Fundamental Research on Waveguide Fabrication for Future Photonic Circuits

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論 文 内 容 の 要 旨

Thesis Summary

The reliance and demand for ever increasing data in the current information age in the field of information and technology (ICT) is ever increasing. With new development and proliferation of connected devices and services such as the internet of things and high definition content, the global internet traffic is expected to surpass 3.2 zettabyte per year by 2021. This extraordinary increase in data consumption however increases the energy footprint of ICT and it is expected to consume 10% of electricity generated worldwide while at the same time contributing to an increase of 5% of direct global CO_2 emissions. This puts a severe strain on the energy and power requirements of ICT devices and systems. Rather than the actual computation of data, more than half of the energy consumed is due to interconnects that transfer data and information from one location to another. Therefore, one of the main research topics to improve energy efficiency is by integrating new logic and device architectures and applying novel integration schemes. Towards this aim, one of the main research topics undertaken and is presented in this thesis is a photonic integrated circuit. Photonic integrated circuit combines the high speed benefits of monolithic integration of photonic devices along with high data processing of electronic devices to realize higher bandwidth, lower footprint, lower power consumption and higher power efficiency to meet the ICT demands.

Two different but interrelated topics for photonic integrated circuits are investigated. The first topic is for a monolithically integrated light source or laser where the novelty of Ge as the material of choice for the photonic integrated circuit is discussed. For the second topic, a multi-layer stacking for sol-gel SiO_2 is developed for cladding and passivation layers of optical waveguides. The fabrication issues and fabrication techniques related to both of these topics are researched and developed in this thesis to realize the aim of photonic integrated circuits

For the first topic, a novel CHF_3 inductively coupled plasma (ICP) based dry etching method is proposed for accurate etching of Ge waveguides. CHF_3 ICP based dry etching produces excellent anisotropy along with good selectivity with regards to regular polymeric photoresist, which leads to the elimination of the issue of under-cut. As a result, an almost vertical sidewall angle of 85 degrees with an etching rate of 190 nm/min was realized with a relatively high selectivity ratio of 5:1 against regular photoresist. The accurate dry etching and near vertical sidewall achieved enables precise fabrication of Ge waveguides and can improve the performance of Ge based lasers and other Ge devices.

For the second topic, a multi-layer stacking scheme using a sol-gel SiO_2 fabrication technique was developed towards stacking thick layers of >0.8 µm for cladding and passivation layers of optical waveguides. The multi-layer stacking scheme resolves peeling and cracking issue due to high stress observed in thick single layer sol-gel SiO_2 and this was accomplished through exploiting a new fabrication technology consisting of an annealing and O_2 plasma fabrication process. Through multi-layer stacking of sol-gel SiO_2, thicker cladding layer of 3.5 µm were obtained. A high resistivity of $>6.6 \times 10^{13}$ Ω/m was also obtained indicating the suitability for sol-gel SiO_2 for passivation layers. Furthermore, optical confinement characteristics were also confirmed with an amorphous-Si core layer with a propagation loss of 10 dB/cm. This demonstrates the potential of sol-gel SiO_2 to realize cladding and passivation layers for the fabrication of optical waveguides.

The fundamental research on waveguide fabrication technologies for both the accurate etching of Ge as well as the multi-layer stacking scheme using a sol-gel SiO_2 technique for optical waveguides cladding and passivation layers may enable the realization of future photonic integrated circuits.