Development of fabrication process of Planar Light-wave Circuit (PLC) : Optimization of the fabrication process of planar light-wave circuit by Hybrid Sol-Gel methods

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Abstract

We report on the optimization of the fabrication process of hybrid sol-gel thin film deposition to produce low cost 1 × 16 splitters for optical communications. We learn that sol-gel film thickness is dependent upon the spinning speeds and viscosity of the sol-gel solutions and refractive index upon the dopant concentrations of Al and Zr in the sol solutions. We could find the optimized physical conditions to achieve the desired thickness of core and cladding layers. We will further carry out the fabrication and measurements of insertion loss, polarization dependent loss (PDL), etc. for the performance of fabricated splitter devices.

1. Objectives and Background

The conventional method of thin film deposition is mostly based on three ways : FHD (Flame Hydrolysis Deposition), CVD (Chemical Vapor Deposition) and inorganic Sol-Gel Deposition[1]. FHD method is to get SiO_2 burnt and powdered to deposit the thin films but this method turned out to be inefficient because of the difficulty of thickness control and fabrication process. CVD method is better way to control the film thickness and refractive indices, but processing itself is expensive and thickness is only about a few micrometers by deposition, which is inefficient for massive fabrication. Sol-gel is a cheap method to produce thin films but deposited film thickness is only a few micrometers and prone to be cracked by inorganic stress and tensile properties of ceramic films. All of these methods have disadvantages to be deposited only a few micrometers by single process, so several times of processes have to be performed to generate desired film thickness of 6 ~8 μm of core and 10~15 μm of cladding layers for the PLC (Planar Lightwave Circuit) such as optical splitters, AWGs (Arrayed waveguide gratings). Also the process temperature about at 1600 °C, where the hydrolysis densification forms, is high enough for the films to be cracked.

To avoid these drawbacks and improve film fabrication productivity, organic-inorganic hybrid type sol-gel method has been utilized. Addition of organo-silicate in the inorganic sol eases the control of thickness and uniformity of deposited thin film due to the improvement of endurance of stress relaxation because the organic moiety is intrinsically flexible. By single process the film can be deposited up to ~8 μm and uniformity can be controlled with high accuracy. Film cracking is also considerably reduced because the sol-gel process is carried out at room temperature.

Furthermore, simple photo-lithography makes the desired patterned splitters because UV-cured area is polymerized and other areas can easily be removed by solvents like acetone. Therefore hybrid sol-gel method eliminates conventional dry etching process and therefore reducing the production costs.

2. Results

Sol solution has been spin deposited on the 4" silicon wafer by spin coating machine (Karl Suss) and baked about 30 minutes on the hot plate at 100 °C. Entire area of silicon wafer is continuously UV illuminated (MA6) and finally thermal-cured again on the hot plate at 160 °C. The processing equipment, spin coater, is relatively cheap

and operation is easy and can achieve film with thickness up to ~15 um by single deposition process.
We learned that film thickness is dependent upon the spinning speed and viscosity of the sol solutions. As the spin speed increases, film thickness decreases. This is shown in the Figure 1. As the viscosity of sol solution decreases, uniformity of film thickness is improved [2], [3]. When the impurity concentration increases (Al, Zr), the refractive index increases because the Si-O-Zr oligomer controls the refractive index. As the sol solution is diluted, the refractive index hardly changes because the Zr (or Al) concentration is not changed by dilution.
From our experiments, we could achieve 6 μm core layers and 15 μm cladding layers which are typical for PLC type waveguides. We are going to utilize 1×16 splitter mask and photo-lithography to make a pattern. We will also carry out packaging and finally measure the optical performances such as insertion loss, polarization dependent loss (PDL), etc. The schematic diagram of the 1×8 splitter mask is shown in Figure 2.

