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Photonic amorphous silicon device technology

C.M. Fortmann [a,*], J. Mawyin [b], R.J. Tonucci [c], A.H. Mahan [d]

[a] *Department of Applied Mathematics, Stony Brook University, Stony Brook, NY 11794-3600, USA*
[b] *Department of Material Science, Stony Brook University, Stony Brook, NY 11794, USA*
[c] *Naval Research Laboratory, 4555 Overlook Ave, Washington DC 20375, USA*
[d] *National Renewable Energy Laboratory, 1617 Cole Blvd. Golden, CO 80401, USA*

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Abstract

Optically smooth hot-wire deposited films were characterized with respect to the photonic application by examination of the slab wave guiding of the room temperature bulk photoluminescence. Films displayed strong photoluminescence as well as strong slab wave guiding of the light to the edge. These properties are consistent with materials suitable for photonic engineering. Waveguide structures were prepared using previously described hydrogen implantation techniques and tested using novel methods. We report the first successful demonstration of refractive index engineered amorphous silicon devices.

Keywords: Photonic; Hydrogen implantation; Waveguides

1. Introduction

Hot-wire amorphous silicon materials were chosen as the basis of this work because it produces the required 1–2 μm thick, optically smooth amorphous silicon films inexpensively and quickly [1–3]. Also these films typically have high, near IR transparency due to low mid-gap defect concentrations and by our previous work found to have optically smooth surfaces. Therefore, amorphous silicon may be one of the most ideal materials by which to engineer photonic and integrated optical circuits. These devices would best operate in the near IR spectrum. Near IR light routing and transmission is the basis of the optical communication industry. Furthermore, owing to the high solubility limits of impurities such as hydrogen in amorphous silicon and the refractive index change induced by these impurities, it is possible to image a photonics technology based on hot-wire deposited amorphous silicon. Here we document some of the progress towards this goal.

2. Experiment

Three experiments provide the basis for the present discussion. The first employed a Helium-neon (~633 nm) laser illuminated 2 μm thick hot-wire amorphous silicon film (see [4] for details on film preparation) situated as shown in Fig. 1. This experiment elucidates the pertinent materials properties: sufficiently low defect density so as to

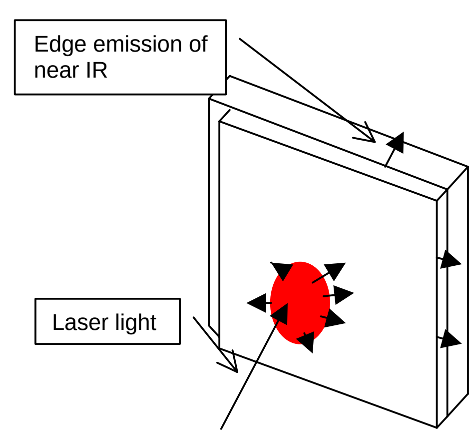

Fig. 1. Test configuration used for the slab waveguide experiment discussed below.

* Corresponding author.
E-mail address: fortmann@ams.sunysb.edu (C.M. Fortmann).

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luminescent and a sufficiently smooth surface so as to convey the sub-gap luminescence to the edge.

Waveguide structures were prepared using the masking and hydrogen implant process steps shown in Fig. 2. Hydrogen implantation was carried out at 50, 100, and 175 KeV at a fluence of 10^{18} cm^2 as previously described [3]. It is to be noted that subsequent SIMS analysis of the implanted film revealed hydrogen peaks approximately 25% deeper than anticipation based of SRIM calculations and a crystalline silicon surrogate.

