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UC Case No. **2003-318-2**

CONFIRMATORY INSTRUMENT

Application for:	Injection Lasers Fabricated from Semiconducting Polymers
Inventors:	Alan J. Heeger, Marc Pauchard, Daniel Moses, Ludvig Edman and Martin Vehse
Provisional Serial No.:	60/454,144
Prov. Filing Date:	March 12, 2003
Serial No:	10/797,259
Filing Date:	March 9, 2004
Contract No:	F49620-02-1-0127
Contractor:	The Regents of the University of California

The Invention identified above is a "Subject Invention" under Patent Rights clause, 37-CFR-PART-401 included in Contract No. F49620-02-1-0127 with AIR FORCE OFFICE OF SCIENTIFIC RESEARCH which does not include the communications satellite paragraph of DAR 7-302.23(g).

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Signed this 28th day of February, 2005

Linda S. Stevenson

By: Linda S. Stevenson
Title: Patent Prosecution Manager
University of California
Office of Technology Transfer

INJECTION LASERS FABRICATED FROM SEMICONDUCTING POLYMERS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of Provisional patent application No. 60/454,144, filed Mar. 12, 2003.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

This invention was made in part with government support under contract F49620-02-1-0127 awarded by the Air Force Office of Scientific Research. The Government has certain rights in this invention.

FIELD OF THE INVENTION

This invention relates to the field of solid state light emitting organic polymers

BACKGROUND OF THE INVENTION

Light-emissive polymers are outstanding laser materials because they are intrinsically "4-level" systems, they have luminescence efficiencies higher than 60% even in undiluted films, they emit at colors that span the visible spectrum and they can be processed into optical quality films by spin casting.

Since the discovery of laser action in polymers in 1992 [U.S. Pat. No. 5,237,582] remarkable progress has been made in implementing semiconducting polymer materials into different resonant structures for optically pumped lasers.[U.S. Pat. No. 5,881,083 and references therein; M. D. McGehee and A. J. Heeger, Adv. Mat. 2000, 12, 1 and references therein]. The high photo-luminescence quantum efficiencies of neat films with emission wavelengths ranging over the entire visible spectrum demonstrates the importance of this class of luminescent semiconducting polymers as gain media.

Early in 1996 Hide et al. [F. Hide, B. Schwartz, M. A. Diaz-Garcia, A. J. Heeger, Chem. Phys. Lett. 1996, 256, 424] observed lasing from polymers in the solid state for the first time when they blended titania nano-particles into a MEH-PPV/polystyrene film in these lasers, the random array of titania particles scattered the light emitted by the MEH-PPV in such a way that the feedback loops needed for lasing were provided. Later in 1996, four research groups independently observed stimulated emission from photo-pumped neat films of conjugated polymers. These observations showed for the first time that neat films, which were capable of conducting current, could in fact amplify light and that it was not unreasonable to attempt to make polymer diode lasers. Graupner et al. observed stimulated emission from films of a poly(para-phenylene)-type ladder polymer (using pump-probe techniques [W. Graupner, G. Leising, G. Lanzani, M. Nisoli, S. D. Silvestri, U. Scherf, Phys. Rev. Left. 1996, 76, 847]. Tessler et al. [N. Tessler, G. J. Denton, R. H. Friend, Nature 1996, 382, 695] obtained lasing by sandwiching poly(p-phenylenevinylene) (PPV) between a dielectric mirror and a silver mirror to form a microcavity. Hide et al. [F. Hide, M. Diaz-Garcia, B. Schwartz, M. Andersson, Q. Pei, A. Heeger, Science 1996, 273, 1833] and Frolov et al. [S. Frolov, M. Ozaki, W. Gellerman, V. Z., K. Yoshino, Jpn. J. Appl. Phys. 1996, 35, L1371; S. Frolov, W. Gellerman, M. Ozaki, K. Yoshino, Z. V. Vardeny, Phys. Rev. Left. 1997, 78, 729] observed line narrowing from films of PPV derivatives that were not part of a resonant structure.

The mechanism of line narrowing was demonstrated to be from amplified spontaneous emission (ASE)[M. D. McGehee, R. Gupta, S. Veenstra, E. K. Miller, M. A. Diaz-Garcia, A. J. Heeger, Phys. Rev. B 1998, 58, 7035]. ASE occurs even when the gain coefficient is small because the spontaneously emitted photons are waveguided and thus travel a large distance through the gain medium, where they are amplified by stimulated emission.

In analogy with organic LEDs, one of the most obvious approaches to the injection laser is to use a vertical cavity laser configuration in which the active material is a thin film between two electrodes [N. T. Harrison, N. Tessler, C. J. Moss, K. Pichler, R. H. Friend, Opt. Mat. 1998, 9, 178; V. G. Kozlov, G. Parthasarathy, P. E. Burrows, V. B. Khalfin, J. Wang, S. Y. Chou, S. R. Forrest, IEEE J. Quant. Electr. 2000, 36, 18; M. A. Diaz-Garcia, F. Hide, B. J. Schwartz, M. D. McGehee, M. R. Andersson and A. J. Heeger, Appl. Phys. Lett, 70, 3191 (1997)]. Despite the fact that threshold current densities estimated from the excitation density required for optically pumped lasers have been exceeded in polymer diode structures by an order of magnitude [N. Tessler, N. T. Harrison, R. H. Friend, Adv. Mater 1998, 10, 64; I. H. Campbell, D. L. Smith, C. J. Neef, J. P. Ferraris, Appl. Phys. Lett. 1999, 75, 841] electrically pumped laser emission has not been demonstrated. The losses in the electrically pumped devices are higher than in simple photo-pumped waveguides because of two additional loss mechanisms: losses introduced by the metal electrodes and charge induced absorption [M. D. McGehee and A. J. Heeger, Adv. Mat. 2000, 12, 1].

BRIEF SUMMARY OF THE INVENTION

The present invention provides a method for overcoming difficulties associated with the losses introduced by the metal electrodes and charge induced absorption by using an architecture known as the light-emitting field effect transistor (LEFET) configuration and to utilize injection-induced amplification of the "cut-off mode" to achieve gain narrowing and lasing. In particular, solid state lasing structure is provided, comprising a field effect transistor in which source and drain electrodes are disposed on a semiconducting light emitting organic polymer forming an active layer on a gate whereby current between the source and drain electrodes defines and flows along a channel in the active layer to define a recombination and emission zone.

In a particular embodiment, a solid state lasing field effect transistor is formed of a solid, semiconducting light emitting organic polymer having a 4-level lasing energy system in which source and drain electrodes on one side and an indium-tin-oxide gate formed on the opposite side define the active layer containing the channel and recombination and emission zone. The gate is supported on a glass substrate and a SiO_2 gate insulator layer is disposed between the gate and the light emitting organic polymer.

In a further embodiment, an additional layer of semiconducting organic polymer containing polycations and counteranions (or polyanions and countercations) is disposed between the source and drain electrodes and the light emitting organic polymer, and n and p doped regions are provided therein by applying a source-drain voltage at an elevated temperature for a time sufficient to mobilize the counteranions to form p-i-n junctions upon cooling, with an n doped region in contact with the source electrode and a p-doped region in contact with the drain electrode.

In another embodiment, Bragg or other reflectors are disposed on opposite sides of the channel to provide resonance with feedback whereby to generate coherent laser light.