CURRENT AND HEAT TRANSFER PATHS IN NANOWIRE NETWORK STRUCTURE

Kazuya Tatsumi

Department of Mechanical Engineering and Science, Kyoto University
tatsumi@me.kyoto-u.ac.jp

ABSTRACT

Distribution and paths of transport phenomena - electric current, fluid flow, heat transfer, mass transfer - in complex system and network structure are important subjects in engineering. An object can be considered as a continuum if the area of interest consists of sufficient number of elements and components. However, the paths and characteristics of transport phenomena deviate from continuum as the number of elements decreases. Such transient state appears when the scale of the object decreases or when the number of components in the integrated system increases. Examples of the former system is nanoscale materials, and the latter can be semiconductor devices, microfluidic devices, microchannel heat exchangers, fuel cells, etc. In such systems, it is essential to understand how the current, fluid, heat, and species form their transport paths, and the relationship with the overall system characteristics to provide insight into the design and development of applications. This further requires the understanding of the difference between the continuum and single path, and the development of a mathematical model which represents the transient state between the two. In this talk, I will introduce the measurement of the current and heat transfer in nano-wire network to discuss and demonstrate the characteristics and modeling of transport phenomena in the network structure. Numerous studies have been made for the electrical and thermal properties of a nano-wire, single contact point characteristics, and overall pattern based on the assumption of isotropy especially in the fields of electronics and semiconductor. However, the distribution characteristics of current and temperature, and the effect of anisotropy, variance of contact characteristics at junctions, and number density of nanowires on the distribution have not been investigated and are still unknown due to the measurement difficulty. We have been able to measure the temperature distribution of Ag nanowire (Ag-NW) network caused by the Joule heating when electric current was applied using the "thermoreflectance imaging" technique. We further obtained the current of the Ag-NW and the contact resistance at the Ag-NW junctions by performing an inverse analysis for the temperature distribution of the measurement based on numerical computation. The non-uniform characteristics of the temperature, current, and contact resistance and their effects will be introduced in the talk, together with the statistical models we have developed based on the modified Poisson distribution and Weibull distribution that can represent the relationship between sheet resistance and number density of the Ag-NWs, and the probability density function of the temperature.

BIOGRAPHY

Dr. Kazuya TATSUMI is Associate Professor of Mechanical Engineering and Science, Kyoto University. He received a PhD from Kyoto University in 2003, and worked at Osaka Prefecture University from 2003 to 2006 as Assistant Professor and returned to Kyoto University in 2006. The specific areas of interest are convective heat transfer, heat exchanger, microfluidic devices for medial and chemical applications, and micro-nano heat transfer in electronic devices. His research interest includes, flow and heat transfer characteristics of network structures, nano-scale measurement of thermo-characteristics, non-Newtonian fluid flow, control of transport phenomena and particle/cell motions in microchannel flows, and development of microsensors. Dr. Tatsumi is recipient of 2023 HTSJ Scientific Contribution Award, 2023 JSME Outstanding Paper Award, and contribution awards from JSME (2021) and HTSJ (2016).