Modeling Dark Current in Vertically Stacked Amorphous Selenium Based Photodetectors

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Understanding of the transport characteristics and physical principles of blocking layers, including ways to control electrical hot spots, and thereby the breakdown voltage, is key to improving the performance of avalanche amorphous selenium (*a*-Se) devices. As a first step, technology for computer-aided design (TCAD) simulations are employed to identify relevant current carrying mechanisms in *a*-Se based detectors, which use a mixture of parameters obtained from experimental data, and in-house bulk Monte Carlo (MC) simulation. Based on the similarity in terms of hopping transport via localized states between disordered organic solids (molecularly doped polymers) and chalcogenide glasses (*a*-Se and As_2Se_3),[1] the bulk defect density of states (DDOS) distribution, and organic models such as the Poole-Frenkel mobility model (PFMOB) and the Langevin recombination, were used. The PFMOB is fitted with the measured field-dependent mobilities (**ref. Fig.1**).[2] We performed a calibration of the *a*-Se DDOS distribution (**ref. Fig.2**) by fitting the dark current density (J_D) in a Au/*a*-Se/Au structure with the measured values at low fields from Johanson,[3] and at high fields from Pfister (**ref Fig.3**).[4] At avalanche fields, when holes in *a*-Se undergo impact ionization, our simulations use Selberherr's impact ionization model with parameters obtained from the in-house MC simulations (**ref Fig.4**).[5] The simulated intrinsic *a*-Se layer (*i*-layer) is then used as a foundation for vertically stacked *a*-Se based photodiodes, with an *n*-like hole blocking layer (HBL) and a *p*-like electron blocking layer (EBL). Next, a structure with solution-processed quantum dot CeO_2 HBL and As_2Se_3 EBL is simulated. To validate, we compare our simulation result with the measured J_D in the *p*-*i*-*n* structure (**ref. Fig.5**).[6]

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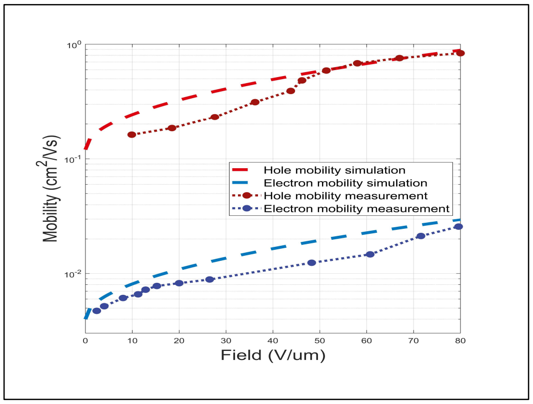

Fig.1: Mobility in a-Se using PFMOB compared with measured field dependent mobility from Juska et al. [1].

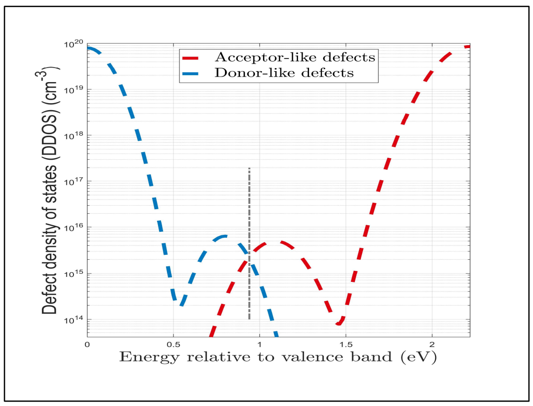

Fig.2: The donor and acceptor defect density of states distribution in the a-Se forbidden band gap.

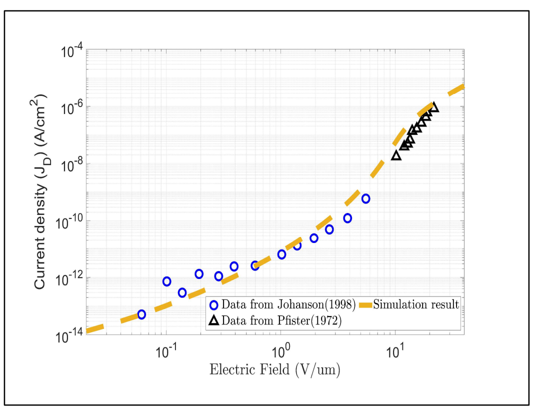

Fig.3: Dark current density as a function of electric field in Au/a-Se/Au structure. The circles are measurements at low fields from Johanson et al. [3] while triangles are measurements at high fields from Pfister et al. [4].

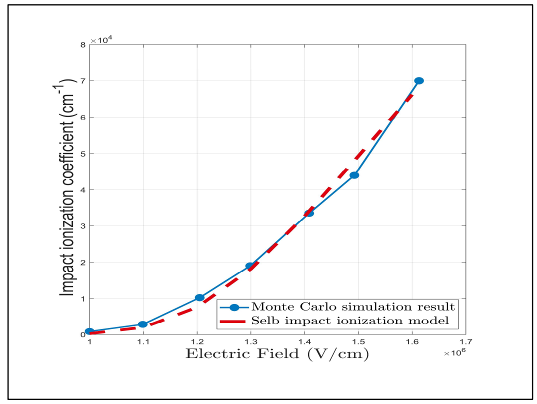

Fig.4: Field dependent impact ionization coefficients calculated from Selberherr's impact ionization model, and from Monte-Carlo simulation.[5]

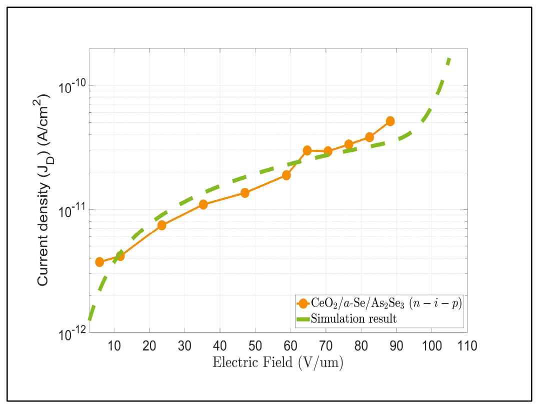

Fig.5: Dark current density as a function of electric field in p-i-n a-Se based avalanche structure with CeO_2 HBL and As_2Se_3 EBL from the simulation as compared to that from Kannan et al.[6].