Energy saving become more and more significant, nowadays. In optical engineering the light emitting diode (LED) is considered to be the most efficient for energy economy. It’s new high-tech light source. The main advantage of LED is their high luminous efficiency. Luminous efficiency shows how much energy is converted to light flux. For comparison, efficiency of incandescent lamps is 10-15 lumens per watt (LPW), that of discharge fluorescent lamps is 40 - 80 LPW, and LEDs possess the efficiency of 70-130 LPW. However, the limit of luminous efficiency can be as high as 263 LPW for white light, and scientists seek to achieve this limit.

Currently produced LEDs are made from gallium nitride. Gallium nitride is used because its band gap is 3.4eV. This corresponds to the quant with the wavelength of 585nm. If we consider the principle of doubling the resonance frequency of semiconductor, GaN LEDs can radiate in the ultraviolet range with the wavelength of 292nm. This fact makes it possible to create white LEDs with luminophore. If we use GaAs doped with phosphorus, we get LED with wavelength 590nm. This is what makes GaAs not appropriate for white LEDs creating.

Our aim is to increase luminous efficiency and lights flux for white LEDs. To perform this we are to solve two problems.

The first problem is high current through the p-n junction which increase heating in the semiconductor by the Joule-Lentz low. This process leads to destruction of semiconductors heterostructure and failure of a LED. Moreover, there occurs the “effect of bottleneck”. Bottom line of the effect is that current concentrate in narrow channel. This causes uneven heating and defects in the heterostructure. As a result, absorption increases, and the quantum yield and efficiency decrease.

Second problem is that GaN crystal grown on sapphire (\(\text{Al}_2\text{O}_3\)) only. Sapphire and gallium nitride possess different periods of the crystal lattice and thermal expansion coefficients. Therefore, the temperature change leads to crack formation in the junction of GaN and sapphire. This means that defects in the heterostructure can cause LED breaking.

The luminous efficiency of the LED and light flux decrease, and in LEDs with the horizontal structure (Fig. 1) in particular. To solve the problem we can separate GaN LEDs from the sapphires substrate. The separation occurs by the formation of plasma and shock wave. The feature of plasma formation process is evaporation of material from the solid phase bypassing the liquid phase. Separation of GaN from sapphire substrates by irradiation of high power pulsed laser from the back side of the substrate is called as a laser lift-off technique (lift-off).

Laser lift-off processing is schematically illustrated in Fig. 2, where the band diagram is also illustrated. The high power ultraviolet pulsed laser is irradiated to the interfacial GaN from the backside of the sapphire substrate. The laser energy thermally decomposes the GaN by selective heating up, while the laser light is not absorbed in sapphire. The chemical reaction taking place at the interface can be expressed by

\[
2\text{GaN}(s) \rightarrow 2\text{Ga}(l) + \text{N}_2(g)
\]

There have been a couple of reports on the thermal decomposition of GaN, in which nitrogen flux \(\Phi(N)\) from GaN under vacuum can be expressed by a following equation:

\[
\Phi(N) = N_0\exp(-E_a/kT) \text{ (cm}^2\text{s}^{-1})
\]
where \( N_0 \) is a constant, \( E_a \) is an activation energy for the decomposition, \( k \) is the Boltzmann constant, and \( T \) is the absolute temperature.

After the laser lift-off, the compressive stress in a GaN film mainly originated from the thermal mismatch between the GaN film and the sapphire substrate is relieved. The relieved stress and vaporization pressure of \( N_2 \) formed by the decomposition of the interfacial GaN are the possible origins of the film failure as shown in Fig. 3. Thus, the choice of the laser is the most critical to set up the laser lift-off system since the decomposed area by the local heat up needs to be as thin as possible to reduce the vapor pressure of \( N_2 \) and to avoid any damage to the crystal quality of the epitaxial film above. In addition, the area distribution of the laser power needs to be very uniform to achieve the laser lift-off of very thin GaN.

This technology makes it possible to create LEDs with a vertical structure (Fig. 4). This type of the construction solves the problem of the “bottleneck effect”. In this case metal could be used instead of sapphire to solve the problem of excess heating.

Another important factor is that lift-off process is to be realized by the single pulse. In case of a several pulses GaN crystal will heat to the melting temperature, the heterostructure of the LED will be damaged. As a result the lift-off process cannot be implemented.

This method of LED production (Fig. 6) will make it possible to achieve the luminous efficiency about 200 LPW without increase in its price. The luminous flux of more than 1000 lumens per one LED can be created. This is going to make a breakthrough in lighting.

References