4H-SiC epitaxial radiation detectors for harsh environments

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The 4H Silicon Carbide polytype has emerged as an outstanding material for semiconductor radiation detectors, particularly in harsh environments, due to its wide bandgap (3.27 eV at 300K), high thermal conductivity, mechanical robustness, and radiation hardness. Schottky barrier detectors (SBDs) fabricated on 4H-SiC epitaxial layers are recognized for their excellent performance in charged particle detection, rivaling silicon detectors. Figure 1(a) shows the pulse height spectrum (PHS) obtained using our Ni/4H-SiC (20 μm thick epilayer) SBD exposed to a ^{241}Am test source, demonstrating excellent energy resolution for 5486 keV alpha particles. However, their application in detecting ionizing radiation such as gamma (γ) photons and fast neutrons has been limited by the thinness and low active volumes of available 4H-SiC epitaxial layers. For effective detection of X-/γ-photons and fast neutrons, a larger active volume is essential.

Advancements in growth technologies have enabled the fabrication of radiation detectors on epitaxial 4H-SiC layers up to 250 μm thick, enhancing their applicability for penetrating radiation. Figure 1(b) shows a PHS obtained using a 250 μm thick epitaxial Ni/4H-SiC SBD. Nevertheless, utilizing the full thickness requires high biases, increasing bulk and surface leakage currents, which adversely affect detector resolution.

Chemical passivation of the semiconductor surface has proven effective in reducing leakage current and preventing breakdowns under high bias conditions. Surface passivation in 4H-SiC is typically achieved through nitrogen or hydrogen passivation. Alternatively, passivation with a thin high-κ dielectric material enhances minority carrier diffusion length, indicating reduced interfacial or surface recombination of holes.

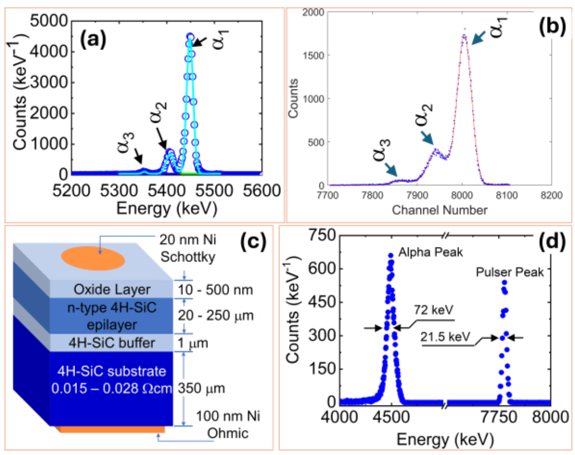

Fig. 1 PHS obtained using a 20 um **(a)** and 250 um **(b)** thick Ni/4H-SiC SBDs exposed to a ^{241}Am alpha source. **(c)** The schematic of a MOS detector. **(d)** PHS obtained using a self-biased Ni/Y_2O_3/4H-SiC MOS.

Recently, thin oxide-layer incorporated metal-oxide-semiconductor (MOS) detectors have been extensively studied. Figures 1(c) and 1(d) show the MOS detector geometry and the self-biased radiation response of a Ni/Y_2O_3/4H-SiC MOS detector. This paper reviews these findings, comparing the radiation response of vertical MOS devices with various high-κ interfacial oxides and SiO_2 layers. We discuss their potential as high-resolution and high-efficiency semiconductor radiation detectors for ionizing radiation applications, offering promising advancements in radiation detection technology.