Structural Properties of III-Nitrides Received by UV Stimulated Technology

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In terms of structural studies, X-ray diffraction (XRD) studies are discussed in this paper. Based on the experimental results, X-ray diffraction graphs of III nitrides obtained with and without UV irradiation are shown and is evaluated the role of UV stimulation in magnetron sputtering technology.

Keywords: 2θ degree, intensity, FWHM.

1. Introduction

Modern micro and nanoelectronics at its current stage of development requires the creation of stable, sustainable, new technology-based and budget-friendly devices. The reduction of the size of integrated circuits and elements has given rise to new requirements for the materials on the basis of which various micro- and nanodevices are made. One of the main places in materials research is structural research. Structural analysis gives an answer about the quality of the material. The first thing that is checked from the parameters of the obtained new material or the material obtained with the new technology is its compatibility with the existing experimental or literature data. If the material is structurally formed in such a way that it allows the realization of the set goals (device creation), then other types of research, such as optical, electrical, mechanical, morphological, chemical, and others, begin to be conducted.

The presented paper discusses the structural analysis of III nitrides (GaN, AlN, InN). These nitrides are obtained by reactive magnetron sputtering technology stimulated by ultraviolet radiation [1,2,3]. This technology has been the leading technology for many decades to obtain thin metallic, semiconductor and dielectric films. With this technology, it is possible to obtain not only individual elements, but also their compounds. Such compounds are represented by wide-bandgap semiconductors gallium nitride (GaN), aluminum nitride (AlN) and indium nitride (InN). For this purpose, magnetron sputtering takes place in the presence of the reagent gas whose chemical compound we want to obtain. In our case, such a reagent gas is nitrogen (N2). An important factor in obtaining clean and high quality materials along with technological processes is the use of clean precursor materials. These materials include the material to be sputtered from the magnetron, in our case gallium, aluminum and indium, and the purity of the reagent gas. The purity of the metals used in the experiments was 99.95%, and in the case of the reagent gas nitrogen - 99.9999%.

Novelty and innovation in the technology of obtaining III-nitrides is the use of ultraviolet (UV) radiation [4,5,6] directly in the process of obtaining nitrides (Fig.1). UV radiation (365 nm wavelength) falls directly on the surface on which the nitrides are grown. Its intense absorption by the deposited first monoatomic layers helps to change the mutual arrangement of atoms and by this way prevents the formation of defects, since the formation and growth of the crystal in any crystallographic direction depends on the structure of the first monoatomic layers. Since III-nitrides are obtained on sapphire plates, it becomes even more important in the technology to eliminate defects at the boundary separating the two environments. Because it is known that in relation to sapphire, III nitrides have a large lattice mismatch. Therefore, introducing an additional stimulating component and reducing defects is a priority in these studies.

2. Experiment

To obtain III nitrides, reactive magnetron sputtering technology is used, which is performed on a ,,УВН-2М-1’’ vacuum unit. This device is equipped with a two-stage vacuum system - a mechanical pump and a turbomolecular pump. By their action, the vacuum system can obtain a vacuum of 1•10-6 torr. Vacuum measuring instruments and mass spectrometer (RGA 200) for residual gas analysis are attached to the vacuum chamber (Fig. 1).

High purity metals (Ga, Al, In 99.999%) are used as sources in magnetrons, and the reagent gas is nitrogen of 99.9999% purity. 2-inch 400-micron-thick sapphire plates with crystallographic orientation (002) are used as the wafer. Samples were heated to the required temperature with 250 W halogen lamps. A lamp with a wavelength of 365 nm and a power of 400 W is used as a source of ultraviolet radiation. The UV lamp was designed so that the radiation emitted from it was a cone of rays 2 inches in diameter that fell directly on the sapphire plate. That is, the density of light energy falling on the sample was 5 W/cm2.

The purpose of the experiments was to develop the technology for obtaining III nitrides, which involved the selection of modes under which high-quality, well-structured samples were obtained.

