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# Effect of laser energy variation on the optical characteristics of GaN/Quartz thin films

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**ABSTRACT**

In this study, the pulsed laser deposition (PLD) technique was used to fabricate a GaN thin film. Ultraviolet-visible (UV-VIS) absorption spectra were used for testing the nanofilms. GaN thin films were produced on quartz substrates using pulsed Nd: YAG lasers with varied laser energies from 1200 mJ to 2000 mJ. Experimentally measured optical properties of the as-grown film include the optical transmittance spectrum; the optical transmittance value ranged between 62% and 84%, absorption behavior, energy gap determination, as well as the effects of laser pulse energy on these properties. A forward relationship was observed between the energy gap and thickness. It was noticed that the multi-optical energy bands of the grown GaN Nano film was tastes and calculated to have the values of 3.46, 3.35, 3.42, 3.61, and 3.64 eV, respectively. X-ray diffraction analysis showed that gallium nitride on porous silicon exhibits a polycrystalline and a cubic structure. Furthermore, a hexagonal structure was found under optimal conditions (0.532 micrometers, 1.6 J, 300 °C) with a high intensity peak and a high crystalline size at 2θ = 25.95°, 36.69°, 57.80°, and 63.75°, which correspond to the planes (200), (101), (110), and (103), respectively.

**Keywords:** *Gallium nitrite, Optical properties, Pulse laser deposition, Pulsed laser flounce, Thin films.*

## 1. INTRODUCTION

Gallium nitride (GaN) is a wide bandgap semiconductor material that has a variety of electronic and optical properties [1, 2]. It is commonly used in the manufacturing of light-emitting diodes (LEDs) and laser diodes, as well as in the production of power electronics devices such as high-voltage and high-frequency transistors [3, 4]. Gallium nitride has a high electron mobility, which lets it work at high temperatures and frequencies. Gallium nitride is a good thermal conductor as well as an electronic material. This helps to get rid of heat that the device makes while it is working, which makes it more reliable and lasts longer [5, 6]. GaN thin films made using the pulsed laser deposition (PLD) method have many benefits, such as being able to work at high temperatures, voltages, and power densities [7, 8]. These traits make GaN thin films very appealing for use in future electronic systems [9, 10]. Gallium nitride is a very useful semiconductor for high-power and high-frequency uses because it has a large bandgap of 3.4 eV, high electron mobility, and a saturated electron velocity [11, 12]. It is thought to be a third-generation semiconductor material and a great compound material made up of elements from the III-V group [13, 14]. GaN also has a lot of unique properties that make it perfect for advanced electronic and optoelectronic systems [15, 16]. There are many ways to make gallium nitride into a thin film. Some of these are chemical vapor deposition (CVD) processes like molecular beam epitaxial, atmospheric pressure CVD, low-pressure CVD, plasma enhanced CVD, metal-organic CVD, and hot wire CVD. Others are physical vapor deposition processes like PLD [17-20]. There are many benefits to using PLD for III-nitride semiconductor materials, including its simplicity, adaptability, and quick film production [21, 22]. The deposition process creates a very focused a column of material that can be deposited with high precision in terms of chemical composition and very little harm to the environment [23, 24]. These advantages render PLD an appealing technique for the fabrication of III-nitride semiconductor films. Because of these unique qualities, GaN has a lot of potential for use in a wide range of fields, including biosensors, gas sensors, and optoelectronic devices [25, 26]. PLD is thought to be a new way to grow thin films. PLD has a lot of advantages over traditional thin film deposition methods, like being cheaper and easier to keep up with. Also, it gets rid of the risk of contamination by getting rid of the need to touch the substrate or target directly. PLD has made it much easier to make multilayer films [27, 28]. This study involved the deposition of GaN onto substrate of a quartz utilizing the PLD method, followed by an examination of its optical properties.

## 2. EXPERIMENTAL WORK

Figure 1 shows the main steps for getting GaN/quartz ready and doing UV testing.

