FP6-2002-IST-1-002131

PICMOS

Photonic Interconnect Layer on CMOS by wafer-scale integration

STReP - Specific Targeted Research Project

IST – Information Society Technologies

D5.1 - Delivery of PECVD deposited waveguides to WP3 and WP4

Due date of deliverable: M18 – Date: M21

Start date of project: January 1, 2004 | Duration: 36 Months
Lead contractor : STM | Revision: Final
Contribution Partners: CEA

Dissemination Level: Confidential, members of the consortium (including Commission Services)

I Public Abstract

The aim of this deliverable D5.1 was to develop an innovative approach for fabricating the optical waveguides, based on the use of PECVD materials. The rationale of such an approach is the full integration with CMOS BEOL process with a low cost deposition method. STM and CEA-LETI worked jointly one two types of materials: The first study concerned the polymer one which are widely used in interconnects as insulators and therefore promise to form a highly CMOS compatible solution. The main advantage of this approach was the in-line integration ability, especially in terms of temperature processing. The second type of materials studied was PECVD SiN for comparison between dielectric and organic. Indeed, contrary to waveguides based on Si-derived materials, which usually require thermal post treatments at a temperature too high to be carried out in presence of active components such as transistors, temperature was limited here to 400°C for deposition and annealing. This deliverable D5.1 reports only on the material studies that lead to an optimized composition material for the fabrication of low temperature optical waveguide on top of a CMOS circuit. The optical performance of the circuits is described in deliverable D5.3.

Using PECVD, amorphous carbon layers were deposited in a wide range of properties. Effect of the plasma type, power and precursor were investigated. Different chemistries were demonstrated depending on the monomer structure and plasma type (RF and LF). This study highlights the importance of the ionic bombardment obtained either by a low frequency plasma or by auto-polarisation process in a radiofrequency one. By tuning the deposition power and the type of excitation, highly crosslinked layers, showing a good thermal stability, a controlled stress and a refraction index close to 2 have been obtained. Unfortunately, the intrinsic losses of the materials are huge, especially for highly crosslinked materials. So, PECVD amorphous carbon combining a high refractive index, low intrinsic optical losses, and mechanical characteristics compatible with a back-end process integration can not be obtained. Therefore the application of these films is limited to low refractive index range applications with low integration density, which are out of the scope of the PICMOS project.

Silicon Nitride layers have been intensively studied in the microelectronics field for different applications (thin film transistor insulator or passivation layer). Besides, its high refractive index compared to SiO2 was interesting for integrated optics and has lead to the development of optical waveguides. However most of the technologies thus far proposed in literature used high temperature processing for denser layers with reduced optical losses. Most studies are based on LPCVD deposition or PECVD deposition with high temperature annealing. The originality of the work conducted here was to develop a low temperature process (<400°C) with low losses for the specified application (refractive index above 1.8 and optical losses < 1dB/cm in the NIR). PECVD Silicon Nitride is largely hydrogenated and hardly stœchiometric. Incorporation of a large amount of H or Si leads to a reduced gap. The various deposited layers were characterized by ellipsometry, IRTF and Mlines (METRICON) for loss measurement. The deposition used a mix of SiH4/NH3/N2 in a capacitive RF reactor. Starting from a typical microelectronics recipe, gazes ratio, pressure, and power were varied in order to improve the quality of the layers. An optimized composition has been determined with a medium refractive index of 1.85 compatible with the miniaturisation of optical functions. However, optical losses at 1.55µm are too high (2.5dB/cm) without a high temperature annealing in order to reduce the N-H bonds. So applications will be sought at 1.3µm (0.5dB/cm) or below in the visible range. For example, in the biology field, CEA-LETI demonstrated the optical manipulation of live cells and dielectric particles on the surface of silicon nitride waveguides. **The completion of this work has led to the delivery of SiN-waveguide circuits to WP4 and WP3 (Milestone 5.4)**