A SPICE Model for Silicon Photodiode

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Outline

- Silicon photodiode is fabricated for a variety of industrial applications at wavelength 640/850nm
- An advanced macro model is proposed for SPICE circuit simulation
- Model includes different geometry scalability of the photodiode
- DC and RF characterization are performed for the photodiode
- Model and measurement results are presented
- Finally, model is implemented in CMOS design kit

Photodiode

- n-well photodiode is fabricated in a 0.35µm CMOS-Opto process platform
- No additional mask steps or CMOS process changes are required
- An anti-reflection-coating (ARC) layer is deposited for the specific range of wavelength
- Cathode of the photodiode is formed by the n-well implantation on standard p-type wafers with doping concentration of 10^{15} cm-3.
- P-substrate is used as a cathode of the photodiode
- P+ epilayer is optional with cost of one additional mask

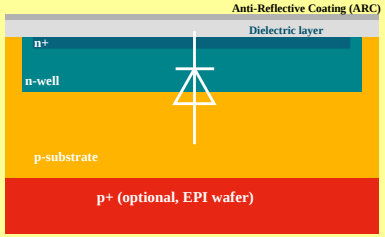
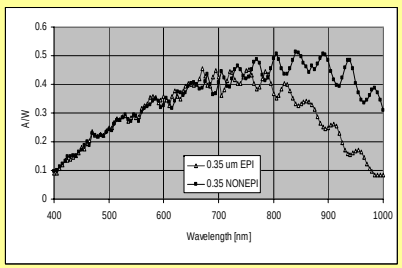


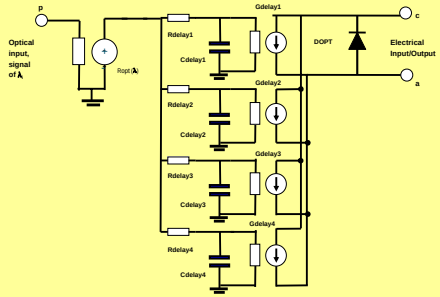
Photo Responsivity

- Optical sensitivity is measured between 400 and 1000nm for an EPI and non EPI photodiode.
- Photodiode is illuminated by white light in combination with a monochromator, which selects a narrow band of wavelengths from the source of radiation.
- In order to get the spectral responsitivity the photocurrent is measured as a function of the wavelength of the light source.
- An ARC layer on top of the standard passivation improves the sensitivity of the n-well diode.



Model Description

- Photodiode is modelled as a sub-circuit of a diode and voltage controlled current source.
- Voltage controlled current source is used for modelling the photo-current gain.
- Additionally, 4 RC networks are added in parallel to account for four time constants of the diffusion current delay under light.
- Model is scalable with the diode width (W), length (L) and number of fingers connected in parallel.



Dark Current Model

- DC current is measured using Agilent 4156 Semiconductor parameter analyzer under completely dark condition
- Measured and modelled dark current plots of different geometries of the photo diodes (W/L= 50/50, 100/100, 150/150 and 450x 50 µmxµm) for a typical wafer at T=27 °C

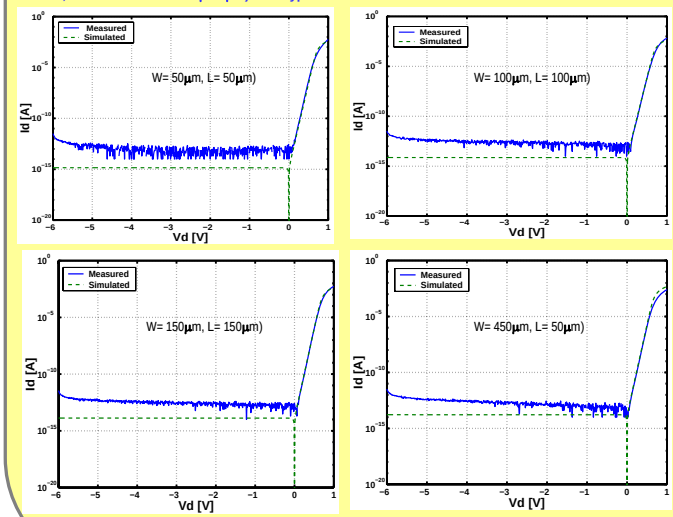
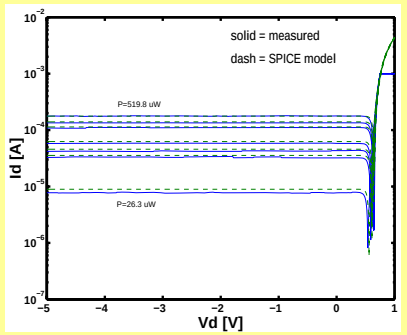


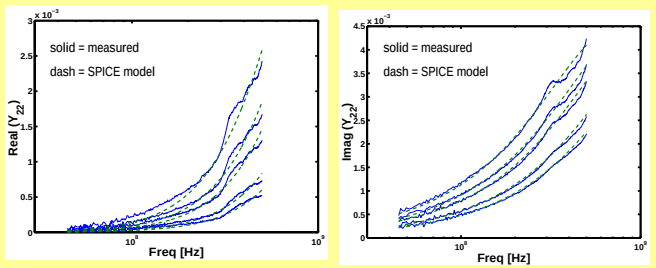
Photo Current Model

- Photo current is measured on-wafer with a lensed, multimode fiber probe using laser with wavelength of 850nm
- Photo current modelling of the photo diode (W=150µm, L=150µm) for a typical wafer under different power (26.3, 104.7, 134.9, 184.1, 334.9, 412.1 and 519.8 µW) of light (λ = 850nm)



RF Model

- RF characterization is performed for mainly focus of the capacitance modelling of the photodiode
- Measured and modelled real and imaginary part of Y_{22} of a photo diode (W= 150mm, L = 150mm) for a typical wafer under dark condition. Vd =0, 0.5, 1, 3 and 5V



Summary

- Photodiode has been fabricated in a 0.35um CMOS-Opto process
- An advanced macro model has been presented for SPICE simulation
- DC and RF measurements has been performed for extraction of model parameters
- Photodiode model shows very good agreement with measurement results
- Presented photodiode model can be implemented in any SPICE simulator and provides sufficient accuracy for low-risk design of optical ICs.

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