# 論　文　要　旨
# Thesis Abstract

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主論文題名　(Title) Microstructure Fabrication for Photonic Nanojet Applications and Surface Modification in Polymers by Proton Beam Writing
陽子線描画による フォトニックナノジェット 応用のためのポリマーマイクロ 構造作製と表面改質

内容の要旨　(Abstract)

Proton beam writing (PBW) has been considered one of the next-generation lithography methods in micro/nano fabrications. At Shibaura Institute of Technology, the proton beam writing has been applied to various fields of study ranging from materials sciences, semiconductors, microelectronics, and radiation effects. Due to the feasibility of producing a smooth microstructure on typical resists with a controllable depth of penetration. It is convinced that it would be applicable for micro-optical applications and micro modifications. In this thesis, the first study on the proton beam optimization was executed by the data analysis of the user records which have been typically used for maintenance purposes only. Multiple parameters, such as beam uniformity and beam flux, can influence the beam quality for microfabrication which requires expertise. Therefore, this optimization will enable the PBW user to obtain the optimal set of parameters.

Secondly, polymethylmethacrylate (PMMA) positive resist was used to fabricate microcylinder and hollow microcylinder structures for the purpose of optical applications. The light interaction with microstructures has theoretically proved the possibility of focusing plane waves to a high-intensity beam spot with sub-wavelength beamwidth and several-wavelength long named photonic nanojet (PNJ). These fabricated structures were subsequently characterized by the in-house confocal laser microscope system at Mie University. The successful formation of the PNJ was achieved and its characteristics were analyzed from both measured and simulated results by means of finite-difference-time-domain (FDTD) numerical method. Effects of geometric configurations as well as surrounding medium were investigated experimentally. After that, further analysis of other parameters such as PMMA wall and surrounding refractive index was done. The design of a hollow microcylinder is predicted to perform below diffraction limit and provide more parameters to be optimized although the experimental proofs were still facing challenges.

Lastly, the micro modification by the high-energy protons in the common non-resist polymer was also investigated since the localized effects by the protons with the beam scanning would provide a range of applications. The micro crater-like structure was formed in linear low-density polyethylene (LLDPE) film. The proton-induced chemical changes of this structure were analyzed spectroscopically and morphologically. The transition between roughened surfaces to crater-like structures was found to be fluence-dependent. The linear increase of the depth profile by the focused proton beam may be useful for polymer science and engineering.

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