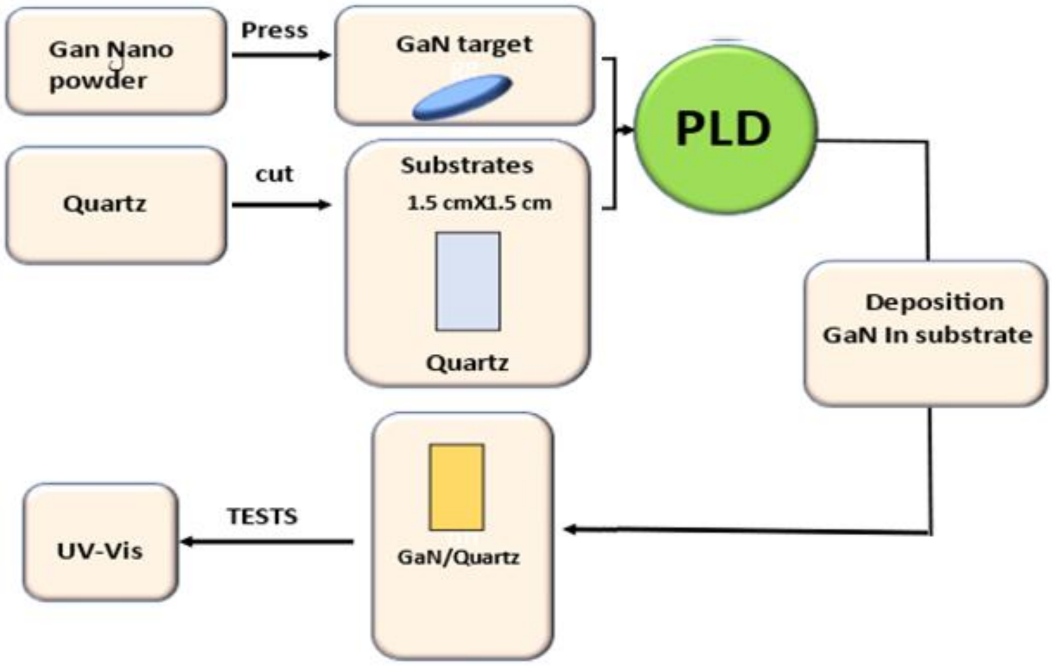


**Figure 1.** Experimental work diagram

### 2.1 Preparation Quartz

To get a high adhesion rate, you need to get rid of dirt and fingerprint sections that are 2 cm × 1 cm and 1 mm thick. The first step in the cleaning process is to wash the item by hand for 10 minutes. Then, it is sterilized by being submerged in liquid ethanol for five minutes and dried in hot air. Before the deposition process, the quartz substrates were kept in clean plastic containers after they had been cleaned. The quartz was chosen as a substrate because it can handle high degree temperatures at a free cracking or breaking. It also lets more wavelengths through than other materials [29, 30].

### 2.2 GaN Nano Film Preparation using PLD Method

Method of Pulsed laser deposition (PLD) is used to deposit the GaN Nano structure on a quartz substrate at pressure vacuum of $10^{-2}$ mbar of for optimum conditions. Using Nd:YAG Q-switching for the best results, this used deposition method is used to make GaN Nano films on a quartz substrate in a vacuum of less than 10-2 mbar. The Nd: Q-switched The YAG pulsed laser was set to 1064 nm, 3 Hz, and 10 ns for the pulse duration. The Nd:A YAG laser beam is focused on a pellet made of GaN that is 2 cm in diameter and about 0.5 cm thick. The pellet is 99.999% pure. At a substrate temperature of 300 °C, 250 pulses of laser energy were used, with values ranging from 1200 to 2000 mJ. Different amounts of ablation energy to find the best amount to use to make GaN films. Figure 2 shows a diagram of how to deposit a GaN thin film on quartz.

