Amorphous Silicon In-line Photodetector for Integrated Photonics Applications

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We report on the tunability of the optical properties of amorphous silicon (a-Si), its integration on a photonic platform and operation as a visible range photodetector. We present the details on the experimental methods, optimization procedure, design, fabrication techniques and experimental characterization of the present photodetector operating over the optical gap bandwidth up to 700 nm wavelength.
Keywords: photonic integrated circuits, optical waveguides, optical materials, photodetectors, visible light

1. Introduction

Programmable photonics integrated circuits (PICs) are being developed for applications in many different fields, including communications, imaging, nano-particle detection, biosensing, nanomedicine. Accurate calibration and robust control of these architectures require on-chip detectors providing information on the actual state of the circuit in order to counteract any deviation from the desired working point.

Recently we demonstrated non-invasive light observation in silicon photonics devices by exploiting photon interaction with intra-gap energy states localized at the waveguide surface, operating in IR region [1]. In this work we demonstrate the feasibility of an in-line visible-light waveguide detector exploiting a thin film of amorphous silicon (a-Si) integrated on a conventional glass waveguide. The light intensity is tracked by measuring the change of the electrical conductance of the a-Si film, due to photo-generated free carriers.

2. Device fabrication and characterization

We investigated the change of the optical and electrical properties of a-Si films deposited by PECVD, keeping constant growth parameters such as the RF power (50W at 13.56MHz), chamber pressure (500 mTorr) and growth time (5 min), whilst parameters such as substrate temperature T_s, flow of the gas precursor (SiH_4) and gas carrier (N_2) have been varied. From optical ellipsometric spectroscopy and Tauc plot analysis we observed a temperature dependent red shift of k values up to a nominal one for T_s=300°C, in agreement with previous reports [2]. To further increase the optical responsivity in the visible range, k was red shifted by decreasing the N_2 flow to 50 sccm (see Fig. 1.a, $\lambda = 530nm$).

The photogeneration properties of the a-Si film were tested on the device illustrated in Fig. 1.b, where electrical contacts were realized by patterning gold pads on a 100 nm thin a-Si film deposited on a silica substrate. As shown in Fig 1.c, by illuminating the sample from the top with a green light beam ($\lambda = 530$nm) with 1 mW/mm^2 intensity, we observed a three order of magnitude variation in the conductivity of the a-Si film between illuminated and dark conditions.

As a proof of concept for integrability on PICs, we deposited a 160-nm-thick layer of a-Si on top of a silicon oxynitride (SiON) waveguide with a 2.2 x 2.2 µm core (refractive index $n = 1.527$ at $\lambda = 633$nm, see inset of Fig. 1.c). To guarantee optimal evanescent field overlap with the deposited photoconductive film, the thickness of the silica upper cladding was wet etched in buffered HF to $\sim 1\mu m$ (as shown in Fig. 1.d). After the deposition of the a-Si films, we observed a loss increase by 6 dB across a waveguide length of 6 mm (see Fig. 1.d), which is in line with the expected absorption induced by the a-Si film. These results indicate that the proposed strategy can enable the realization of compact in-line visible light detectors integrated in optical waveguides.

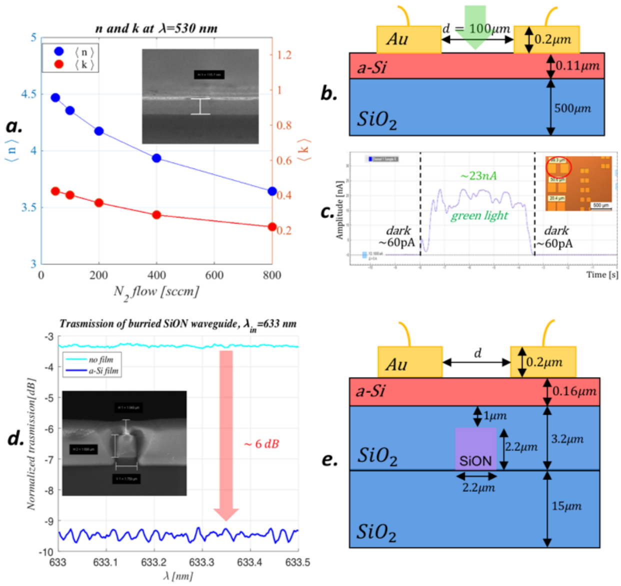

Figure 1: a) n and k at $\lambda = 530nm$; SEM image of the deposited a-Si on testing platform; b) An illustration of the testing platform; c) Photoconductivity signal at $\lambda = 530nm$; d) Transmission of SiON waveguides at $\lambda = 633nm$; SEM image of the PIC testing platform; e) An illustration of the PIC testing platform;

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