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Referee's report of doctoral dissertation:

Investigation into properties of indium arsenide films with respect to the emission of terahertz radiation

Presented by Michał Kozub at

Wrocław University of Science and Technology

Faculty of Fundamental Problems of Technology

Department of Experimental Physics

During his thesis the author studied films of InAs in view of their optimisation for generation of high intensity THz radiation. His main goal was to find the way to increase the power of THz generation from InAs thin films.

The author put the hypothesis that by the introduction of a heavily doped reflection layer right underneath the active (radiating) layer it is possible to achieve enhancement of intensities of THz radiation coming from InAs based structures. For this purpose, a large set of samples was grown, via the MBE technique, with varying doping densities, reflection layer width and also doping method. This action was followed by a systematic study of the influence such a reflection layer has on the emission efficiency. The great number of results including THz spectra, Hall measurements and reflectivity spectra are presented and discussed.

Very positive side of this thesis is that author has taken a very wide spectrum of several actions in different research fields:

• growth and investigation of MBE growth of heavily doped thin films of InAs and InAs-containing heterostructures,

• design and construction of a terahertz time domain spectroscopy (THz TDS) setup capable of measuring THz radiation from optically excited InAs films,

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• comparison of the emission efficacy of distinct structure types and investigation the effects of the doping and rapid thermal annealing
• development of semi- phenomenological theoretical models for analysis of THz radiation enhancement scheme.

Another positive result of this work is also construction and implementation of dedicated THz-TDS measurement setup at the Department of Chemistry, Wrocław University of Science and Technology, based on LT-GaAs dipole antenna detectors.

The weak point of this work is that in spite of very important efforts only relatively weak improvement of the THz emission intensity was achieved (only 30% improvement above existing p-type InAs sources). Also the effect of annealing on the samples' THz radiation intensity was found to have a detrimental effect.

Another weak point is that the work indicates that this result can be further improved by optimizing growth conditions, i.e. by the maximization of mobility/carrier density in the reflection layer, but estimation of the theoretical or technological limits is not given work. I would expect that the estimations and idea of improvement/or not by one or two orders should be discussed.

The manuscript is clearly written and its great advantage is presentation the historical development of THz methods and their theoretical fundamentals, description of early experimental deployments, discussion modern available generation and detection. The introduction gives also very valuable overview of the majority of available techniques. Also it is written the way that can be used by future master and PhD students.

Publication record of the candidate is good and proofs that he is able to present his work for the researcher's community.

Finally I judge that by wide experimental actions starting from growth of the samples their characterization, building experimental systems, making advanced measurements ,their analysis and publications the candidate proofs its capacity to guide its independent scientific research. Therefore, it shows all necessary capacities to obtain a PhD degree.

Yours faithfully

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