sensor or sensor (Liquid-Crystal-Based sensor) due to the specific optical and electrical characteristics of the LC, especially in the files of bio-chemical researches. The Liquid-Crystal-Based sensor were also regarded have high potentials to be rapid and simple sensors in many fields. However, the applications LC sensor in environmental science and engineering are still very rare in the literatures. In our previous study, a LC-based (Cholesteric Liquid Crystal, CLC) sensor was developed for the rapid-quantitative measurements of the Volatile Organic Compounds in the atmospheric environments. According to this previous study, the detections of the concentrations of VOCs by the CLC sensor were highly correlated to the thinness of CLC layer. Therefore, the thinness of CLC layer was controlled between 5.0 to 40.0 (5.0, 10.0, 20.0, 30.0, and 40.0) micrometers (um) in this present study. A series of experiments were conducted to identify the correlations between thinness of CLC layer and the concentrations of VOCs, and three VOCs compounds including Acetone, Toluene and Xylene were tested in this study. The physical directions of the CLC molecules will be changed when the prepared CLC sensor contact with the VOCs compounds, and resulting the color on the CLC surface changed from a green color to colorless which can be captured by using a digital image analysis system. Moreover, it was also found that the color change from Green to colorless is more rapid when CLC sensor contact with higher concentrations of VOCs. The durations of color change from Green to colorless was also found presented a liner relationship with the concentrations of VOCs, therefore, the concentrations of VOCs in the atmosphere environment can be identified. The CLC sensing VOCs experiment was duplicated for eight times, and the standard deviation and variation was also calculated to evaluate the consistency of each experiment. Very low variations around 10% were found to indicate high consistency was performed in the CLC sensing VOCs experiments.

The results of the experiments also shown that a thicker CLC layer used in the sensor can detect lower VOCs concentrations. For detecting the acetone compound, the acetone concentrations ranging from 9,997 ppm to 36,657 ppm in the atmospheric environments can be identified when the thickness of the CLC layer is controlled with 5.0 to 40 μm, respectively. On the other hand, xylene with the concentrations between 40 ppm and 1,196 ppm and toluene with concentrations between 98 ppm and 2,305 ppm can be also identified when the thickness of the CLC layer was controlled between 5.0 to 40 μm. Finally, an Artificial Neural Networks (ANNs) model were used to correlate the thinness of LC layer and the concentrations of VOCs, which presents a precise predicting result with the $R2$ of 0.98.

Keywords: Cholesterol Liquid Crystal, Liquid crystal sensor, Volatile organic compounds, Artificial Neural Networks