Ecole Doctorale des Sciences Fondamentales

Title of the thesis: Red pixels based on III-nitride micro-domains

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Summary :
Light sources on flexible media are present in many applications. The dominant technology is based on organic light-emitting diodes (OLED). The latter have weak points: relatively low luminance and sensitivity to aging. Comparatively, inorganic LEDs (III-V semiconductors) are brighter and more stable over the long term. Manufacturing flexible micro-displays from blue, green and red nitrides of elements III - alloys (In) Ga (Al) N - LEDs would be particularly attractive.
The thesis project aims to develop the most critical building block of full nitride LEDs: red LED based on layers of InGaN transferable on a flexible substrate.
Several challenges have to be taken up:
- For red emission, the In concentration of InGaN active layers must be high enough without generating structural defects that could damage the device.
- Separating the active structure from its original substrate should be possible with a simple and inexpensive process.
The success of the project requires different tasks at the Institut Pascal (Université Clermont Auvergne) and at the C2N (Université Paris-Saclay) and relies on the expertise of these two research laboratories.
The work of the PhD student is based on the crystal growth of micro-domains of III-N alloys on a surface prepared by electron beam lithography. The initial selective growth will take place either in the openings of a SiN_x mask deposited on a GaN "template", or on graphene units deposited on SiO_2.
For both cases, the starting surface will therefore consist of crystalline zones, with a diameter of a few tens of nanometers, surrounded by a dielectric material.
The characteristics of two crystal growth techniques, hydride vapor epitaxy (HVPE) at the Institut Pascal and molecular beam epitaxy (MBE) at the C2N, will best be used to carry out the following steps:
- the formation of the first seeds of compound III-N on the crystal units defined above; - the lateral extension of the III-N germ to obtain micrometric domains, comparable in size to that of an LED for micro-displays;
- the use of these micro-domains as micro-substrates for the growth of a planar structure with quantum wells of InGaN emitting in the red.
Thus, each of these areas can constitute a red micro-display pixel.

To limit the mechanical stress in InGaN quantum wells, the micro-domains serving as microsubstrates can themselves be made in InGaN, by choosing an appropriate In concentration. The realization of these micro-pixels will be followed by a complete characterization of its structural and optical properties. We anticipate poor adhesion of III-N micro-domains to the dielectric surface. This should allow them to be easily detached from the initial substrate for transfer to a host substrate. As part of the thesis, we will also develop such a transfer process.