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Development and Application on the Distributed Signal Integrated Amplification Sensor of Polymer Electrolyte Membrane Fuel Cell

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ABSTRACT

In the study of in-plane signal acquisition and measurement of polymer electrolyte membrane fuel cells, it is difficult to ensure the accuracy of direct signal measurement because the voltage drop of the shunt resistor that needs to be used is small and easily disturbed and generates transmission loss. This paper develops a distributed signal integrated amplification sensor (DSIAS) using PCB segment measurement technology, which amplifies the segment voltage drop signal instantaneously before transmission and acquisition. It avoids the loss and interference of small signals in the transmission process. In addition, a unique collector structure is designed to meet the matching installation between the endplate and the PCB sensor, thus enabling online amplified measurement of planar information without affecting the internal system of the fuel cell. This signal amplification sensor has been initially measured and applied planar segment impedance. Under standard operating conditions, measurements were taken to obtain the impedance information of the in-plane segments. The electrochemical impedance spectra of the cell single and each segment were plotted separately using the FFT algorithm of MATLAB software. These works can be applied to understand and explore the internal mechanisms of fuel cells in more depth.

Keywords: PEMFC, DSIAS, Integrated Amplification, EIS, FFT, In-plane Impedance

1. INTRODUCTION

Proton electrolyte membrane fuel cells have become an important research object in the field of energy because of their advantages, such as high efficiency zero pollution emission in operation [1,2]. Due to the large active area of the proton exchange membrane and the complex reaction mechanism of the fuel cell, the electrochemical reactions in different regions may be inconsistent, especially in the actual large cell size PEMFCs, which directly affects the performance and service life of fuel cell [3,4]. Therefore, online monitoring of the electrochemical reaction differences in different regions of fuel cells spatially and scale is of great significance for optimizing design improving the performance and the service life of fuel cells [5]. However, due to the lack of advanced and effective internal detection technology, the closed structure of fuel cells brings many difficulties to the online measurement of internal reaction parameters.

In recent years, to explore the electrochemical processes in the fuel cell, a significant number of model simulations and experimental verification methods have been conducted for internal parameters to optimize and improve the performance of fuel cells [6-10]. In addition, some invasive and non-invasive measurement methods are usually used to obtain as accurate as possible the operating parameters of the fuel cell in various operating states. [11-12]. Most of these test systems are not suitable for practical vehicle applications due to their complex test systems and expensive test equipment. As an in-situ partitioning measurement method, the printed circuit board (PCB) technique is often used to study the current density distribution and internal polarization processes of PEMFCs [13-16]. This paper, by analyzing the different principles of how PCB partitioning currents are acquired and converted current signals and considering the difficulty and cost control of PCB fabrication process level, the ohmic voltage divider method, and the mature multilayer rigid board production process are used. At the same time, for the small signal of in-plane shunt resistor ohmic voltage drop easy interference and transmission loss and other characteristics, using the advantages of PCB technology such as integration and through-hole conduction, the design and development of non-embedded PCB distributed signal amplification sensor. And applied to

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the measurement and study of in-plane partition impedance of fuel cell monoliths, this work is beneficial further to explore the internal working mechanism of fuel cells in-depth and provide a practical reference for practical application in engineering.

NONMENCLATURE

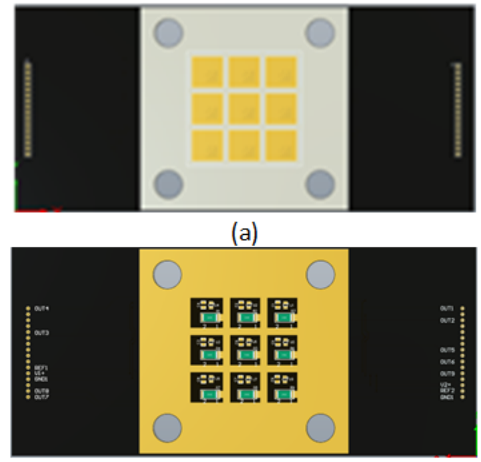
DSIAS	Distributed signal integrated amplification sensor
PEMFC	Polymer electrolyte membrane fuel cell
MEA	Membrane electrode assembly
PCB	Printed circuit board
EIS	Electrochemical impedance spectroscopy
FFT	Fast Fourier transforms
n	Segment No.
I_n	Segment current(A)
V_n	Segment ohmic voltage drop(V)
R_n	shunt resistance(Ω)
V_{out}	Amplified voltage
R1/R3	Magnification
V_{REF}	Reference voltage

