Sensors and Actuators B 267 (2018) 636–646

Contents lists available at ScienceDirect

Sensors and Actuators B: Chemical

journal homepage: www.elsevier.com/locate/snb

Application of Polycrystalline SnO_2 Sensor Chromatographic System to Detect Dissolved Gases in Transformer Oil

Jingmin Fan[a,*], Feng Wang[b], Qiuqin Sun[b], Huisheng Ye[c], Qinji Jiang[d]

[a] School of Automation, Guangdong University of Technology, Guangzhou, 510006, China
[b] College of Electrical and Information Engineering, Hunan University, Changsha, 410082, China
[c] State Grid Hunan Electric Power Corporation Research Institute, Changsha, 41007, China
[d] State Grid Hunan Maintenance Company, Changsha, 41007, China

ARTICLE INFO

Article history:
Received 1 October 2017
Received in revised form 4 March 2018
Accepted 3 April 2018
Available online 10 April 2018

Keywords:
Gas chromatography
Dissolved gas analysis
Polycrystalline SnO_2 detector
Chromatogram denoising
Peak detection
Power transformer

ABSTRACT

Dissolved gas analysis (DGA) has an essential role to transformer status. A gas sensor is fabricated for DGA by using the developed one-dimensional polycrystalline SnO_2 fiber material. On basis of this, a portable gas chromatographic device (PGCD) is developed for DGA. A wavelet-genetic algorithm (GA) threshold denoising method is proposed for noise reduction and applied to chromatogram to detect the weak peaks of the PGCD for latent transformer faults. Then, an improved filter matching method based on gray incidence degrees for peaks detection is presented to overcome the limitations of the derivative method. Results indicate that the proposed signal processing method demonstrates competitive performance, thereby providing a favorable foundation for quantitative analysis. Tests were conducted to measure the repeatability and accuracy of the developed polycrystalline SnO_2 sensor and PGCD. Comparison with the commonly used flame ionization detector is performed, and the effectiveness of the developed sensor and the corresponding PGCD are verified.

1. Introduction

The condition-based maintenance of power transformer inevitably replaces conventional regular overhauling given the development of smart grid construction and substation automation [1,2]. DGA remains to be the easiest and most effective method for examining latent faults of oil-immersed power transformers [3–5]. At present, transformer online monitors based on the gas sensor are applied widely to avoid transformer failure [6,7]. However, the effectiveness of the monitor is determined by the accuracy, minimum detection limit, cross-sensitivity, and the corresponding signal processing technologies of the gas sensor. Cross-sensitivity is an issue that must be considered because feature gases involve mixtures, such as H_2, CO, CH_4, C_2H_4, C_2H_2, and C_2H_6.

Various gas sensors have been applied to DGA but with certain limitations. For example, thermal conductivity sensor [8] shows low sensitivity to hydrocarbon gas and requires helium, which is high cost, to be the carrier gas; flame ionization detector (FID) [9] performs well on minimum detection limit but is only suitable for laboratory applications because hydrogen is required. The photoacoustic spectroscopy sensor [10] does not require carrier gas and is free from mixed gas separation. However, its accuracy and stability are difficult to ensure because it could be easily disturbed by the electromagnetic environment of the substation.

To overcome the limitations of these sensors, continuous efforts on gas sensors have been exerted to enhance safety and reliability of oil-immersed transformer. For example, Zhou et al. [11] studied the CH_4 sensing properties of ZnO sensor; Lu et al. [12] studied the nickel-doped carbon nanometer tube sensor, whose gas-sensing properties on C_2H_2, C_2H_4, and C_2H_6 were investigated. These studies mainly concentrated on one or several key characteristic gases, such as CH_4 or C_2H_2, C_2H_4, and C_2H_6, whereas cross-sensitivity [13], which is essential for detecting mixed gases, are disregarded. At least five gases, such as H_2, CH_4, C_2H_4, C_2H_6, and C_2H_2, are required for the fault diagnosis of a transformer [14,15], and cross-sensitivity should be considered. Fan et al. [16] developed an online transformer monitoring system with a six-component gas detector to address this issue. This system utilizes gas chromatography (GC) combined with a commercial SnO_2 sensor and proposes a mathematical model for qualification.

Performance can be improved because the commercial SnO_2 sensor that is used in [16] is not designed for a special DGA application; thus, a gas sensor based on polycrystalline SnO_2 fiber material with a large surface-to-volume ratio is developed in this study.

