Abstract:

SOI-based optical devices allow for back-side illumination, and are compatible with standard CMOS processing. The absorption spectrum of SOI substrates can be tailored via modifying the device-Si layer's thickness and doping concentration. We have demonstrated that wide spectral responsivity can be achieved in photo-detectors that use a simple metal-insulator-semiconductor (MIS) structure (based on two-layer dielectric stack: a SiO2 layer, and a high-k film such as HfO2) fabricated on SOI substrates. Additionally, these devices have lower dark current, compared to their metal-semiconductor (MS) counterparts. For a moderately thick device-Si layer (~ 3 μm), the absorption in the ultraviolet (UV) regime is quite large; and the absorption in the near-infrared (NIR) regime is smaller. We have demonstrated enhanced responsivity (in NIR regime) in such MIS photodetectors due to the incorporation of Au-nanoantennas at the optical input port. These nanoantennas modify the propagation of the input optical signals, serving as an effective anti-reflection coating in the NIR wavelength range. In this regime, strong local field enhancements are present at the Au-nanodisk/device interface, further contributing to the detector optical response. The optimal antenna design and the photo-response enhancements have been calculated using detailed FDTD simulations. The maximum responsivity enhancement, 40%, was obtained at 780 nm, while at wavelengths shorter than 720 nm, responsivity is reduced due to absorption losses in the Au-nanoantennas.

For few devices (MIS devices without antennas), metal (Pt) nanoparticles have been embedded in the dielectric stack; these devices form the basis for multi-functional optically-sensitive devices. Three families of optically-sensitive devices with a high responsivity in the spectral range of 240 nm to 900 nm were studied. First, an optically sensitive NVM capacitor, where illumination increased the memory window significantly. A voltage-stress process availed highly sensitive photo-detectors with a very low dark current and a large, linear responsivity. The voltage-stressed devices also served as optically- controlled varactors with high capacitance ratios between the dark and illuminated states. The write-operation in an NVM cell can be initiated by either an electrical or an optical signal. This type of device offers, for example, a NVM functionality where, for a given sweeping voltage, the memory window width (which is a measure of the stored charge) is vastly enhanced under optical illumination. This allows for operation at low voltages which, in turn, reduces the power consumption in imaging applications. The effect of illumination on the static and dynamic properties of optically-sensitive NVMs have been studied. The dynamical properties were studied for many combinations of illumination intensities and voltage pulse amplitudes of varying durations, and different thickness of tunneling layer.

Biosketch:

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