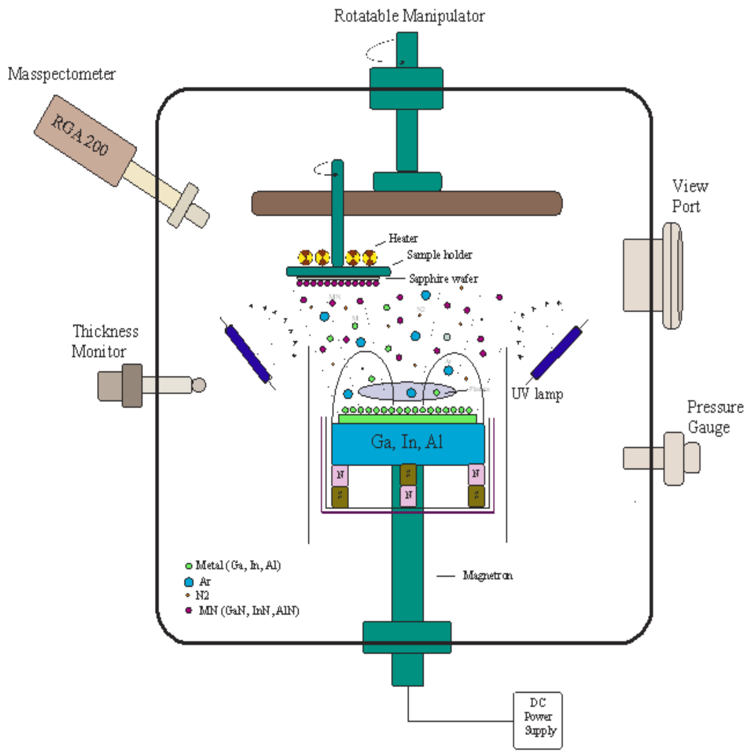

Fig.1 magnetron sputtering system

3. Results and discussions

3.1 GaN

UV exposure

One of the important places in the research of III nitrides was determining the influence of UV radiation in the growth process of nitrides. As can be seen from Table 1, in the process of obtaining gallium nitride, UV stimulation accelerates the process and the deposition rate in the case of GaN-37s and GaN-38s increases from 10.6 nm/min to 12.3 nm/min, while GaN-39s and GaN-40s increases from 17.2 Nm/min to 18.5 Nm/min. In the first case, the stimulation result is 16%, and in the second case is about 7%. The relatively low (7%) stimulation result is due to temperature and deposition current differences. In the case of a 16% increase, the average temperature is 6500C and the deposition current is 100 mA, and in the second case the average temperature is 700C and the deposition current is 150 mA.

Table 1 Technological and measurement parameters of GaN

Specimen #	UV	Temp. ^{0}C	Time, min	2θ, degree	FWHM, sec	Orientation	Thickness, nm	Deposition rate, nm/min	Deposition current, mA
GaN - 27s	-	674	120	31.81	1044	100	1272	10.6	100
GaN - 37s	-	640	120	-	-	-	1272	10.6	100
GaN - 38s	+	660	120	32.08	828	100	1511	12.3	100
GaN-39s	-	60	120	31. 71	1575	100	2068	17.2	150
GaN-40s	+	76	120	31. 97	1560	100	2227	18.5	150
GaN-41s	+	688	120	32.1	768	100	1988	16.5	150

AlN-3s		500	60	-	-	-	426	7.1	150
InN - 2s	-	550	15	31.2	660	100	780	26.7	50

Consider the experimental and measurement parameters given in Table 1. This table shows samples obtained with and without UV. If we compare samples GaN-27s and GaN-38s, we can see that all technological parameters of these samples are the same: deposition temperature (almost the same), deposition current and deposition time. The only difference between them is that the GaN-38s sample is obtained with UV, while the GaN-27s is obtained without UV. It is clear from the data that the structural parameters of GaN-38s are better (2θ=32.08; FWHM=828 sec) than those of GaN-27s. Also, the thickness of the sample obtained with UV (1511 nm) exceeds the thickness of GaN-27s (1272 nm). Which means that UV stimulation increases the deposition rate, and in the case of these two samples, the rate increased from 10.6 nm/min to 12.3 nm/min. Below are the X-ray graphs of GaN-27s and GaN-38s (Fig.2 and Fig.3).

