Pulsed Thermal Processing of Self-Assembled Quantum Dot Structures

The unique properties of nanomaterials hold immense potential to impact various energy-related technologies, such as solid state lighting, photovoltaics, and thermoelectrics. Unfortunately, the majority of nanomaterials cannot be manufactured and distributed in quantities sufficient to realize these benefits on a meaningful scale. For instance, the large scale production of nanocrystals, or quantum dots (QDs), is hindered by a high level of material defects and the propensity of the QDs to conglomerate into bundles that are not easily distributed across a surface.

Oak Ridge National Laboratory (ORNL) is developing a chemical synthesis process for the mass production of quantum dots. This process involves the engineered self-assembly of the nanocrystalline particles onto a surface with a uniform spacing. The spacing between nanoparticles is defined by the length of an organic/inorganic molecule that can be tuned to achieve optimal performance. Initial experiments have demonstrated that correctly spaced QDs can constructively interact to improve optical properties—producing a five-fold increase in photoluminescence efficiency.

Defects in the crystal structure and surface of a quantum dot act as nonradiative recombination sites, where the electron-hole pair of the semiconductor can recombine without the emission of a photon. It has been demonstrated that the number of defects in a quantum dot structure can be dramatically reduced through thermal annealing. Unfortunately, traditional annealing techniques raise the temperature of the bulk structure over long periods of time, allowing the QDs to grow and change composition via diffusion. ORNL has the unique capability to thermally anneal QD structures at extremely high power densities for very short durations. This process, called pulsed thermal processing (PTP), reduces the number of point defects while maintaining the size and shape of the original QD nanostructure.

This nanomanufacturing concept definition study will develop the quantum dot manufacturing system for roll-to-roll thin film processing for use in applications such as solid state lighting. The project will include characterization of the QD thin films, demonstration of scalability toward commercial production, and economic and energy-impact analysis of various market opportunities.

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