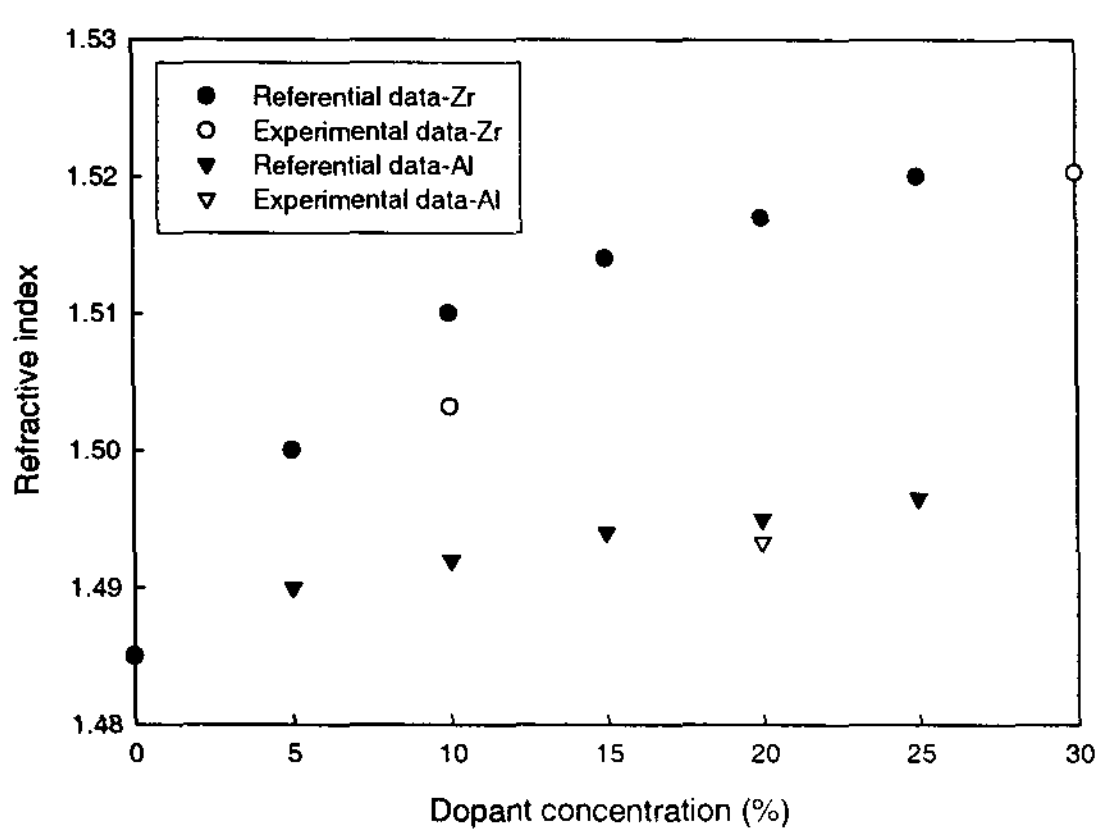

Figure 1. Variation of refractive index of film as a function of impurity concentration.

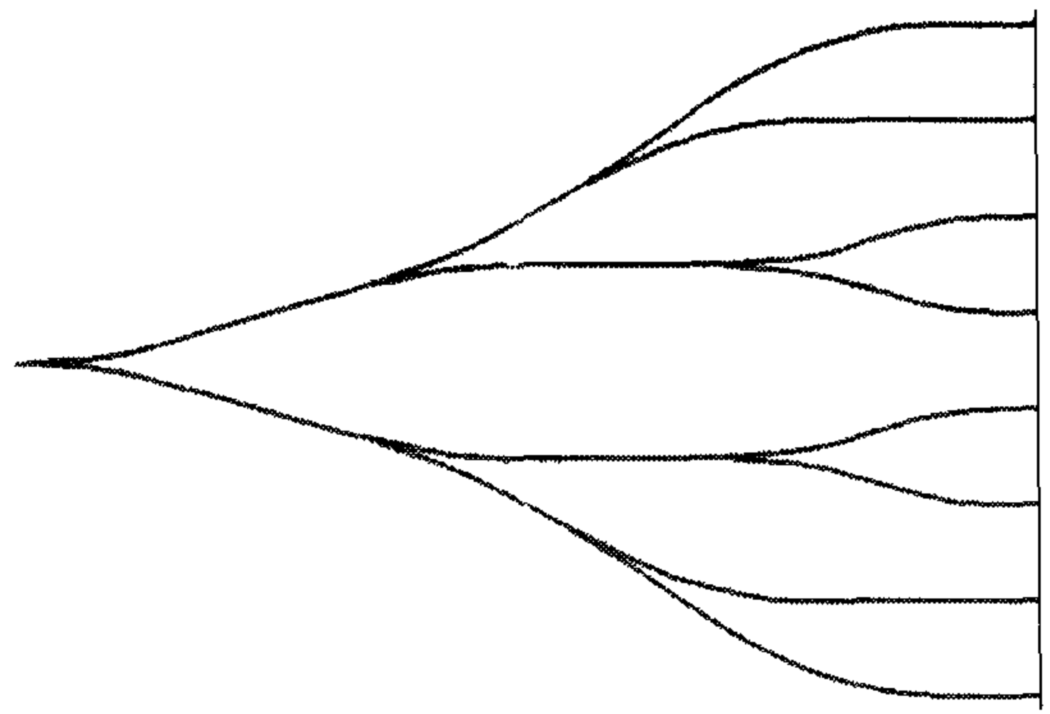

Figure 2. The schematic of 1 ×8 splitter

3. Impact

Recently optical communication has drawn much attention and demand from the consumers and political, financial supports from the government. Many universities, national laboratories, industries are now developing various kinds of components for optical communications and systems. In this work, we are developing 1×8, 1×16, 1×32 optical splitters especially for the FTTH (fiber-to-the-home) optical netwrks.
Hybrid sol-gel method has been proved to be an excellent way to produce thin film deposition for the planar light wave at a low process, low cost and high performance with low insertion loss, low PDL. This method is a promising and will provide a powerful process to produce highly efficient and cheap products.

4. Acknowledgements

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5. References

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