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チップ上における高密度波長多重通信のための物理蒸着による窒化シリコンプラットフォームに関する研究

A Silicon Nitride Platform by Physical Vapor Deposition for Dense Wavelength Division Multiplexing on Chip

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[Introduction to PVD-SiN$_x$ platform] Silicon on insulator (SOI)-based Si photonics platform is so far well studied taking advantages of its CMOS-compatibility. However, silicon is not an ideal platform material for dense wavelength division multiplexing (DWDM), since its large thermo-optic coefficient (TOC) and its strong optical nonlinearity at ~1550nm. Silicon nitride (SiN$_x$), on the other hand, is a promising platform material because of its negligible two-photon-absorption, and for its smaller TOC than that of silicon. The allowable bending radius of SiN$_x$ waveguides should be small enough to integrate it on a chip. To build high quality SiN$_x$ films for waveguides, chemical vapor deposition (CVD) methods have been used. The drawback is H contamination leading absorption at ~1520nm, and H evacuation requires a high annealing temperature over 1100°C. This makes impossible to implement the CVD film deposition process in the back end of line. The present study demonstrates that SiN$_x$ deposited by physical-vapor-deposition (PVD) process at room temperature is free from H-associated absorption, and that thermal resonance shift of the present SiNx rings is < 11(pm/K) and is further reduced to < 5(pm/K), employing upper cladding of an epoxy resin.

[Device fabrication] 650nm-thick SiN$_x$ film was deposited onto 15µm-thick SiO$_2$ film on Si wafer. The deposition process was PVD and electron cyclotron resonance (ECR) CVD. 1µm-wide waveguides and ring resonators were fabricated. The sample with spin-coated UV curable epoxy as upper-clading were also prepared. Optical transmission measurement was performed to obtain resonance spectra where the chip temperature was controlled by a Perlite element.

[Results and Discussion] Fig. 1 shows typical transmission spectra of these waveguides. The absorption peak of N-H bonds (~1520nm) is not completely eliminated by anneal at 900°C, whereas as-depo PVD sample is free from N-H absorption. Fig. 2 shows resonance peaks of ring resonators at various temperatures.SOI ring is also plotted for comparison. The TOC for each core material are calculated from peak shift, and summarized in the Table. 1 below. PVD- and CVD-SiN$_x$ rings show excellent thermal stability, i.e., thermal shift is less than 100GHz (0.8nm). Nearly athermal behavior, i.e., 5pm/K is achievable using an epoxy resin (dn/dT=-5.8×10^{-4}/K) as upper cladding. As in Fig. 3, the strong light confinement in Si incurs unfavorably wavelength dependent of athermalization [1]. SiN$_x$ on the other hand, provide a higher stability in TOC wavelength because of its weak light confinement.

[Acknowledgment] Facility and equipment for fabrication are provided by VDEC, at Takeda building clean room.

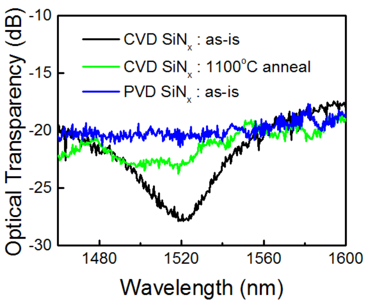

Fig. 1 N-H absorption of the film

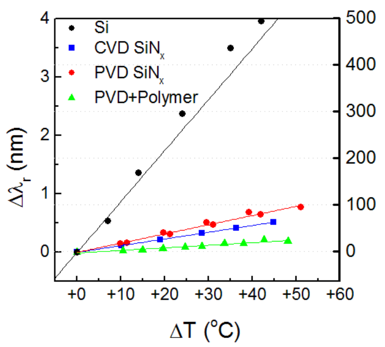

Fig. 2 Peak shifts of the ring resonator

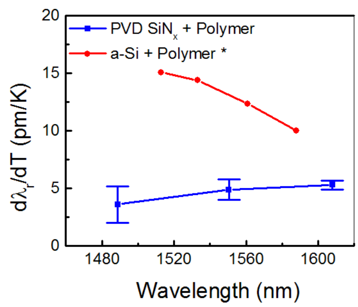

Fig. 3 Wavelength dependency on shifts
*data on literature[1]

Core Material	Si	CVD-SiN$_x$	PVD-SiN$_x$	PVD + Polymer
Peak Shifts (pm/K)	46	11	15	5
TOC ($\times10^{-4}$/K) of the core material	1.74	0.18	0.24	

Table.1 Obtained TOC of materials in this study.

[1] Vivek Raghunathan et al., *Optics Express* **18**, 17-17631(2010)