Solid State Lighting: A Bright Opportunity for Nanotechnology to Impact Energy Efficiency

Paul E. Burrows
Pacific Northwest National Laboratory, Richland, WA 99352
burrows@pnl.gov

ABSTRACT

Without artificial lighting, modern society as we know it could not function. So much of our daily life occurs under artificial lighting that we do not notice until it is gone. Beyond illuminating our work and leisure, artificial lighting is found in street lamps, traffic signals, advertising signage and video displays. It should not be surprising, then, that artificial lighting uses an *enormous* amount of energy. In 2001, for example, fully 22% of the electricity generated in the U.S. (equivalent to 8% of the nation's total energy) was used for artificial lighting, at a cost of roughly $50 billion to the consumer and 130 million tons of carbon-equivalent emissions to the environment. Most of the artificial lighting we currently use is very inefficient. Overall, it is estimated that the existing installed base of lighting in the U.S. (mostly incandescent, fluorescent and high intensity discharge) only converts about 18% of the electricity used into visible light. The rest forms heat. Solid state lighting can be defined as the direct conversion of electricity to light near room temperature in a solid. Light emitting materials can be organic (carbon-based molecular or polymeric compounds) or inorganic (for example gallium nitride or zinc oxide). In both cases, however, the efficiency of illumination-quality light generation demonstrated to date (in bright, scalable devices) is significantly lower than the theoretical limit. Historically, light emitting materials have been discovered rather than designed. Closing the gap between actual and potential performance may be enabled by recent advances in nanoscale fabrication and characterization coupled with our growing capacity for multi-scale modeling. The challenge is to design sets of materials with complementary properties of charge injection and transport, light emission and optical outcoupling to achieve 100% of the thermodynamic limit for charge to light conversion.