μLaue diffraction and XEOL to study structure and light emission in materials

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The emergence of disruptive functionalities in nitrides is strongly related to the growth and technology process controls, but also to the development of advanced characterization techniques with high spatial resolutions. Focused X-ray beams provide innovative solutions to analyze quantitatively and correlatively the strain and light emission by combining μLaue diffraction (μLaue) and X-ray excited optical luminescence (XEOL), the two signals being recorded for the same time during mappings. We will illustrate in this communication some recent experimental and analysis breakthroughs obtained at the BM32 beamline of the European Synchrotron Radiation Facility.

The light emission of GaN μwires [1-3] and μLEDs obtained by etching GaN/InGaN Multiple Quantum Well (MQW) of commercial MOVPE UV heterostructures are studied by XEOL hyperspectral analysis, and the local strain variation and lattice rotation is obtained from μLaue analysis. A complete mapping of μLED takes benefit from the small beam size (~ 250 nm), short counting time (~1 s) and from the polychromatic diffraction Laue pattern method that can record many Bragg reflections without rocking the sample.

The XEOL data are analyzed with the principal component analysis and with the Non-negative Matrix Factorization method. It is shown that the three main emissions of the samples (MQW, near band edge peaks and defects band) can be directly retrieved in a fast and "ab initio" way. The μLaue analysis will be first illustrated by a conventional method of indexation and of the refinement of the diffraction patterns (i.e., with the LaueTools program developed on the ESRF BM32 beamline), but also with a new method based on feed-forward neural network (FFNN) that is able to index in real-time the diffraction spots recorded during the synchrotron experiments [4].

The results of the combination of both methods enable to correlate the visible emission and the crystalline structure of the materials, and therefore to improve manufacturing techniques. It will be also demonstrated that fast scans allow obtaining a statistical description of the samples opening the way to production control and to a fast and systematic screening of optoelectronic materials and microstructures.

References

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