Electron Dynamics at the ZnO $(10\bar{1}0)$ Surface

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ABSTRACT

We use femtosecond time-resolved two-photon photoemission spectroscopy (TR-2PPE) to study the dynamics of electrons excited at the ZnO $(10\bar{1}0)$ surface. Efficient relaxation of hot electrons within the Γ valley of the bulk conduction band results in sub-20fs lifetimes for electron energies ≥ 0.2 eV above the conduction band minimum (CBM). These relaxation rates, which are orders of magnitude faster than those reported for other semiconductors over the same energy range, are consistent with the emission of longitudinal optical (LO) phonons via the Fröhlich interaction. For energy at or below the CBM, the excited electron lifetime increases exponentially with decreasing energy to as long as 1 ps. Dynamics in this region can be described by electronic relaxation within a quasi-continuum of defect-derived surface states whose density decreases exponentially into the band gap. Deliberately increasing defects on the ZnO $(10\bar{1}0)$ surface drastically decreases the lifetime of electrons in this energy region. Existence of these states is consistent with observed upward band-bending and Fermi level pinning at the $(10\bar{1}0)$ surface.

KEYWORDS: femtosecond spectroscopy; hot electrons; semiconductor; time-resolved photoemission; two-photon photoelectron spectroscopy; surface photovoltage; zinc oxide; photovoltaic.