主 論 文 の 要 約

論文題目　Nanowire Structures Embedded in Microfluidic Channels for Biomolecules Manipulation and Analysis （ナノワイヤ構造体を組み込んだマイクロ流体チャネルによる生体分子の操作と分析）

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論 文 内 容 の 要 約

This thesis proposes the biomolecules manipulation and analysis based on nanostructure and nanomaterial. The objective in this research consists of 3 parts 1) nanopore DNA sequencing (chapter 2-3), 2) nanowire growth techniques (chapter 4-6) and 3) DNA elongation, separation, filtration by nanowire structure embedded in microfluidic channel (chapter 7-10).

In Chapter 2, the Electrode-embedded Nanopore (EN), which is the next generation DNA sequencing, has been introduced to sequence the DNA oligomer. We fabricated 0.8 nm Au electrode gap by electromigration breaking technique on Si substrate. EN provides us to know the sequence of DNA oligomer by the electron tunneling current measurement during translocate through the nanopore.

In chapter 3, micropillars were putted in front of nanopore to elongate λ DNA (48.5 kbp)
before in translocate to 50 nm nanopore on Si substrate. We could detect the DNA translocation by measure the blocking current during DNA pass through nanopore. However, it still difficult to elongate long DNA molecule because we could observed the different level of blocking current from DNA folding during λ DNA translocate at nanopore. Thus the separation and elongation of the DNA molecules is required.

In chapter 4, we synthesized ZnO nanowire by hydrothermal method to control the anisotropic nanowire growth in c plan. We found that the

concentration of Zn ionic species play an important to control the growth direction of nanowire. This strong concentration dependence on the crystal plane is understood in terms of a difference between (0001) plane and (10-10) plane at a critical concentration for a nucleation.

In chapter 5, we investigated and optimized the Vapor Liquid Solid (VLS) nanowire growth techniques to control the crystal phase of metal oxide material. By vapor flux control, we could vary the crystal phase of nanowire from Rutile phase (SnO2) to Fluorite phase (ISO) and Bixbyite phase (ITO). We found that metastable ISO nanowires has resistivity range2/2 of 10-4 Ω.cm.

In chapter 6, the resistivity of ITO nanowire has been reduced by controlling of component of Sn in In2O3 target material under VLS nanowire growth mechanism. The resistivity of ITO nanowire which growth through Au catalyst differ from ITO thin film due to the nucleation probability of liquid-solid (LS) interface.

In chapter 7, we have demonstrated self-assembly nanowire structure, which is bottomup approach nanostructure, embedded in microchannel as spot-array structures for single molecule DNA manipulation. The T4 DNA (166 kbp) could elongate by nanowire spot array structure more than 80 % of its contour length. We also demonstrated the DNA separation by nanowire spot array and random growth nanowire in microfluidic channel. Consistent with our results, spot-array nanowire structures have a feasibility to integrate with other nanostructures to detect biomolecules such as nanochannel or Electrode-embedded nanopore.

In chapter 8, three-dimensional (3D) nanowires structure devices have been developed for DNA electrophoresis to overcome the limitation of separation range and save the analytical time of DNA molecules. The 3D nanowire structures can be synthesized by decorating Au catalyst on the nanowires by sputtering and growing the branch of nanowires by VaporLiquid-Solid (VLS) technique. This method allows researchers to control the pore size between nanowires by increasing the number of nanowire growth and to determine a suitable growth time for the size of DNA molecules. This rigid network structure enables analysis of DNA under applied DC electric fields for a large DNA size range (100 bp – 166 kbp) within 13 s, which are much wider and faster conditions than those of any existing methods.

In chapter 9, we also interesting to apply the highly dense 3D nanowire structures to separate the protein molecules which is much more complex and smaller than DNA molecules. We could separate 6 fragments of small DNA molecule (50 - 1000 bp) within 50 s. Interestingly, the 5 mixture of SDS modified - proteins (20 - 340 kDa) were separated within 5 s, and 0.1 - 1 kb RNA ladder was separated within 25 s by the highly dense 3D nanowire structures devices under applied DC electric field. Based on our concept, the controlling 3D nanowire pore size by nanowire growth cycle can be applied to separate DNA, protein and RNA molecules in short time.

In chapter 10, self-assembled nanowires was growth in microfludic channel to use as filter for ultrafast DNA filtration with high throughput. The λ DNA can filter from T4 DNA within 1 s at the entrance of self-assembled nanowires filter. We observed the single DNA molecule migration behavior and we found that λ DNA could pass through the nanofilter while T4 was trapped.

Chapter 11 is conclusion of the biomolecule manipulation and analysis based on nanostructure and nanomaterial. This research provides the new approaches, which has a potential to reduce the analytical time and analysis cost for biomolecule analysis.