A Novel Wavelength Detection Method Based on Wavelength Absorption in Silicon

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Abstract

The modern spectrometers have indispensable dispersing elements, such as prism, diffraction grating[1]. A new filter-less method of detecting the spectrum based on wavelength absorption in silicon fabricated in CMOS technology without dispersing elements is proposed in this paper.

The light penetration depth in silicon depends on the wavelength[2], thus we can gain the wavelength spectral information by measuring the photon generated electron-hole pairs as a function of depth. As seen in the Figure 1, N-doped silicon is used as the substrate. A uniform electric field and an external uniform magnetic field are applied along the positive x direction and negative z direction respectively, as shown in Figure 1. The generated electron-hole pairs are separated by the electric field, and the electrons move along the negative x direction and holes move along the positive x direction. An external uniform magnetic field is applied, thus holes' current flow towards the electrode under the Lorenz force. P+ electrode is a heavily doped region and forms a PN junction. This junction is reversed biased in order to collect holes only. For the specific electric and magnetic field, the angle of deflection of holes' current is constant, so that the electrode could collect the holes from a specific depth.

We use the steady-state continuity equation to describe the carrier behavior under the constant incident illumination [3]. The model reveals the relationship of photo-generated carriers and penetration depth for three wavelengths, 450nm, 550nm, and 700nm, for blue, green and red, respectively. Figure 2 and Figure 3 show two situations, without and with the uniform electrical field, respectively. Both figures validate that the wavelength is distinguishable. The difference of two figures will be discussed in details in the full paper .

The generated carrier concentration is measured by electrode current. Figure 4 gives a result of current vs. wavelength modeled using the COMSOL Multiphysics® software. The details are discussed in the paper.

An external magnetic field is employed for a better sensitivity, because more generated carriers will be collected under Hall Effect. This paper gives a useful method to simulate the Hall Effect in silicon. The wavelength is distinguished by sweeping the external magnetic field. The results will be shown in the paper.

Reference

[1] Tkachenko, Optical Spectroscopy - Methods and Instrumentations. Elsevier, 2006.
[2] D. K. Schroder, Semiconductor Material and Device Characterization, 2nd ed. New York: John Wiley & Sons, 1998.
[3] S. K. B. B. J. Streetman, Solid State Electronic Devices, 6th ed. Pearson Prentice Hall, 2006.

Figures used in the abstract

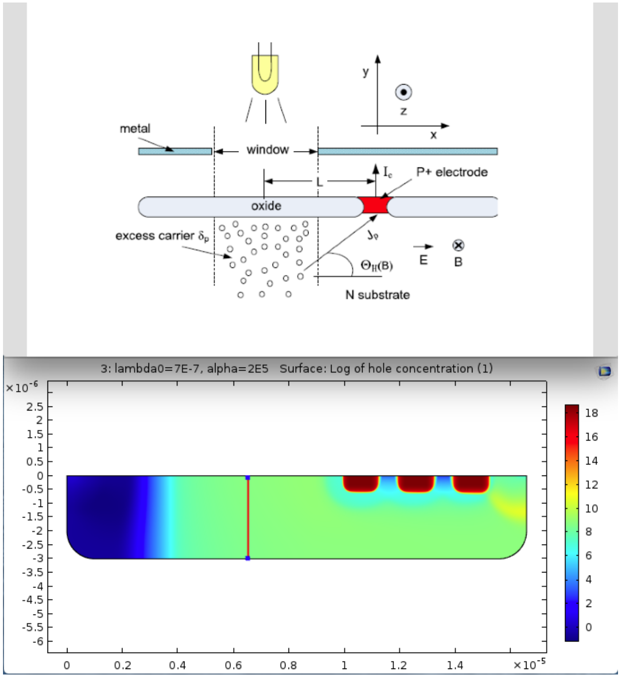

Figure 1

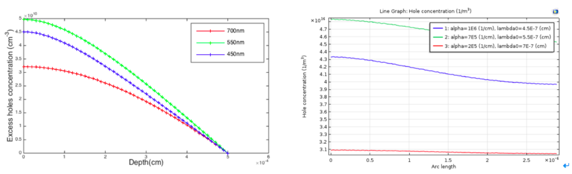

Figure 2. Photo-generated-hole profile without electric field.
Simulated by MATLAB and COMSOL

Figure 2

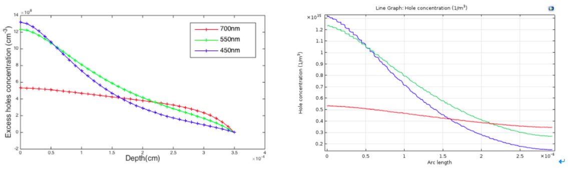

Figure 3. Photo-generated-hole profile under electric field.
Simulated by MATLAB and COMSOL

Figure 3

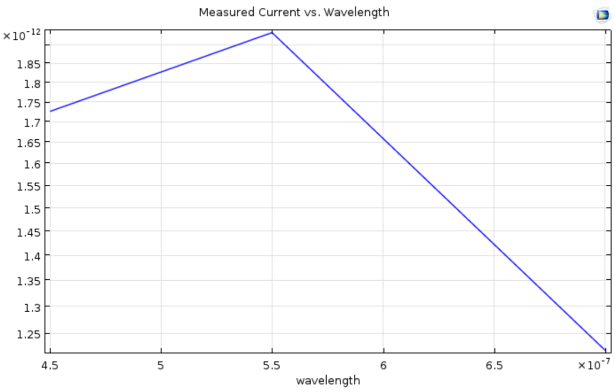

Figure 4