Abstract

Polariton organic light-emitting diodes (POLEDs) and polariton organic semiconductor lasers represent a rapidly evolving class of optoelectronic devices with potential use as compact, low-cost, and tunable light sources. While optically pumped polariton lasers based on organic materials have been extensively investigated, achieving electrically driven lasing remains a major challenge due to limitations in charge transport, optical losses, and thermal stability. This thesis presents a systematic study of the optimization of thermally evaporated polariton OLEDs and polariton lasers in terms of electrical performance, optical confinement, and device stability, complemented by the development of suitable measuring and driving methods for future electrically driven polariton lasers.

Polariton organic semiconductor lasers are known for achieving exceedingly low nonlinear thresholds but they suffer from low stability. Here, a stable polariton laser based on 4,4bis[(N-carbazole)-styryl]biphenyl (BSBCz) and a simple Fabry-Pérot microcavity formed by distributed Bragg reflectors (DBRs) was realized by introducing additional stabilization layers. The resulting laser achieved lasing thresholds as low as 8.9 µJ/cm^2 and operational stability exceeding 100,000 excitation pulses at three times the threshold energy. Miniaturization of the active area was further demonstrated to reduce the lasing threshold down to new record pump fluence for organic polariton lasers (0.2 µJ/cm^2) and show lateral confinement effects.

Polariton OLEDs can show angle-independent and narrowband emission but so far have not been demonstrated in the blue spectral range. In this work, high-performance blue polariton OLEDs were developed using BSBCz, the same emitter also used for the polariton lasers studied in this thesis. Device architectures were systematically optimized by electrical engineering, resulting in top-emitting structures with current densities up to 1600 mA/cm^2 and luminance levels exceeding 20,000 cd/m^2, when excited with constant current. By additional thermal engineering (employing silicon substrates) record current density and luminance values for blue polariton OLEDs were achieved (> 8000 mA/cm^2, > 120,000 cd/m^2). To address thermal degradation under high current densities and significantly improve stability, materials with elevated glass transition temperatures were investigated.

For the development of an electrically driven polariton laser, the device designs of polariton lasers and OLEDs were combined and new architectures were explored. Final devices were operated under short-pulse, high-voltage electrical excitation and achieved current densities up to 1 kA/cm^2, reaching the range estimated to be required for electrically driven polariton lasing.

These results highlight the crucial role of material selection, cavity and electrode design, and substrate choice in advancing polariton optoelectronics. The demonstrated advances provide a foundation for the integration of optimized polariton OLEDs into microcavity structures of the laser, opening pathways toward the realization of electrically driven polariton lasers.