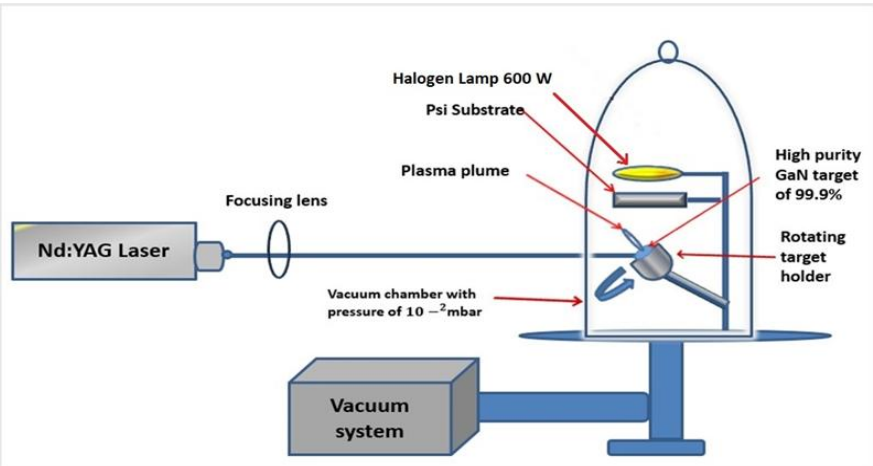


**Figure 2**. A diagram illustrating the pulsed laser deposition technique.

**Table 1.** The parameters practical for the conditions of deposition

| Parameters of PLD | Values |
|---|---|
| Laser Wave lengths | 1.064 micro meter |
| Frequency | 3Hz |
| Pulse duration | 10 ns |
| Energy Pulse | 1.2-2 J |
| Repetition rate | 2mm |
| Focal length of lens | 12cm |
| Substrate | quartz |

To get the best ablation, the beam of the pulsed laser was directed towards the surface of the GaN target at a slope angle of 45 degrees with a size of spot of 1.6 mm and the lance focal length are equal 120 mm. The space between GaN and substrate is 5 cm. In general, you need to rotate the target to avoid hitting the same spot. Table 1 showed all of the PLD parameters.

### 2.3 UV-Visible Spectrophotometer (UV-VIS)

The UV-VIS spectrophotometer (model: Metertech SP-8001 from Taiwan) was used to test the spectra of transmittance (T %) for the deposited GaN Nano films. In the first section, a quartz reference slide was placed, and in the second section, the membrane was placed. The selected spectral range was from 200 to 1000 nm. We used the following formula to figure out absorption ($A_b$) [31-33]:

$$A_b = \log10\,[1/T*10^{-2}] \quad (1)$$

The optical energy gap (Eg) was studied by using the Tauc plot of (hν) as a function of $(\alpha h\nu)^{0.5}$, where the value of (h) is a constant of Planck and equal to $4.1355 \times 10^{-15}$ eV. The beam of the UV-Vis frequency (ν) and the value of the coefficient of absorption (α) were used from the Equations (2), and (3) [34-36].

$$\alpha = (2.303\,A_b)/t \quad (2)$$
$$\nu = C/(\lambda) \quad (3)$$

where C is the speed of light ($3 \times 10^8$ m/s), and t is the thickness [37]. This method of analysis was done at the University of Technology's Department of Laser and Optoelectronics Engineering in Iraq, as shown in Figure 3.


**Figure 3.** UV- Vis –Spectrophotometer.

### 2.4. X-Ray Diffraction (XRD)

Using an X-ray diffraction (XRD) analyzer manufactured by Shimadzu in Japan, we were able to find and identify the crystal structures of the GaN thin films we made. Using X-ray diffraction analysis, you can find out important things about an alloy, such as the size of its crystals, their orientation, their lattice parameters, and their chemical composition. A Shimadzu XRD 6000 diffraction spectrometer system was used, featuring a Cu-Kα copper radiation source emitting a wavelength of 1.54 at 30 A and 40 KV.

## 3. RESULT AND DISCUSSION

Figure 4 displays patterns of the X-ray diffraction for Nano GaN films deposited on a tne substrate of PSi at laser energies of 1200 mJ and 1600 mJ, maintaining a constant wavelength of 532 nm and 300 °C substrate temperature. It was found that there were four the peaks of the XRD at 2theta = 25.951, 36.963, 57.802, and 63.753 degrees. These peaks correspond to the [lines (200), (101), (110), and (103) respectively. The intensity of the peaks and accuracy went up as the crystallization structure went up, from 1.2 J to 2 J of the pulsed laser energies. Because the h-GaN nanoparticles are so good. When the laser energy value is 2

J, the intensity peak began to go down as a result of the crystallization structure decrease. These peaks matched standard GaN diffraction data (JCPDS cards No. 50-0703) and were found in a previous study [38, 39].

