論文 / 著書情報
Article / Book Information

題目(和文)	3次元光インターコネクトに向けたシリコングレーティングカプラの研究
Title(English)	Study of Si Grating Couplers toward 3-Dimensional Optical Interconnect
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出典(和文)	学位:博士（学術）, 学位授与機関:東京工業大学, 報告番号:甲第9696号, 授与年月日:2014年12月31日, 学位の種別:課程博士, 審査員:西山　伸彦,荒井　滋久,水本　哲弥,宮本　恭幸,廣川　二郎,裏　升吾
Citation(English)	Degree:, Conferring organization: Tokyo Institute of Technology, Report number:甲第9696号, Conferred date:2014/12/31, Degree Type:Course doctor, Examiner:,,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

専攻： Department of	電気電子工学	専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of	(Philosophy)
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

In this thesis, the multi-stacking process of a-Si:H waveguides and optical devices such as connection of those multi-layered waveguides were investigated for the realization of 3-dimensional (3D) optical interconnects.

In chapter 1, as an introduction of this thesis, interconnections composed of optical devices are explained. Conventional electrical interconnect is now approaching their performance limit as the speed and amount of the transmitted data are grown and will grow constantly. Instead of the conventional electrical interconnect, an optical interconnect can provide a high speed and low power-consumption solution. As an on-chip and on-board interconnection, silicon photonics attracted much attention for its characteristics such as small foot print, cost-effective approach, and CMOS compatible process, etc. Among Si-based materials such as c-Si and poly-Si, only a-Si:H is back-end process compatible material since it can be deposited at 300℃ which is necessary for monolithic integration of optical devices on LSI chip. Moreover, by stacking a-Si:H and SiO_2 alternatively, multi-layered optical interconnects can easily be realized for higher transmission density.

In chapter 2, the fabrication process of a-Si:H and SiO_2 multi-layer structure and a demonstration of low-loss multi-stacked waveguides are presented. If we consider the multi-stacking of optical layers, degradation of the surface roughness could be a serious concern. In order to achieve low-loss a-Si:H waveguides at the multi-stacked waveguides, the process pressure was reduced from 130 Pa to 30 Pa and the surface roughness (root-mean-square value) of 2nd a-Si:H layer was improved from 1.06 nm to 0.30 nm. Even the 3rd layer showed the surface roughness of only 0.52 nm. Next, the propagation loss of the multi-layered waveguides were measured. The propagation losses of the 1st c-Si, the 2nd, and the 3rd layer a-Si:H waveguides were 1.6 dB/cm, 3.8 dB/cm, and 3.7 dB/cm, respectively.

In chapter 3, the inter-layer grating couplers are numerically investigated. As a vertical coupler between multi-layered waveguides, inter-layer grating coupler without metal mirrors are designed. Full etched gratings are used for this design in order to simplify the structure and the fabrication process. The peak coupling efficiency of the designed inter-layer grating couplers is 19%. Then, in order to increase the coupling efficiency, metal mirrors are introduced to the inter-layer grating couplers. The coupling efficiency for the inter-layer grating couplers with metal mirrors is estimated to be 90%. Additionally, inter-layer apodized grating couplers with metal mirrors are designed for the layer-distance independent operation. The output mode-profile of the grating coupler are tuned to be symmetric shape in propagation direction. The coupling efficiency of more than 90% is maintained for a wide range of the inter-layer distance up to 4 μm.

In chapter 4, the experimental results including fabrication and coupling efficiency measurement of the inter-layer grating couplers and high-speed data transmission through inter-layer grating couplers are shown. The coupling efficiency of the inter-layer grating couplers with metal mirrors was 83% which was almost 4 time higher than that of without metal mirrors. Finally, high-speed data transmission through the inter-layer grating couplers with metal mirrors was demonstrated. Clear eye openings were confirmed at the data rates up to 50Gbps which indicated there was no degradation of signal even with reflections at the metal mirrors.

In the chapter 5, other application of grating couplers for 3D optical interconnect are presented. As an optical I/O of the 3D optical interconnect, a grating coupler for the fiber to waveguide connection is designed. As an apodization of grating, 4 arrays of holes are introduced instead of gratings of short groove length for the practical structure considering the fabrication process. The minimum groove length of 100 nm is successfully designed with 150 nm of the hole diameter. The coupling efficiency is 87.1% and it drops to 80.6% in the case of the same design without holes which only had 15 grating periods. Based on the above designed grating with holes, the fiber grating coupler was fabricated. The distance from the metal mirror to the grating was 915 nm and there was 2~8% difference in the designed and fabricated values of duty ratio which were responsible for the slightly-low measured coupling-efficiency of 70%. Then, the integration of long-wavelength VCSEL on the Si substrate was considered for the light source of the 3D optical interconnect. The target design was to use Si high-index-contrast grating (HCG) as a reflector of one side mirror of VCSEL. The structure of HCG was not fully optimized yet, the reflectivity of 99.4% was obtained in the 3D-FDTD simulation.

As a summary, the possibility of the a-Si:H optical devices as 3D optical interconnects have been discussed in this thesis. Low loss multi-stacked a-Si:H waveguides were demonstrated with a loss of 3.7 dB/cm even for the 3rd layer a-Si:H waveguide. The coupling efficiency of more than 80% was demonstrated by the inter-layer grating couplers with metal mirrors and calculated coupling efficiency of 90% was maintained for the inter-layer distance up to 4 μm by introducing an apodization of the grating. Also, the coupling efficiency of 70% was demonstrated for the grating coupler between single-mode fibers and a-Si:H waveguides. Finally, in order to integrate VCSELs on a Si substrate, a Si HCG structure of high reflectivity was reviewed.

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