Nano-structured thin-film materials fabricated by oblique-angle deposition for energy harvesting applications

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We present nano-structured optical thin-film materials by using electron-beam oblique-angle deposition (OAD) and their applications especially for energy harvesting. At first, the performance enhancement of polycrystalline Si and III-V multi-junction solar cells by using an optimized discrete multilayer anti-reflection (AR) coating with broadband and omni-directional characteristics is presented. Discrete multilayer AR coatings are optimized by a genetic algorithm, and experimentally demonstrated by refractive-index tunable SiO_2 nano-helix arrays and co-sputtered $(SiO_2)_x(TiO_2)_{1-x}$ thin film layers. The optimized multilayer AR coating shows a reduced total reflection, leading to the high incident-photon-to-electron conversion efficiency over a correspondingly wide range of wavelengths and incident angles, offering a very promising way to harvest more solar energy by virtually any type of solar cells for a longer time of a day. Secondly, we present an array of TiO_2 nano-helixes by electron-beam OAD technique for improving the performance of dye-sensitized solar cells (DSSCs) and quantum-dot-sensitized solar cells (QDDSC) through considerable light-scattering effect, and enhanced electron transport along the near-single-crystalline TiO_2 nano-helixes. DSSC and QDSSC with TiO_2 nano-helixes array show enhanced performances such as higher light absorption and power conversion efficiency than the reference, which are attributed to the larger specific surface area, enhanced light scattering by the 3-dimensional nano-helixes array, and fast transport time of photo-injected electrons enabled by the near-single-crystalline TiO_2 nano-helixes. In addition, a number of potential applications including dichroic filters for high efficiency white light-emitting diodes and high performance chemical sensors will be discussed.