Pulsed Laser Deposition Technique for Controlling Micro-to-Nanoscale Thickness and Deposition Stress in Thin Films for Photonic Waveguide Engineering

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Abstract

Over the last 25 years has seen an unprecedented increase in the growth of phonic components based on semiconductor lasers, glass and polymer based optical fibres, organic LED, and solid-state lasers. Each of these components suffers from its intrinsic materials related limitations, which then limit the performance in integrated devices.

A solution to the materials limitation is to develop device fabrication strategy which then allows multi-materials processing on a substrate, without compromising the structural, thermal, and spectroscopic performances. The challenge then one confronts is that the semiconductors are grown on an MBE machine, whereas the polymeric thin film materials are fabricated by traditional spin coating. By comparison, the glass and crystal based materials are processed via sputtering, or sol-gel techniques. None of these techniques, therefore, are compatible for a single-step device fabrication, due to materials chemical and physical incompatibility. A vast majority of rare-earth ion doped glass- and crystal-based devices are often pumped with semiconductor lasers, which then suggests that the glass-semiconductor devices might perform better when structurally integrated, and that engineering such structures might lead to reduction in pump energy and high photon-to-photon conversion.

In this presentation, we explain the nano- and femto-second pulsed laser deposition techniques for controlling the structure of thin-films grown on desired silica-on-Si (SiO_2-Si), silica, and silicon substrates. Examples of materials deposition on dissimilar substrates for stress-matched waveguide fabrication are discussed and the light emission properties of rare-earth ion-doped glass, Si, polymer, and 2D-MoS_2 films are explained. The thin film stress modelling tool (COMSOL) was used *a priori* for waveguide engineering for ascertaining the extent to which the structural incompatibility, so that the mismatch strain can be minimized during deposition by controlling thickness. The structure and spectroscopic properties of rare-earth ion doped thin films on silica, polymer, and semiconductor GaAs substrates were examined in detail and are reported. We demonstrate the formation of glass-polymer super lattice structures, ion-implanted waveguide structures, and nano-silicon deposited waveguides for semiconductor integration.

The machining properties of such composite structures using femto-second Ti-sapphire lasers is also described, which clearly shows that such complex structures from start-to-finish can be fabricated using different types of pulsed lasers. The amplified spontaneous emission and gain properties of such waveguides are characterized for a range of device applications.

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