2. EXPERIMENT

2.1 DSIAS Development

The DSIAS adopts a laminated structure hardboard PCB and a nine-segment (3*3) current collection arrangement with a signal amplifier at the segment location. As shown in Fig 1(a), the top layer of the DSIAS is gold-plated PAD to realize the current segmented collection, and the current is led to the bottom layer of the DSIAS through the corresponding segmented vias and connected directly to the connected shunt resistors (5mΩ) respectively Fig 1(b). The associated amplifying components are integrated with the shunt resistors at the bottom segment position, and the segment current is gathered at the particular collector. The primary function is to realize the integration and immediate amplification of the segmented ohmic voltage drop signal, avoiding the loss and interference of the signal during transmission.

In addition, the structure of the cathode collector is uniquely designed to meet the matching installation between the endplate and the PCB sensor. Thus, it is possible to achieve online amplification and measurement of planar information without affecting the internal system of the fuel cell.



(a)

(b)

Fig 1 PCB distributed signal integrated amplification sensor
(a) Top Layer (b)Bottom Layer

2.2 Experiment Schematic

This experiment was conducted on the Scribner Associates 850e fuel cell test bench. The fuel cell single with DSIAS was connected to the test bench. Table 1 summarizes the test-related measurement equipment information.

The sampled signals at both ends of the in-plane shunt resistor are input into the INA214 amplifier for amplification and then output directly from the connector to the NI USB-6218 acquisition device of LabVIEW to complete the acquisition of the amplified signals. Fig 2 shows the DSIAS test schematic.

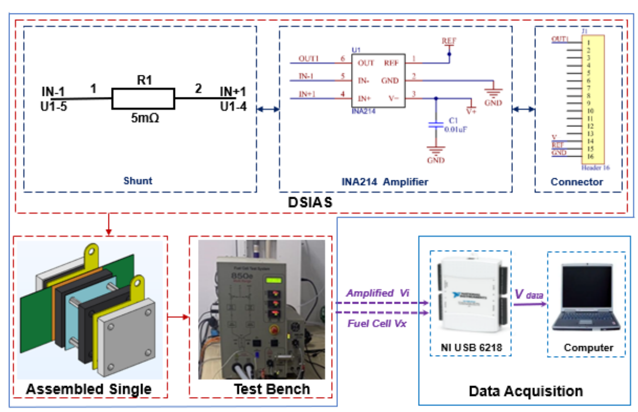


Fig 2 DSIAS test schematic

Table1. Measurement Devices Information

Measurement Devices	Suppliers	Specification
Test Bench	Scribner 850e	America
Fuel Cell	Nanjing University	$25cm^2$ Single
MEA	Yangtze Energy Technologies	Serpentine channel
DSIAS	/	4-Layer board
		3*3 segments
		5mΩ/shunt
Current Collector Plate	/	Gold-plated
	NI USB-6218	32 Inputs
Data Acquisition		16-bits
		250kS/s
Power Supply	GWINSTEK	GPS-4303C

2.3 Segment impedance measurement

The segment impedance spectrum measurements were performed in current excitation mode with a sweep frequency range of 0.2 Hz to 2 kHz. After each loading, the cell was kept stable for 20 min. In addition, 8% of the DC operating current was set as the AC excitation signal amplitude to maintain stable operation of the fuel cell and accurate sampling of the voltage. Table 2 shows the operating conditions of the test.

$$V_{out} = (I_n * R_n) * \frac{R_1}{R_3} + V_{REF} \qquad (2)$$

V_{out}: amplified voltage; R1/R3 magnification, V_{REF}: reference voltage.