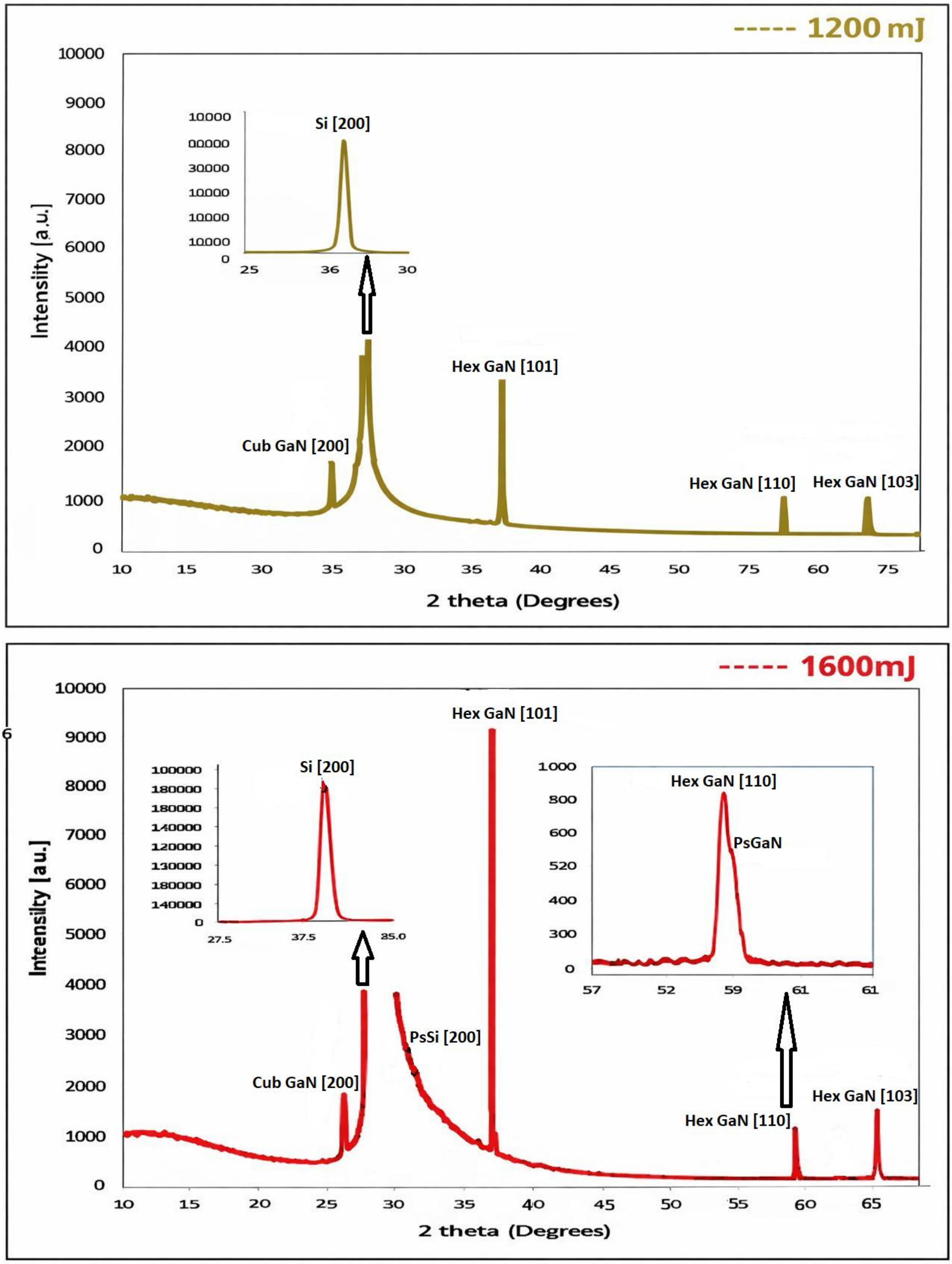


**Figure 1.** GaN/PSi X-ray diffraction pattern produced at different pulsed laser energies of 1.2 J and 1.6 J, 1.064 micrometers, and 300 °C.

