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- 1) Όλα τα μέλη ΔΕΠ του Τμήματος Επιστήμης και Τεχνολογίας Υλικών
- 2) Τους εκπροσώπους των Μεταπτυχιακών φοιτητών του Τ.Ε.ΤΥ
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Πρόσκληση σε Δημόσια Παρουσίαση της Διδακτορικής Διατριβής του

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(Σύμφωνα με το άρθρο 12 του Ν. 2083/92)

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θα γίνει η δημόσια παρουσίαση και υποστήριξη της Διδακτορικής Διατριβής του υποψήφιου διδάκτορα του Τμήματος Επιστήμης και Τεχνολογίας Υλικών

κ. Jayaprakash Rahul με θέμα:

«Novel approaches to robust polaritonics»

ABSTRACT

The possibility of having low-threshold, inversion-less lasers, making use of the macroscopic occupation, of the low density of states, at the bottom of the lower polariton branch, has intensified polariton research in the last two decades. State of the art devices based on this admixed quasiparticle have already been realized using GaAs and CdTe active layers, although the accomplishment of room temperature lasers has been limited by their relatively weak exciton binding energy. The high exciton binding energy and oscillator strength, as well as the advantageous relaxation dynamics of wide bandgap semiconductors, such as GaN, are well suited for room temperature polariton operation.

The up to date demonstrations of GaN based polariton lasers have used as the active layer bulk GaN, GaN quantum wells (QW's), and GaN nanowires. In the latter approach, individual nanowires are positioned in a microcavity showing remarkable polariton characteristics, but questions remain on the scalability of the approach, as well as on how to turn these nanowire-based structures into real electrically-injected devices.



The former two cases are technologically viable, but are currently limited by the relatively poor quality of the active region, due to the structural disorder introduced by the bottom GaN based Distributed Bragg Reflector (DBR) mirrors.

In this thesis, a very straightforward processing technique is used to etch away an In-GaN sacrificial layer, using photo-electrochemical (PEC) etching, creating ultra-smooth membranes containing GaN/AlGaIn QW's, which are then embedded between high quality dielectric DBR mirrors, on which polaritonic studies are performed. The GaN membrane or the active region is carefully engineered, ensuring superior optical properties, both prior to and after etching. At room temperature, the QW emission is state of the art, with a linewidth of $\sim 28\text{meV}$, and a corresponding lifetime of $\sim 275\text{ps}$. The PEC lateral etching parameters are optimised in such a way, that the rms roughness of the membranes, measured by Atomic Force Microscopy (AFM), is as small as 0.65nm , very close to epitaxial quality. A temperature dependent study on the full-microcavity structure, unveils the strong coupling regime, exhibiting a robust Rabi splitting as large as 61meV at room temperature. The non-linear properties are examined, under nonresonant quasi-continuous excitation, with polariton lasing demonstrated at an ultralow threshold of $\sim 4.5\text{W/cm}^2$, the lowest ever reported for a 2D GaN based system, accompanied by a spectacular condensation pattern in k -space. The latter is attributed to a site-specific polariton trapping mechanism, where polaritons accumulate in discrete levels within the trapping potential, helping to escalate the polariton density locally.

This, along with the high optical quality of the all-dielectric microcavity (Q-factor ~ 1770), explains the obtained ultra-low threshold. It should be noted that the use of ultra-smooth GaN membranes in microcavities is fully compatible with the realization of electrically injected GaN polariton devices. In the direction of obtaining even more robust polaritonic devices, the basic optical properties of high quality, strain free, GaN nanowires are studied. However, to make the most out of this novel system, the absorption coefficients are extracted from as-grown GaN nanowires, on silicon<111> substrates, developing an all-optical method, analyzing merely the reflectivity spectra, which is demonstrated for the first time. It should be noted that the absorption coefficients (directly proportional to oscillator strengths) corresponding to the excitons, provide a glance into the appropriateness of the respective GaN nanowire system, as optimal candidates for hefty polaritonics. However, the nanowires studied here, failed to show an enhancement of absorption, which can be mainly attributed to the nanowire dimensions. The new method demonstrated here, can be extended to any family of nanowires, provided they are grown on a substrate having considerable difference in permittivity with the nanowire-air matrix.