Development of a prototype micro-EIT system using three sets of 15×8 array electrodes

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Abstract. We developed a new microscopic electrical impedance tomography (micro-EIT) system to visualize admittivity distributions within a miniature hexahedral container, where we place small biological samples with a background solution or gel. Each of two facing sides (left and right) of the container is fully covered by a solid metal electrode. We inject current between them, thereby producing a uniform parallel current flow along the longitudinal direction inside the container. Each of three sides at the bottom, front and back is equipped with a 15×8 array of voltage-sensing electrodes. Switching modules are located underneath the container so that we can measure voltage between any neighbouring pair of electrodes. Three switching modules are connected to a 16-channel multi-frequency EIT system to collect induced voltage data from the three sets of 15×8 array electrodes subject to the single fixed current injection. Voltage data set from 360 voltage-sensing electrodes on three sides are utilized to produce cross-sectional images of the admittivity distribution. We describe the design and construction of the new micro-EIT system. Our future work should include development of a customized image reconstruction algorithm for the micro-EIT system and experimental validation.

Keywords: Micro-EIT, admittivity image, biological tissue sample

1. Introduction

To monitor the behavior or functionality of a biological tissue and cells, many researchers have developed numerous techniques using miniature semiconductor sensors, optical sensors and so on [1,2]. Microelectrode systems have been successfully used to investigate growth and migration of monolayer cell cultures. By applying a voltage across a sample and then measuring the current flow using different kinds of measurement method, various cell functions have been monitored [3-5]. Methods such as scanning impedance imaging have also been applied to cell-culture studies [6,7]. Impedance monitoring is potentially useful in monitoring cell proliferation, morphology and motility since impedance changes occur in cells in response to physical and also chemical changes. Impedance changes could be monitored during cell growth and used to provide information about cell functions [8]. Responses to the stress or chemical changes can be measured in terms of impedance changes. Impedance imaging could be used in developing an automated cell based system for detection of infection or effects of drugs against diseases [9].

We have developed a microscopic impedance imaging system called the micro-EIT system with a...
goal to noninvasively visualize admittivity distributions of miniature biology tissue samples and cell cultures. As a prototype of a true micro-scale admittivity imaging system, we constructed a micro-EIT system with three sets of 15×8 electrodes. The system is based on the lately developed parallel multifrequency EIT system KHU Mark2. We describe its development for detecting impedance changes related with cell growth and other factors.

2. Methods

2.1. System design
The prototype micro-EIT system is based on the KHU Mark2 EIT system as illustrated in figure 1. It includes a main controller, a digital backplane, impedance measurement modules (IMM), a switch controller, an analog backplane, switching circuits and a sample container with current-injection and voltage-sensing electrodes.

![Figure 1. Structure of micro-EIT system.](image)

2.2. Sample container
The sample container has voltage-sensing electrodes on three sides. On each side at the front, bottom and back, there are 15×8 array electrodes. The total number of voltage-sensing electrodes is 15×8×3=360. Each electrode is coated with gold and has a diameter of 2 mm. The electrodes are placed on a 28×50 mm² rectangular substrate and are separated by a gap of 2.54 mm as shown in figure 2. Though this sample container is not suitable for microscopic imaging, we decided to use it for preliminary testing of our micro-EIT system.

![Figure 2. Sample container with three sets of 15×8 array electrodes.](image)

2.3. Switching method for selecting a pair of voltage-sensing electrodes
We are aiming to measure induced voltage at any pair of neighbouring electrodes. Uniform parallel current flows in the sample container since we inject current between large current injection electrodes at the right and left sides. The voltage distribution inside the container with a fixed shape and size is determined by its internal admittivity distribution. We need to obtain as much information on the
admittivity distribution as possible from three sets of 15×8 voltage-sensing electrodes.

We divide voltage-sensing electrodes into two groups. The first group includes all electrodes from the 1st to 8th columns. The second group includes electrodes from the 9th to 15th columns. In each group, we measure voltages between pairs of electrodes from the even and odd columns. As the 16th column in the second group, we used the common ground electrode for current injection. We implement a switch controller using a CPLD (EPM3064A, Altera, USA) which controls multiplexers (ADG708, Analog Device, USA). It chooses 15 electrode pairs among the 360 electrodes at the same time for simultaneous acquisition of 15 complex voltage data.

We select one electrode per column along transversal direction in the electrode array. It means 24 electrodes can be chosen in one column. Every 8 electrodes are selected by one multiplexer which needs 4 control signals. Every column (8×3 electrodes, one column of container) needs 24 control signals. This allows us to select any neighbouring electrode pair as shown in figure 3(a). To minimize the number of switches and control signals, we used the same control signals for odd and even numbered columns in both groups. The total number of control signals is 48, which are supplied by the switch controller. Though we can choose only a neighbouring measurement pair along the longitudinal direction, we can choose any pair in the transversal direction. Figure 3(b) shows an example of such switch selection.

Among 16 IMMs in the 16-channel KHU Mark2, the 16th IMM is used to inject current between two facing sides (left and right) of the container. We also measure voltage between current-injection electrodes using the voltmeter in the 16th IMM as shown in figure 3(c).

![Figure 3](image)

**Figure 3.** (a) Selection of an electrode pair in the 1st to 15th columns. (b) Example of an electrode selection. (c) Current injection using the 16th IMM.

### 3. Results

Figure 4 shows the constructed sample container for the micro-EIT system based on the KHU Mark2 16-channel EIT system. From preliminary testing, we could observe voltage changes from the container filled with saline as we move an anomaly in it. We plan to perform numerous imaging experiments for static, time-difference and also frequency-difference imaging.

### 4. Conclusion and discussion

We described a design of the micro-EIT system based on the parallel multi-frequency EIT system KHU Mark2. The sample container with electrodes and switching circuits is the key component of the micro-EIT system. The present implementation incorporates 360 voltage-sensing electrodes within the
50×44×28 mm³ container. We could control all switching operations using 48 control signals. We plan to apply a customized image reconstruction algorithm to acquired data from the micro-EIT system to validate its performance. We will fabricate a miniaturized sample container for true microscopic admittivity imaging in our future study.

**Figure 4.** Developed sample container to be used with the 16-channel parallel multi-frequency EIT system KHU Mark2.

**Acknowledgment**

This work was supported by the SRC/ERC program (R11-2002-103) of MOST/NRF.

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