Fabrication and Characterization of Silicon Nitride Grating Coupler: Bridging Filtering and Broadband Coupling with 45% Efficiency

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Abstract:

Here, we are reporting a uniform grating coupler on Silicon Nitride platform which acts as a filter when acting as an input grating coupler and as a broadband grating coupler as output coupler with around 45 % efficiency.

Introduction:

Broadband grating couplers offer significant advantages over edge couplers due to their improved grating efficiency and enhanced alignment flexibility. Grating couplers based on Silicon Nitride (SiN), especially in the near-infrared range, hold great promise for a wide range of applications, including communication, high-speed optical switching, filtering, and sensing. In our research, we introduce an innovative grating coupler design capable of efficiently in-coupling light into six distinct peak wavelengths, while our out-coupler provides a broadband spectrum. A schematic representation of this novel grating coupler is presented in Figure 1. These modes are the result of guided mode resonance (GMR) when the specific grating condition is met [1]. GMR-based devices find applications in various fields, including filtering, sensing, and communication [1-2].

$$n_{avg} < \sqrt{(n_c \sin\theta)^2 + (m\lambda/\Lambda)^2} < n_w \quad (1)$$

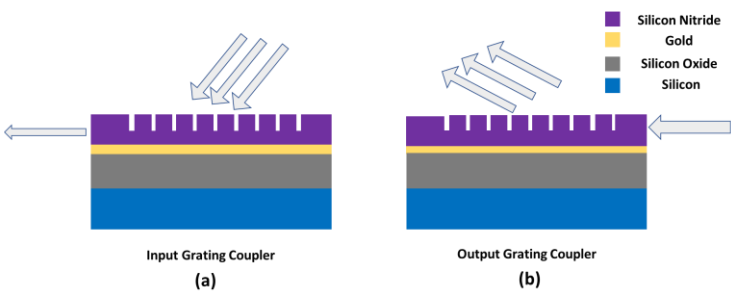

Figure 1: Schematic of SiN Grating Coupler (a)input (b)output

Simulation and Analysis:

The simulation of the grating coupler is carried out using the Finite Difference Time Domain (FDTD) method to determine the transmission characteristics, either for the input or output. The specific simulation parameters are provided in the table below.

Waveguide Parameters	Height(nm)	Width(nm)
SiN Left Waveguide	140	250
SiN Right Waveguide	900	250
SiN Base Waveguide	900	250
SiO_2 Layer	2700	-
Gold Mirror	150	-
Silicon Substrate	4000	-

Table 1

Grating Parameters	Values
Width	250 nm
Tooth Angle	90^0
Etch Depth	150 nm
Duty Cycle	0.6
Period	400 nm
No. of Periods	44

Table 2

The parameters were fine-tuned to achieve the highest possible coupling efficiency for both the input and output gratings. The transmission plots of the simulated couplers are depicted in Figure 2a and 2b, illustrating this optimization process.

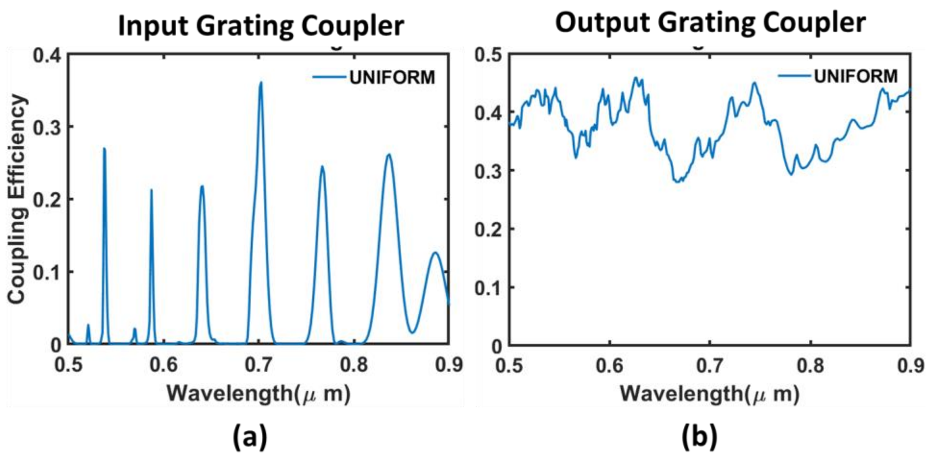

Figure 2: Transmission of SiN Grating Coupler (a) input (b) output

Fabrication Steps:

Figure 3(i) illustrates a fabrication process flow involving a two-step lithography process. The initial step begins with Silicon wafer preparation, which includes piranha cleaning. Subsequently, SiO2 is deposited on the wafer using Plasma-Enhanced Chemical Vapor Deposition (PECVD), followed by the deposition of gold via Sputtering and SiN through PECVD. These depositions occur sequentially.

Following the material depositions, the waveguide and tapering region are defined using E-beam lithography, utilizing negative photoresist MAN2403. The second layer, which consists of the grating layer, is patterned using CSAR. Optical, SEM and AFM images are provided as a visual reference(Refer Figure 3(ii)), allowing insight into the final structure created through this process. The setup depicted in Figure 4 is employed for characterizing the fabricated device.

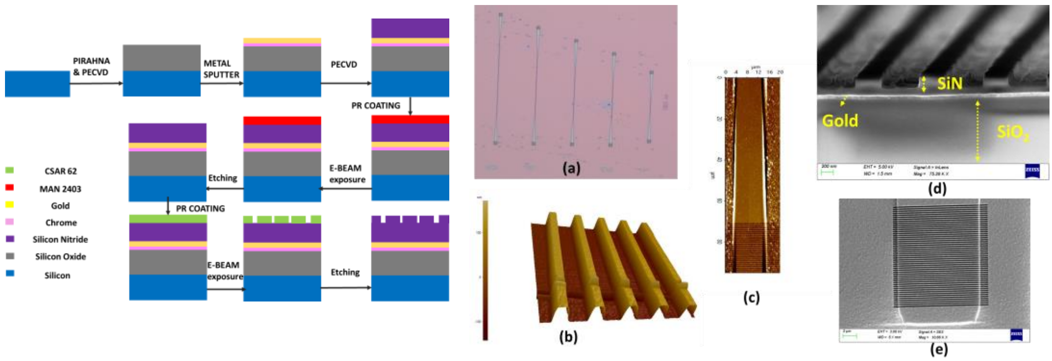

Figure 3(i) Fabrication Steps of SiN Grating , (ii) Optical, SEM and AFM images of device

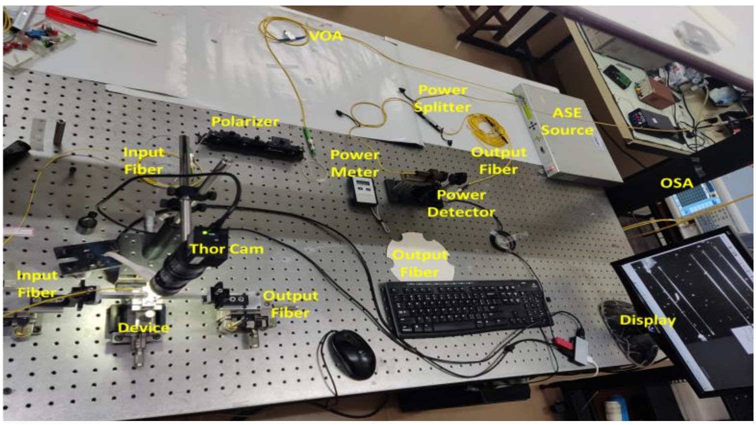

Figure 4: Characterization Set up

Conclusion:

This grating coupler devices fabricated for operation in the visible region offer versatility with numerous applications. They find significant utility in wavelength filtering, which serves various essential roles in imaging devices, sensing, and optical communication. For instance, in optical wireless communication systems, these grating couplers can be employed to efficiently couple light into optical fibers or waveguides, enabling high-speed data transmission and reception.

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