The properties of implanted regions were probed by optical transmission and absorption measurement. Measurements were consistent with a band gap increase in the implanted region (expected result when bonded hydrogen increases [5]) and/or a decrease in the refractive index in the hydrogen implanted amorphous silicon regions shown in Fig. 3. Also, since the probes of Fig. 3 were carried out on different regions of the same sample; and since careful thickness measurements were taken, the optical changes were not the result of film thickness variation. Thus, it is

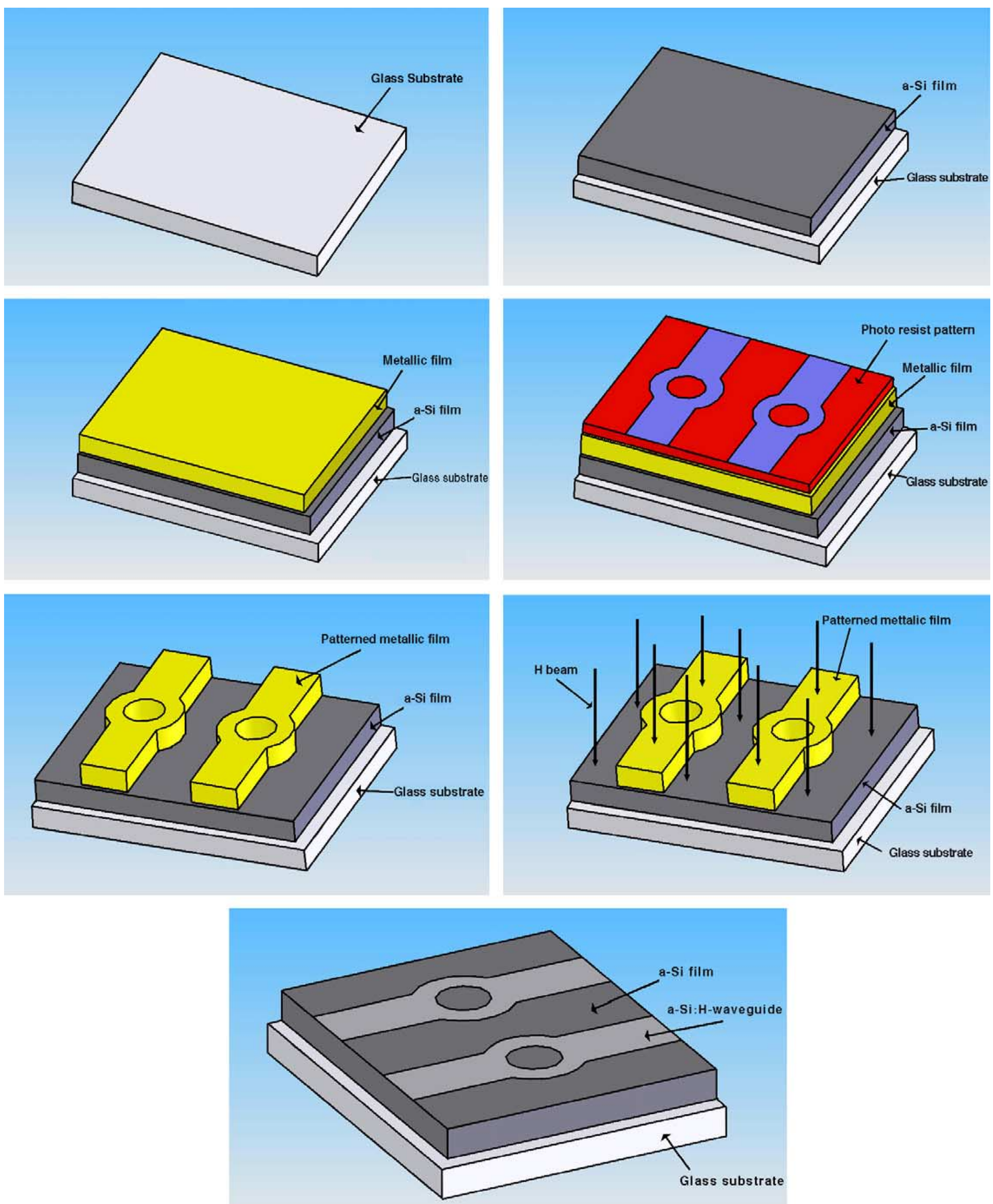

Fig. 2. Illustration of the steps used to prepared amorphous silicon-based photonic structures, devices, and circuits.