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Investigation of the Hurkx model for simulation of trap-assisted tunneling in narrow band semiconductor diodes

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Interest in improvement of long wavelength infrared (LIR) detectors has spurred significant research efforts in narrow bandgap semiconductors such as the type-II band alignment InAs/GaSb superlattice material system. A critical figure of merit for these detectors is detectivity, which depends on both the responsivity of the detector and the dark current. Most recent efforts to improve detectivity for InAs/GaSb based LIR detectors focus on reducing dark currents, which can be produced by a number of different temperature dependent mechanisms including: Shockley-Hall-Read (SHR) generation, Zener tunneling, trap-assisted tunneling, and non-intrinsic shunt currents (e.g., poor surface passivation). Accurate modeling of these components is desirable both to assist in understanding the theoretical limits of the photodetectors as well as for extracting specific material properties of fabricated devices from experimental.

Tunneling, in particular, has been cited as a challenge in type-II superlattice detectors because the sources of tunneling are less well understood than in other narrow band materials like HgCdTe {Yang, 2002 #288}. Recently, it has been shown that the temperature dependence of the dark currents in a LIR type-II detector can be fit using a combination of one-dimensional common analytic dark current terms (e.g., diffusion, SHR, etc.) {Yang, 2002 #288}, which included a trap assisted tunneling term suggested by previous work on HgCdTe {Wong, 1980 #290}. For mesa device, however, two-dimensional numeric analysis would be more desirable to better understand the impact of non-ideal cases like the surface and the impact of the heterostructures. For a numeric model the trap assisted tunneling can be treated with an analytic function dependent on local variables as suggested by Hurkx et al.{Hurkx, 1992 #291}. In this talk, we investigate the Hurkx model for simulating narrow bandgap diodes from the literature. Dark current dependence on bias in InAs implanted diodes fabricated at Sandia National Laboratories can be well explained over a large voltage range with this model. Minority carrier lifetimes are extracted, ~3-6x10^{-10} sec., as a numeric measure of implant damage for different implant conditions. Furthermore, the model is used to simulate previously published type-II detector data and is found to agree relatively well with the published temperature dependence. This treatment differs from the previously published case {Yang, 2002 #288}in at least one important aspect, which is that it fits the temperature dependence of RoA with a single minority carrier lifetime (i.e., trap density and trap cross section) for components current components like SHR, trap-assisted tunneling, and diffusion. In general the numerically simulated temperature dependence agrees well and suggests that this model will be useful for future more complex simulation when extending to two-dimensional structures.

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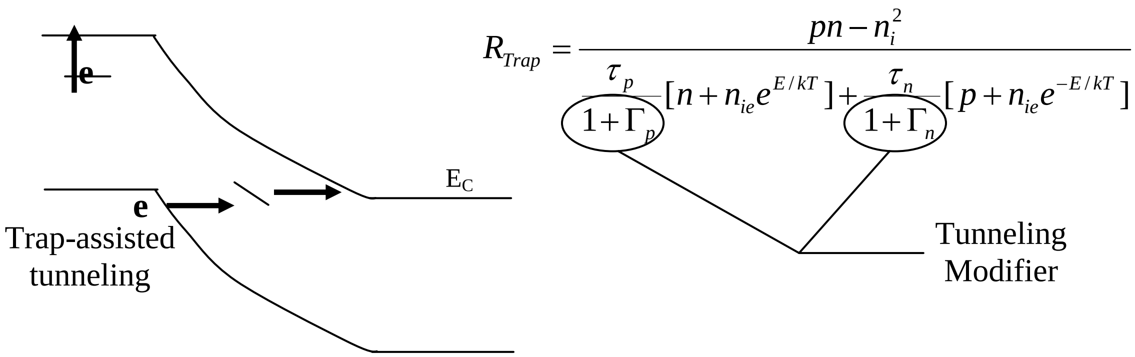


Figure 1. Schematic diagram of trap assisted tunneling and expression for Hurkx tunneling model, which modifies the standard Shockley-Hall-Read generation term.

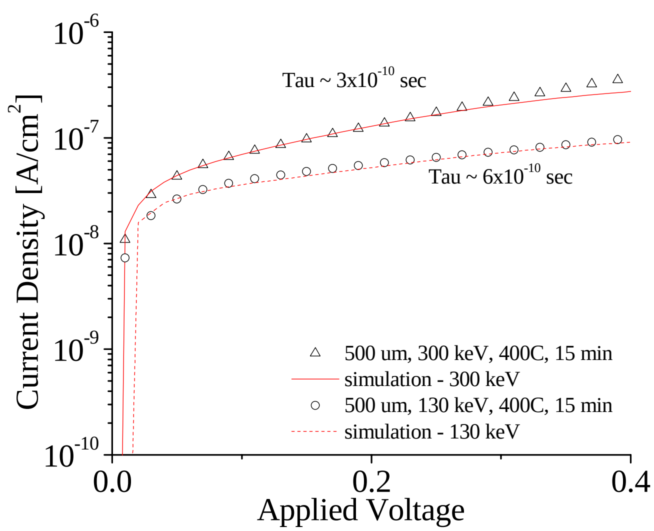
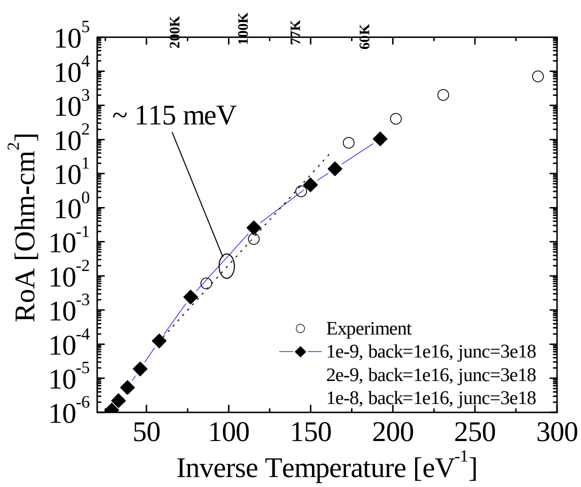
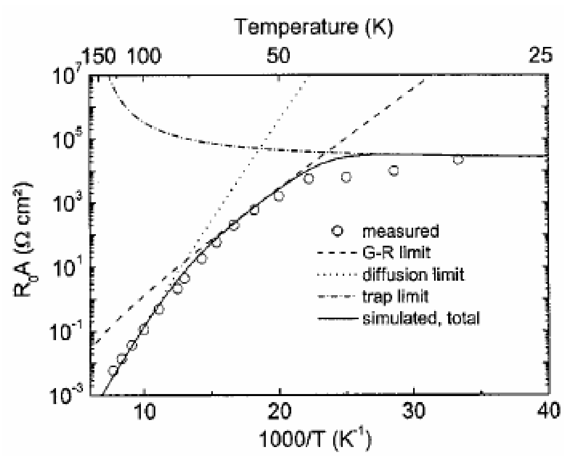


Figure 2. Experimental data and simulation of InAs n^+-p implanted diodes. Minority carrier lifetimes were used as a fitting parameter.



(a)



(b)

Figure 3. (a) experimental and simulated RoA dependence on temperature. Experimental values are from reference 1, and (b) analytic fit published in ref. 1.