Optimal Design of Microscopic Fluid Chip System Used for Scanning Electron Microscopes

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Abstract
SEM with functionality of liquid sample imaging can provide further information such as the cells containing labelled proteins in biological application, nanoparticle synthesis and electrochemical deposition in material science and so on. Moreover, the values of the SEM can also be added by introducing Microscopic Fluid Chip system with continuous buffer liquid pumping, stable thermal control, multiple gas mixtures and real-time monitoring. In this paper, the design of Microscopic Fluid Chip system is presented. The design was also validated by microflow measurements and pressure monitoring and helps integrate the microflow and thermal control modules for SEM.

Introduction
Scanning Electron Microscope (SEM) has been widely applied to different scientific areas including biology, life science, material development, etc. Traditionally, SEM requires a vacuum chamber to allow the emission of the electron beam and to minimize the scattering from other sources. To observe wet samples through SEM, a Si₃N₄ membrane supported by silicon microchip was adopted as a Microscopic Fluid Chip. The chip has broad applications and advantages because of homogeneous material in composition, high resistance to erosive liquids and easy manufacturing. With Microscopic Fluid Chip system, the live tissues in fully hydrated conditions after fixation and staining can be visualized. It would be particularly valuable when applying to the analysis of lipid membranes in cells as they are difficult to preserve during dehydration and washing steps [1]. Moreover, the processes of sample preparation and visualization can also be more efficient by using the Microscopic Fluid Chip system developed by ITRI. In materials science, SEM with the Microscopic Fluid Chip system can provide further understanding of the reactions in energy materials, for instance, the examination of failure modes of batteries during cycling and the development of new materials and microstructures for energy storage. Materials scientists can also be beneficial from both the spatial resolution available with liquid samples in the SEM and the temporal resolution that allows reaction kinetics and mechanisms to be deliberated. Furthermore, electrochemical processes would be an excellent demonstration by using a Microscopic Fluid Chip system filled with an electrolyte and electrodes in the SEM chamber. The liquid movement, Brownian motion and diffusive phenomena in the restricted volume of the Microscopic Fluid Chip system can help better understand the dynamic behavior of particle growth and deposition and consequently develop the quantitative models [2].

Results and Discussion
The Microscopic Fluid Chip system design contains microflow module, thermal module and optional gas mixture module. The system has been commercialized as shown in Fig. 1. It has delicate manufacturing sample holder with an installed microscopic fluid chip, an easy-to-use controller used for precise temperature and microflow control. Additionally, it also has a wireless control panel and makes the users easily adjust the experimental conditions without staying close to SEM all the time. During the design process of Microscopic Fluid Chip system, an innovation methodology, TRIZ (Fig. 2), was used
to satisfy the flexibility and user-friendly at the same time. To further study the flow field and pressure inside the Microscopic Fluid Chip, CFD software (ANSYS Fluent v14.0) was chosen. The pressure is critical because the flowrate needs to be maintained at very low condition in order not to break the membrane. To increase the flowrate and reduce the costs of the flow elements, the geometry and flow conditions were optimized based on the skills of Design Of Experiments (DOE). After simulation as shown in Fig. 3, the pressure on the membrane was found to be decreased dramatically as the diameter of the outlet was enlarged up to 500 um. The results demonstrated the inlet flowrate still could be raised and the size of the Microscopic Fluid Chip system has the space to be further reduced. When the optimization of the Microscopic Fluid Chip system design was achieved, the validation was conducted by testing in microflow calibration system shown in Fig. 4. The tests were undergone three times and the flowrate was increased from 0.8 mL/h to 120 mL/h. At the meantime, the results observed by optical microscope showed that the thin film stayed complete even the flowrate were increased up to 120 mL/h. Finally, the Microscopic Fluid Chip system demonstrates its great capability in SEM and provides the clear images of polystyrene particles in the liquid as shown in Fig.5.

References