Device Simulation with Electromagnetic Field Propagation Models for High-Speed Image Sensors and FDA Noise Analysis

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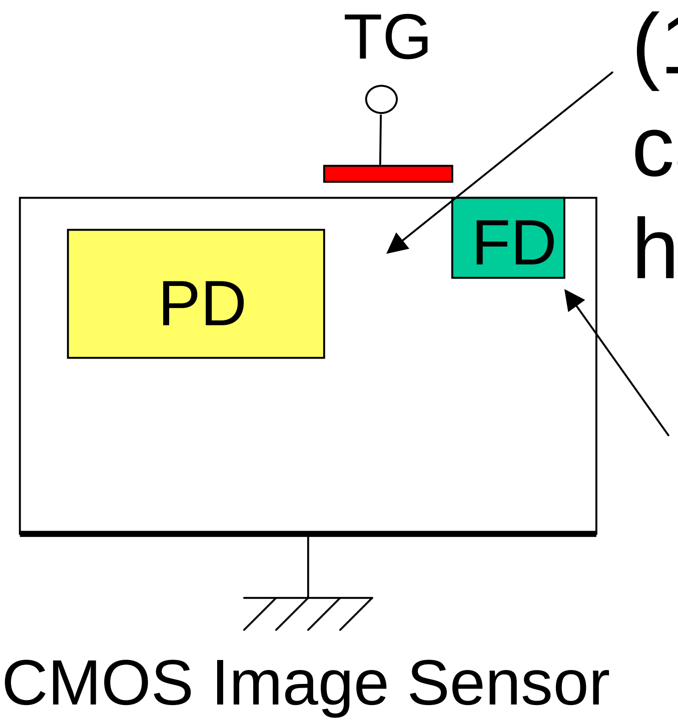
Why electromagnetic field propagation should be considered?



(1) Field propagation delay cannot be ignored in ultra-high speed image sensors

(2) FDA noise is induced by multi-reflected electric field wave packet

Are Maxwell's equations correct?

Charge conservation & principle of superposition

⇩

Carrier generation-recombination is forbidden

⇩

Image sensors cannot work

Maxwell

$$\mathbf{J} = \nabla\times\mathbf{H} - \varepsilon\frac{\partial\mathbf{E}}{\partial t}$$

$$\rho = \varepsilon\nabla\mathbf{E}$$

⇩

$$GR = \nabla\mathbf{J} + \frac{\partial\rho}{\partial t} = 0$$

Scalar field

$$\gamma \equiv \nabla\mathbf{A} + \frac{1}{c^2}\frac{\partial\psi}{\partial t}$$

⇨

QED equivalent

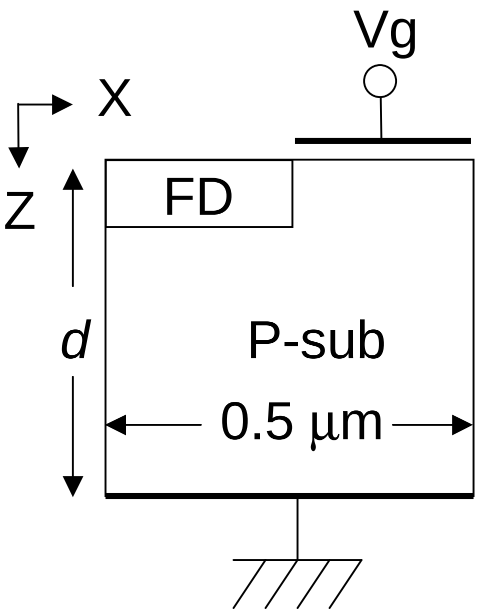
$$\mathbf{J} = \nabla\times\mathbf{H} - \varepsilon\frac{\partial\mathbf{E}}{\partial t} - \frac{1}{\mu}\nabla\gamma$$

$$\rho = \varepsilon\nabla\mathbf{E} + \varepsilon\frac{\partial\gamma}{\partial t}$$

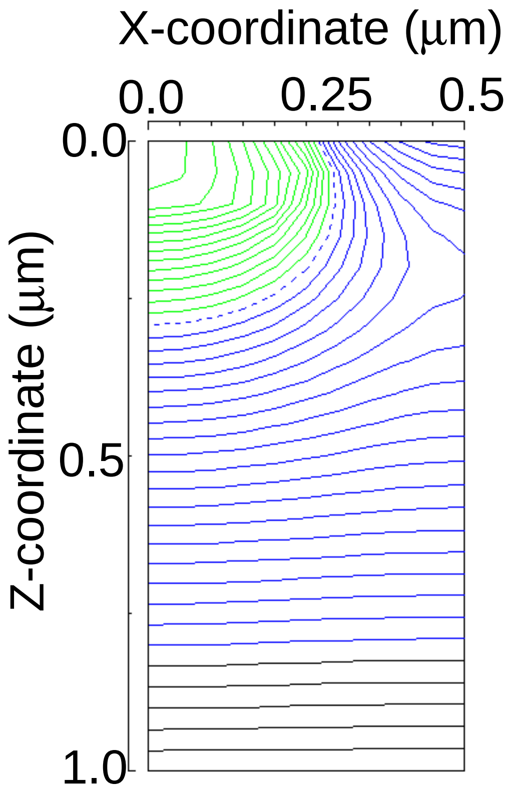
⇩

$$GR = \nabla\mathbf{J} + \frac{\partial\rho}{\partial t} = -\frac{1}{\mu}\Box\gamma$$

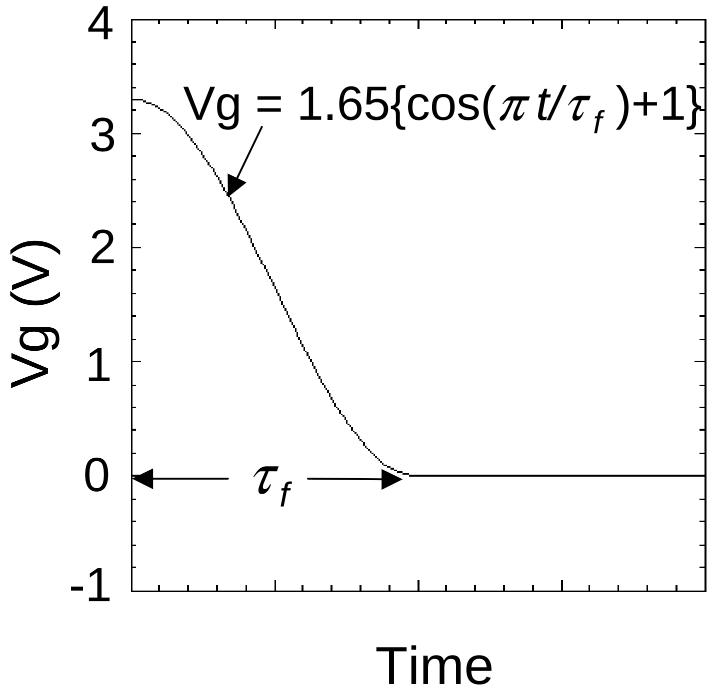
FDA Noise Analysis



Structure



Potential
(d = 1 µm)



Vg dependence on time

FDA noise dependence on substrate thickness
(Wave packet length : $\lambda_p \equiv \tau_f \; c \, / \, n_{si}$)