Electronic stopping power of solar cell materials for protons from first-principles calculations

N E Koval[1] *, F Da Pieve[2] † and E Artacho[1,3,4] ‡

[1]CIC Nanogune, Tolosa Hiribidea 76, Donostia-San Sebastián, 20018, Spain
[2]Royal Belgian Institute for Space Aeronomy, Brussels, Belgium
[3]Theory of Condensed Matter, Cavendish Laboratory, University of Cambridge, Cambridge CB3 0HE, UK
[4] Basque Foundation for Science Ikerbasque, 48013 Bilbao, Spain

Synopsis Space radiation strongly affects both the electronics and the solar panels of a spacecraft. Usually, predictions of the degradation in a space mission are made by simplistic modeling of radiation-induced electronic excitations and atomic displacements in the target, in which several details of the structural properties are neglected. In this work, we study within the real-time time-dependent density functional theory (RT-TDDFT) the interaction of protons with Ge, GaAs, and GaInP semiconductor layers constituting triple-junction solar cells.

Solar cells are used as a primary power source in spacecrafts and are continuously exposed to space radiation. Energetic protons, electrons, and ions interacting with solar cells can create atomic defects which can reduce their performance. Thus, it is essential to study how these particles interact with the materials of solar cells. The key physical quantity that characterizes the impact of a particle onto a target is the so-called *stopping power*, denoted as $S(x) = dE(x)/dx$, which is the energy loss of a projectile, dE, per unit path length inside the target, dx. The energy of the impinging particle is dissipated into different degrees of freedom (electronic, nuclear, vibration), depending on the type and energy of the radiation and on the properties of the material it passes through.

In this work, we focus on the electronic stopping power (ESP) which is determined by electron-hole pair excitations, ionization, and collective charge (plasmon) excitations. We calculate ESP of Ge, GaAs, and GaInP for the impact of protons using RT-TDDFT and the Ehrenfest dynamics (ED) implemented in the SIESTA code [1, 2]. We consider different trajectories of the protons inside the target materials and the impact kinetic energies are in the keV range (Fig. 1).

We also characterize the radiation environment and effects (both the ionizing dose, linked to the ESP, and the non-ionizing dose, linked to atomic displacements) for exposure of solar cells during a possible Space mission scenario, via Geant4-based tools implemented in the SPENVIS interface (www.spenvis.oma.be)

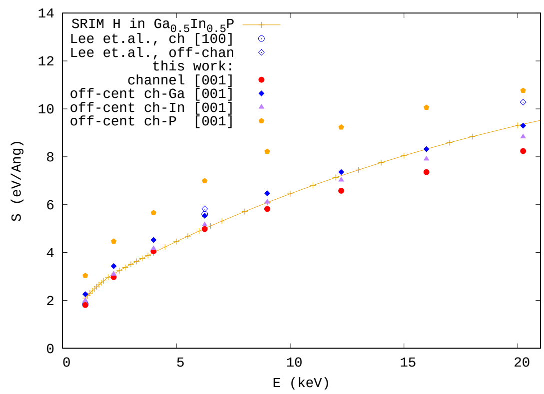

Figure 1. ESP of GaInP as a function of the incident energy for a proton moving along four trajectories in the [001] channel (filled symbols) compared to SRIM [3] (line) and Lee et.al. [4] (empty symbols).

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*E-mail: n.koval@nanogune.eu
†E-mail: fabiana.dapieve@aeronomie.be
‡E-mail: ea245@cam.ac.uk