The Fast Fourier Transform (FFT) is used to obtain the cell single impedance spectrum and the segment impedance spectrum, as shown in Fig 3 (with 5A\10A\15A\20A loads). For FFT data processing, the sampling method used is to define the sampling start point and sampling duration separately for each frequency band.

Table 2 Operating conditions of the test

Test conditions	Unit	Value
Cell Temperature	℃	75
Stoichiometry (A/C)	-	1.5/2
Current density	mA/cm^2	50/100/…/1700
Load	A	1.25/2.5/…/42.5
Dew Point (A/C)	℃	59.5/59.5
Inlet pressure (A/C)	kPa	130/110

2.4 Results and Discussion

The voltage variations corresponding to the cell single and all segments are captured during the step-by-step loading sweep. The segment current on the shunt resistor is calculated using Ohm's law equation (1) and NI214 amplifier's equation (2).

$$I_n = V_n / R_n \qquad (1)$$

n: represents the corresponding partition; I_n: partition current [A]; V_n: partition ohmic voltage drop [V]; R_n: shunt resistance [Ω].

From Fig 3 tested impedance spectra, it can be seen that the segmented impedance spectra match the trend of the cell single impedance spectra with nine times magnification.

3 CONCLUSIONS

This work is the main research object of the distributed voltage signal amplification measurement system for polymer electrolyte membrane fuel cells. A distributed signal amplification sensor is designed and fabricated with PCB segment measurement technology, and the NI acquisition device is used to realize the online measurement of segmented voltage signal amplification and acquisition in the fuel cell plane. This DSIAS was applied to measure the fuel cell in-plane segmented impedance spectrum to realize the extension of the flow channel dimension impedance measurement. In addition, this amplified sensor avoids the PCB buried resistance process in the design process, thus reducing the technical difficulty of PCB production in the fabrication process while controlling the corresponding fabrication cost and increasing the feasibility of practical engineering applications.

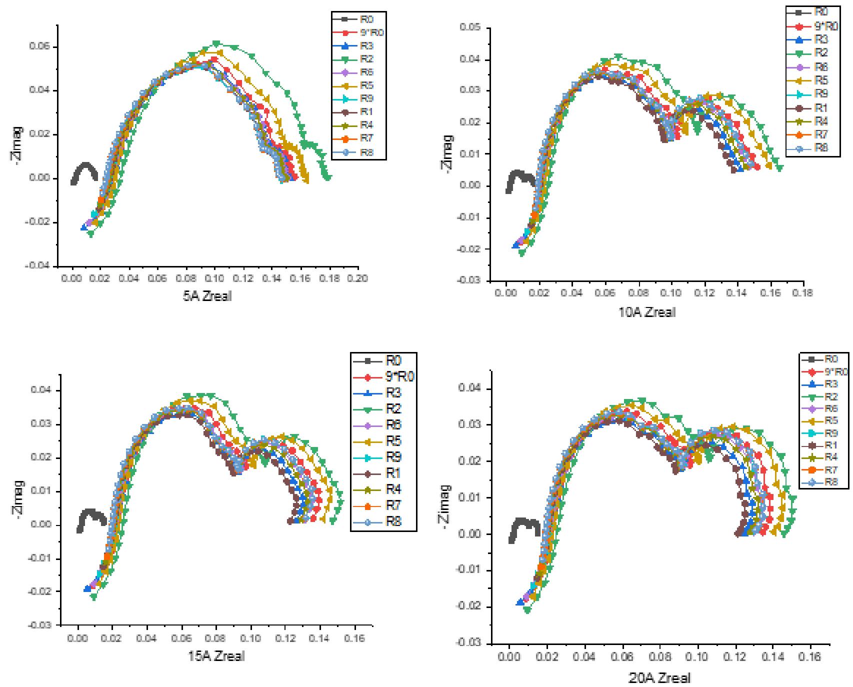


Fig 3 The cell single and segments impedance spectrum

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