The numbers (5, 6, and 7) show that the transmittance at a certain wavelength goes down as the energy of the laser pulse that hits it goes up from 1200 to 2000 mJ. The target absorbed more energy as the incident laser energy increased, which caused more particles to be thrown towards the substrate. When these particles absorb a high-energy laser, they possess a lot of kinetic energy. This leads to an increase in particle density on the substrate. higher and the film thicker, which makes the transmittance lower. Figure 5 and previous research [40, 41] show very clearly that the optical transmittance value goes down. As transmission rises, absorption diminishes owing to an elevated deposition rate. The difference in energy shows that raising the ablation energy will get rid of bigger grains. Figure 6 and previous research [42, 43] show that this behavior clearly changes the optical absorbance values. The energy gap gets smaller, and the wavelength moves to the red. If you lower the ablation energy, smaller particles will be removed, and the energy gap will get bigger. It is noted that a reduction in particle volume leads to an increase in the energy band gap, attributed to quantum confinement. Figure 7 shows a clear change in the optical energy gaps of the nano-films that were deposited. Table 2 also shows the optical energy gap values of the nanofilms that were deposited. [44, 45].

**Table 2.** The optical energy gaps value at various energies of pulsed laser

| Energies of Pulsed Laser (J) | optical energy gaps value (ev) |
|---|---|
| 1.2 | 3.46 |
| 1.4 | 3.35 |
| 1.6 | 3.42 |
| 1.8 | 3.61 |
| 2 | 3.64 |

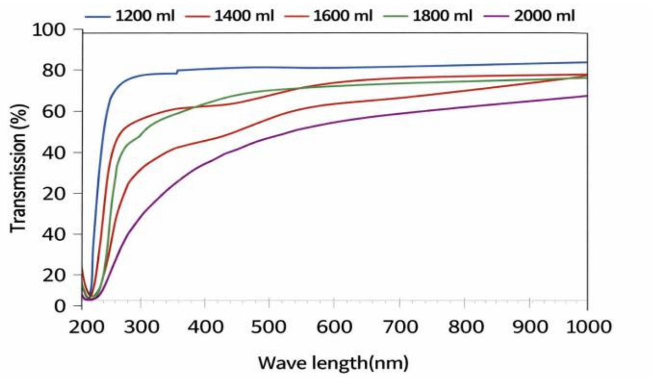


**Figure 5**. Transmission (T%) of GaN/quartz at different energy with 1064 nm laser wavelength and 300 ⁰C substrate temperature.

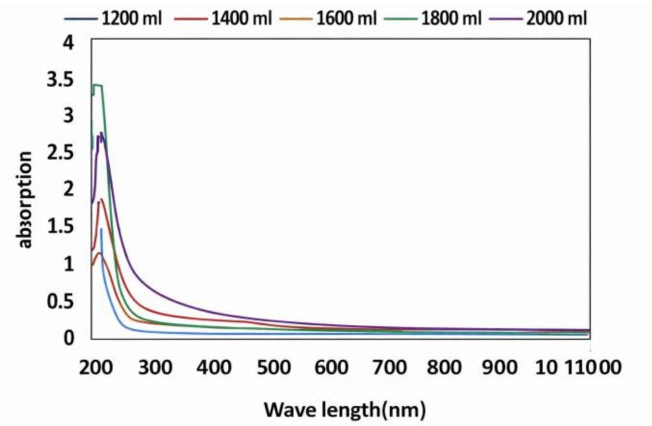


**Figure 6.** Absorption of GaN/quartz at various energies with 1.064 micrometer laser wavelength and 300 ⁰C substrate temperature.

