EDGE ULTRAVIOLET LUMINESCENCE OF GaN:Zn FILMS ACTIVATED IN ATOMIC NITROGEN RADICALS

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Gallium nitride seems to be one of the most perspective material for the production of light emitting diodes and lasers with blue and ultraviolet (UV) emission. The blue band with the energy maximum at 2.8 eV is prevailing in the semiconductor structures obtained recently. The increasing of the intensity of UV exciton and edge emission requires the more complex investigation of the nature of the intrinsic luminescence bands and of the more complex controlling the stoichiometry of the material.

It is interesting to study the influence of the processes of the activation of the acceptor impurities at the luminescent properties of the films. The radiative recombination of the carriers in light emitting structures occurs just in the region of p-type of a conductivity due to the lower mobility of holes. That is why just the emission of a films doped by the acceptors determine the spectral characteristics of the devices. The authors of [1] have observed the increasing of the blue band intensity in GaN:Mg films after the short time thermal annealing (STHA). However, the authors of [2] the similar annealing of undoped films in nitrogen atmosphere resulted both in the decrease of the luminescence connected with the impurities and in the growth of the exciton luminescence. According to the explanation of the authors, these facts testified to the perfection of crystal structure of the films during the annealing process accompanied by the simultaneous changing of their stoichiometry. Then, in [3] the authors had found that the annealing in similar regimes leaded to the regress of the structure of the crystal lattice and to the growth of the intense of all the emission bands.

Our preliminary investigations [4] have proved the donor-acceptor nature of the blue emission with the maximum at 2.8 eV. In this case the donors are nitrogen vacancies in one of its charged states. The annealing in nitrogen atmosphere is needed for the improving the stoichiometry of gallium nitride. It could be mentioned that the STHA in nitrogen atmosphere is not efficient for getting the desirable result because of the distraction of the film surface and due to evaporation of the nitrogen atoms from gallium nitride [2,3]. The increasing of the effective pressure of atomic nitrogen over GaN film is needed with the simultaneous decreasing of annealing temperature in order to diminish the evaporating of the material. Such a process is possible in the case of films annealing in nitrogen plasma in which the part of the atomic nitrogen is considerably higher.

The goal of this work is to investigate the GaN:Zn films of n-type conductivity with electron concentration $5 \cdot 10^{17}$ cm^{-3}, the resistance of about 10^6 Ohm·cm and the non-regularity of the surface about 1 μm. Hall measurements have shown the mobility of the carriers equal to 100-150 $cm^2/V \cdot s$ in un-annealed films. The films investigated were grown by the molecular beam epitaxy method (MBE) on Al_2O_3 substrates with orientation (0001). The annealing of films at temperatures ranging in the interval 600-1000 K during two hours in the atmosphere of nitrogen radicals realized in the discovering of Radical Beam Epitaxy which technology had been described in details in [5]. The nitrogen plasma produced due to RF discharge has passed through the intensive magnetic field aiming at the suppression of the charged components of the plasma. Thus, the annealing had been realized in the atmosphere of neutral nitrogen radicals.

Such kind of an annealing makes it possible to decrease the concentration of intrinsic defects of donor type responsible for blue emission and also to influence at the film conductivity. The doping of gallium nitride by the acceptor impurities (Mg or Zn) in the growth process results in the selfcompensation and leads to the formation of high-Ohmic material. Traditionally either the method of high temperature annealing of the samples in vacuum or the method of irradiation by electron beam are used to diminishing the material conductivity of p-type. It causes the activation of acceptor impurities due to the distraction of their complexes with hydrogen. Simultaneously the process of changing of the stoichiometry of the gallium nitride due to the

evaporation of nitrogen to the vapor phase take place. Usually, in order to overcome the process of annealing in the atmosphere of nitrogen is used. We conclude that in this case the effective pressure of atomic nitrogen is too low for saving the stoichiometry of the material. That is why we had annealed the samples in the atmosphere of nitrogen radicals.

The nitrogen laser ILGI-503 with the wavelength of the emission 337.1 nm and the pulses of 10 ns was used for the excitation of photoluminescence (PL). The spectra were analyzed with a help of MDR-6 monochromator governed by the computer. This has provided the opportunities to obtain the spectra resolution not less than 1 meV. The ohmic planar gold contacts were done on the film surface for measuring the photoconductivity (PC). The PC had been excited with the help of modulated and passed through monochromator MDR-12 light of halogen lamp 100 Wt power. The measurements had been made in the optical cryostat at the temperatures of liquid nitrogen. The type of conductivity, the concentration and the mobility of the carriers had been determined by Hall measurements. While investigating the influence of annealing regimes at the perfection of GaN:Zn film surfaces, the electronic DJEL-2000 microscope had been used.

The influence of the annealing in the atmosphere of nitrogen radicals of gallium nitride films at their PL, PC as well as on the type of the conductivity and on the perfection of the surface had been investigated. The appearance of the intense UV edge emission at 376 nm after high-temperature annealing in the atmosphere in nitrogen radicals had been observed. The considerable diminishing of blue donor-acceptor and exciton PL in GaN:Zn samples had been also found.

Thus, we had shown that the annealing of GaN:Zn films in the atmosphere of nitrogen radicals results not only in the activation of the acceptors due to the distraction of Zn-H complexes forming in the growth process and also to the shifting of GaN stoichiometry to nitrogen excess. At the same time the quantity of donor-acceptor pairs including nitrogen vacancies as the donors responsible for blue emission band of GaN:Zn with the maximum at 2.88 eV had also diminished. The recombination of electrons directly from the conduction band at the acceptor levels Zn_{Ga} begins to prevail and is responsible for the UV edge luminescence band with the maximum at 3.27 eV. Just the edge emission determines the minimum wavelength of the emission of diode structure based on gallium nitride intensively doped by the acceptors.

It had been shown that due to the activation of the acceptors after the annealing of films in the atmosphere of nitrogen radicals they became more insulating materials of n-type conductivity. The photosensitivity in the admixture spectral region growth as well. The high photosensitivity of gallium nitride had been observed for the first time not only in the UV spectral region but also in the visible region. It is due to the electron transfers from the local levels to the conduction band.

It had been found that the annealing in the atmosphere of nitrogen radicals realized by the authors results in the considerable less distraction of the film surfaces in the comparison with STHA [3]. The dimensions of the micro-relieve of the film surfaces after the mentioned treatment are about 1-10 nm and consequently the surfaces of the films remain optically smooth, that is important for production of a number of light emitting structures.

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