* Corresponding author.
E-mail address: fanjingmin2004@163.com (J. Fan).

https://doi.org/10.1016/j.snb.2018.04.014
0925-4005/

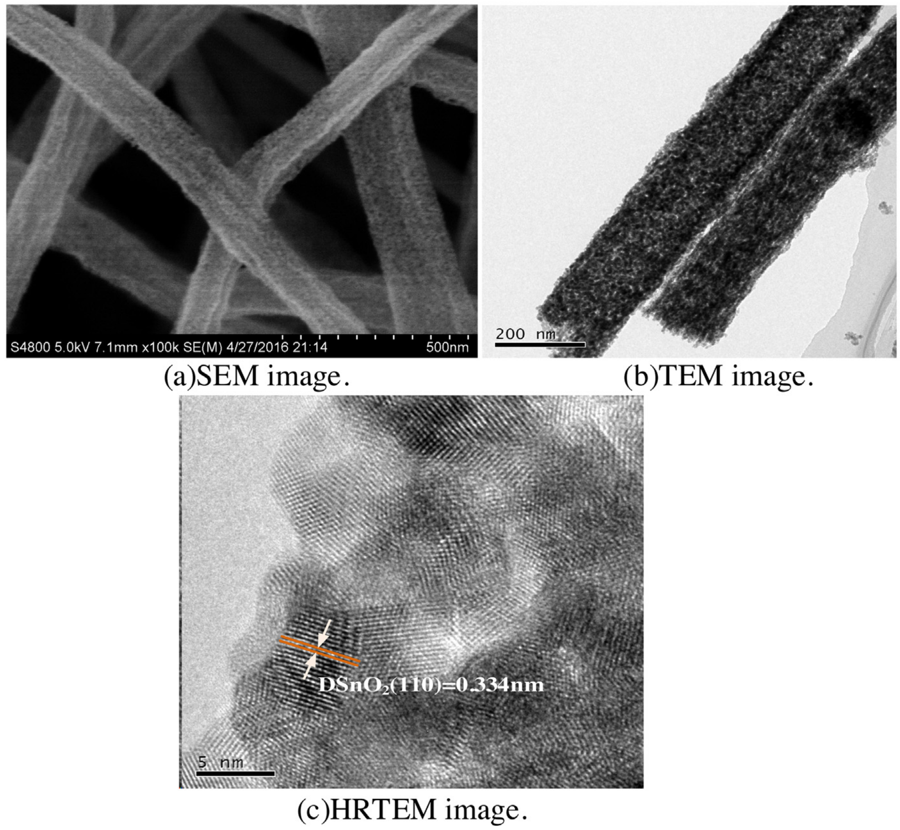

Fig. 1. Polycrystalline SnO_2 characterization images.

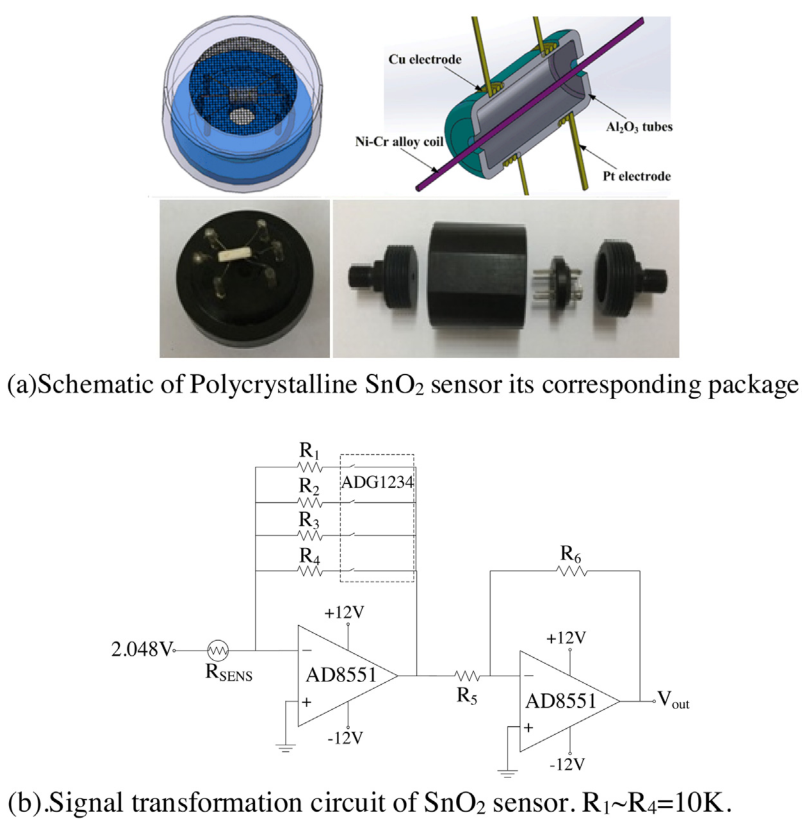

Fig. 2. Detector and circuit of the PGCD.