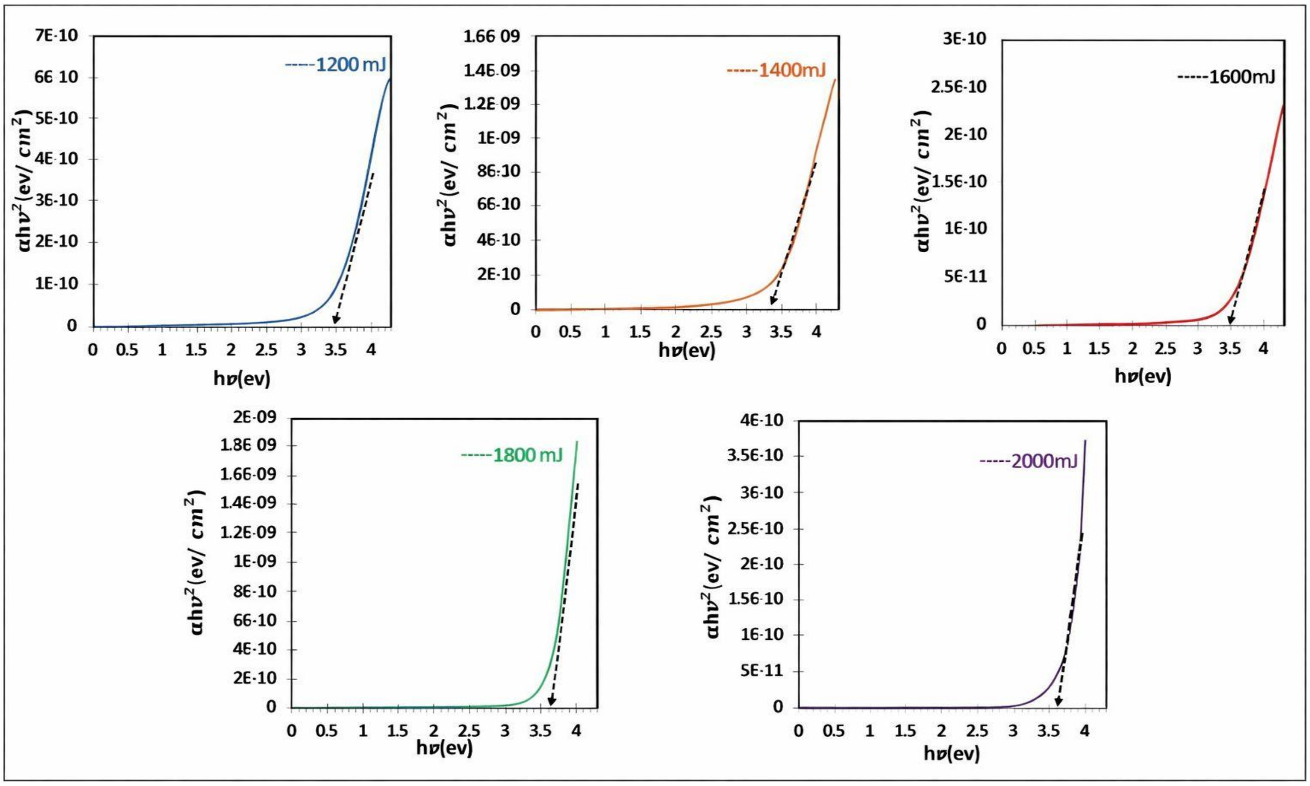


**Figure 7.** Energy bandgap of GaN/quartz at various energy with 1064 nm laser wavelength and 300 ⁰C substrate temperature.

**4. CONCLUSION**

Using a UV-visible spectrophotometer at different laser energies (1.2 J, 1.4 J, 1.6 J, 1.8 J, and 2 J), we looked at the optical properties of GaN thin films. For each of the five samples, we measured the energy band gap (3.46, 3.35, 3.42, 3.61, and 3.64 ev, respectively). The film gets thicker and the density of particles on the substrate goes up when they absorb a high-energy laser. This makes the film less transmissive.

When transmission goes up, absorption goes down. The difference in energy shows that raising the ablation energy will get rid of bigger particles. As a result, the energy gap gets smaller and the wavelength moves toward the red end of the spectrum. If you lower the ablation energy, smaller particles will be removed, and the energy gap will get bigger. It is noted that as the particle volume diminishes, the energy band gap expands owing to quantum confinement.

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