Transformational, Large Area Fabrication of Nanostructured Materials Using Plasma Arc Lamps

Nanostructured materials are rarely synthesized with appropriate phase and/or morphology. Most of the time, small batches are processed, such as using laser techniques over very small areas, several square millimeters. This effort will address critical additional steps over large areas of as-synthesized nanostructured materials, such as annealing, phase transformation, or activation of dopants, dramatically reducing the processing costs of the solid-state lighting and photovoltaic materials.

The concept is to employ high-density plasma arc lamp (PAL) technology to perform critical processing steps. The proof-of-principle sought in this effort is to show that PAL can realize the enhanced properties of nanostructured materials over large areas. The use of PAL will enable the integration of nanostructure features into actual materials over areas as large as 1,000 cm^2 under heating rates approaching 10^6 °C/second, unparalleled by any other technology.

Specifically, this nanomanufacturing concept definition study will focus on a ZnO system for light emitting diode (LED) applications. Nanoscale p-n junctions of ZnO have been expected to enhance the injection rate of carriers many times more than that for a planar ZnO diode, leading to higher lighting efficiency. However, the development of ZnO-based LEDs has been hindered by the difficulty in reliable generation of p-type carriers. Nitrogen substitution of lattice oxygen in ZnO has been recognized as a potential method for p-type doping of ZnO. In this work, we will explore the use of PAL for the activation of nitrogen dopants into acceptor states.

This study will include experimental and computational tasks. Material properties will be measured and PAL experiments will be conducted. The computational effort will include developing new phenomenological models and solution algorithms for dealing with the multiple-scale phenomena and ensuing effects of PAL on the final material properties. The combined modeling of multiple physical phenomena and experimental efforts will generate the knowledge necessary to the design and scale up this nanomanufacturing technique, while decreasing expensive trial-and-error procedures. The computational models being established in this project will provide a unique tool in an emerging field of significant technological importance and increase the confidence in this newly emerging technology. This project will effectively facilitate nanotechnology transfer from laboratory to industry. If this process is successful, it will demonstrate the increase in the production rates of LEDs by using PAL.

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