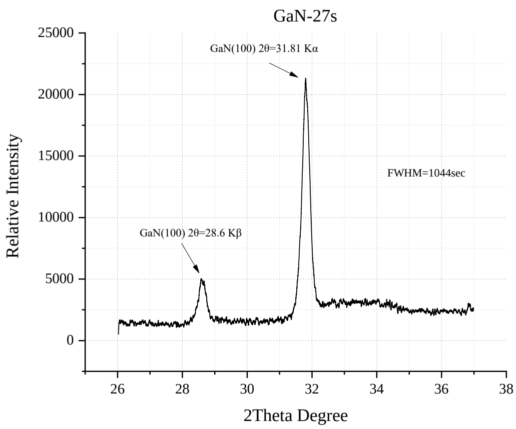

Fig.2 GaN XRD pattern for specimen GaN-27s

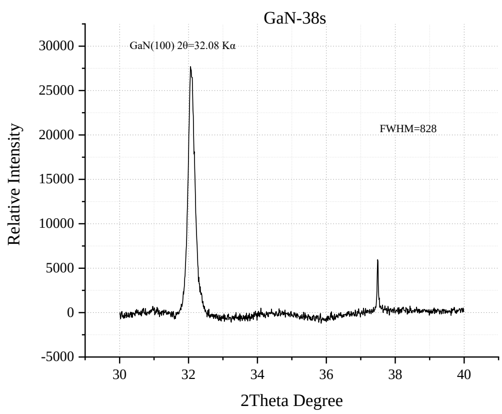

Fig.3 GaN XRD pattern for specimen GaN-38s

Let's compare GaN-39s and GaN-40s samples obtained at low temperature. GaN-39s obtained without UV and GaN-40s obtained with UV. Thay have all other parameters the same. The same result is recorded here as in the case of the previous two samples. The structural parameters are better for the sample obtained by technological processes with UV, than for the sample obtained without UV. Here too, UV radiation stimulates the technological process and increases the deposition speed from 17.2 nm/min to 18.5 nm/min. It should be noted that the effect of UV stimulation in the case of these two samples is less pronounced than the previous two samples, both in terms of structure and deposition rate increase. which is mainly due to the low temperatures of growing GaN films.

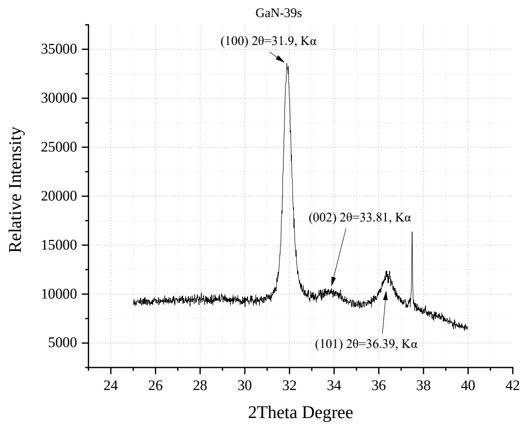

Fig.4 GaN XRD pattern for specimen GaN-39s

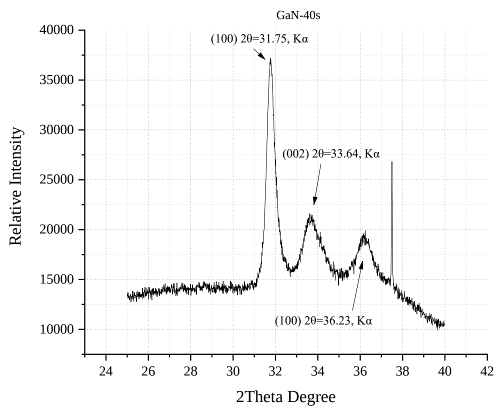

Fig.5 GaN XRD pattern for specimen GaN-40s

Because the temperature in all technological processes plays a major role in the structural, optical and other properties of the obtained thin films. In the technology,which we are considering, UV radiation performs a stimulating function. The stimulating effect of UV is clearly visible for the samples described above. The corresponding XRD graphs of GaN-39s and GaN-40s are given in Fig. 4 and Fig. 5.The best results are shown for the GaN-41s sample. This sample was obtained under UV and all the measured parameters are given in Table 2. The radiograph is given in Fig. 6. Fig. 7 shows the X-ray structural graphs of several samples together.

