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Engineering the electronic and optical properties of a-Se through Ge alloying for photodetection

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Amorphous selenium (a-Se) has recently gained interest as a low-cost, large-area photoconductor for high-energy physics applications, including liquid noble gas detectors. Its low leakage current, high absorption coefficient from the VUV to blue wavelengths, and ability to achieve impact ionization at low fields (~70 V/um) make it an ideal detector for low-light environments. It has also been shown to exhibit slight birefringence at room temperature, increasing under cryogenic conditions, and photo-induced angle-dependent transmission of near-infrared light when pumped with band region wavelengths, offering the potential for the directional detection of incident light. However, a-Se suffers from low carrier mobility and poor sensitivity to photon energies below 2 eV, limiting its application in high-speed detection and its versatility with various scintillators.

The alloying of a-Se has long been studied as a means to improve transport, increase stability, and tune optical properties. Previous works from this group and others demonstrate that alloying a-Se with tellurium (Te) reduces the band gap and increases sensitivity to long wavelengths, though mobility is further reduced. Alternatively, it has been shown that incorporating germanium (Ge) with a-Se can improve electron mobility while reducing charge trapping and altering the band gap; ternary alloys consisting of Ge-Se-Te allow for even more specific tuning of properties. Comprehensive studies on the effects of Ge concentration on optoelectronic properties are limited and primarily focus on applications in memory and switching, revealing a need for greater study of how we may optimize these alloys for photodetectors.

We propose to first explore the effects of Ge alloying, followed by a simulation-guided study of how Ge-Se-Te may be combined to create a high-sensitivity, fast-timing photodetector with photon incident angle detectability. In the work presented here, we discuss our preliminary findings on the co-deposition of Ge and a-Se by thermal evaporation. We explore the optoelectronic properties of GexSe1-x devices, including the optical band gap, carrier mobility, leakage, and responsivity. Preliminary evaluation from a pump-probe setup will delve into possibilities for directional detection of incident light from alloyed detectors. From this, we discuss the next steps in developing an optimized Ge-Se-Te photodetector and its potential for implementation in high-energy physics applications.

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