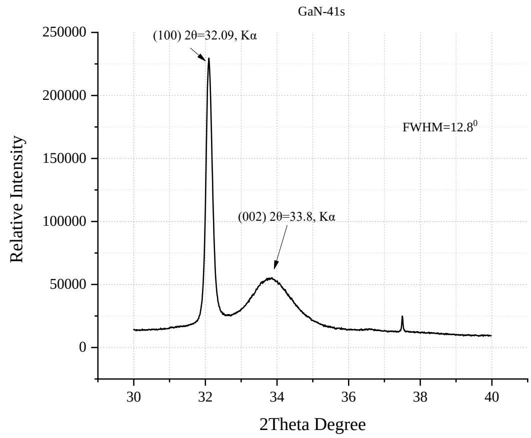

Fig.6 GaN XRD pattern for specimen GaN-41s

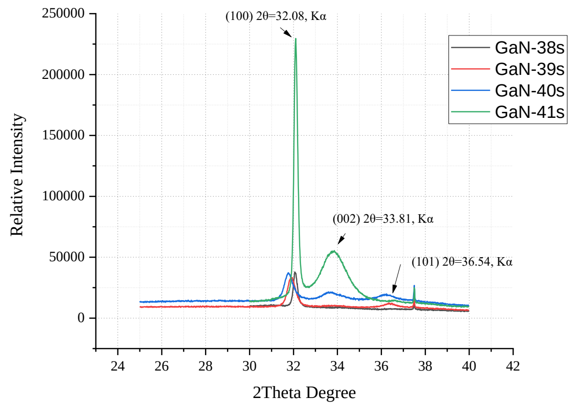

Fig.7 XRD of GaN obtained with and without UV exposure

It is worth noting that the X-ray peak of the GaN-41s sample obtained with UV is higher than the others, despite the fact that their thicknesses are almost the same. However, the diffraction angle is 32.10, which is distorted for a (100) orientation GaN crystal, and the full width at half maximum (FWHM) of the X-ray peak is 768 sec.

3.2 AlN

In the case of aluminum nitride, depending on the conditions of the experiments, amorphous films were obtained, because obtaining aluminum nitride requires higher temperatures (>10000C). Therefore, it is difficult to draw conclusions regarding this material.

3.3 InN

As for indium nitride, as can be seen from Table 1, a well-formed monocrystalline film with (100) orientation is obtained. Also, with a diffraction angle of 31.20 and a FWHM of 660 sec in fig. 8.

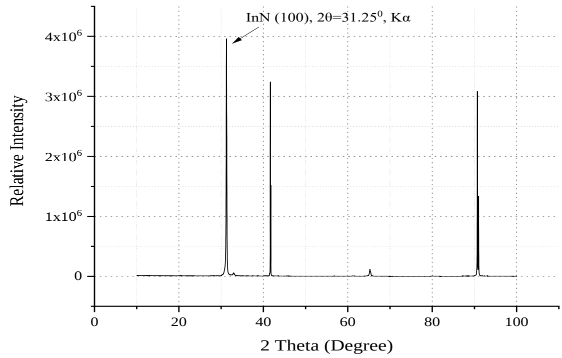

Fig.8 XRD for InN

4. Conclusion

Research outcomes have shown that stimulation with UV irradiation increases the deposition rate by up to 16%, and most importantly, the results of these studies show that UV exposure improves the structural properties of the deposited material. This was well demonstrated in the case of gallium nitride, when samples obtained at the same temperature, performed better those irradiated with UV rays.

Thus, multifaceted studies have shown that the properties of gallium nitride can be improved using technical and technological innovations. In particular, the inclusion of UV stimulation in reactive magnetron sputtering technology improves the properties of gallium nitride. For other III nitrides materials - aluminum nitride and indium nitride, the improvement of their parameters was not affected by UV exposure.

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