

Pattern characteristics and resolution of GaN sample through

Parameter of Indirect Microscopic Imaging

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Abstract: With smaller DOF (Depth of Focus) achieving focus at the center of the photoresist also became harder. Currently it is big issues to achieve, the super resolution by optical microscope because due to the diffraction limit. In this letter, the pattern characteristics and edge resolution of GaN sample has been studied through an indirect microscope. In this new discovery, we would like to see whether the etched part is fully etched without SiNx in the sample. Some Electronics microscope such as SEM, AFM have already developed for sub nano resolution. But due to time taken, more expensive ,it is not easy to find every place. In this way, we proposed a new imaging method (PIMI), which is differ from all non-optical and traditional optical imaging system. We found that image resolution of GaN samples under measurement is near about 80 nm. All the measurements have been done by PIMI system.

1. Introduction:

Gallium nitride (GaN) is a binary III/V direct bandgap semiconductor commonly used in light-emitting diodes since the 1990s. The compound is a very hard material that has a Wurtzite crystal structure. Its wide band gap of 3.4 eV affords it special properties for applications in optoelectronic, high-power and high-frequency devices. For example, GaN is the substrate which makes violet (405 nm) laser diodes possible, without use of nonlinear optical frequency-doubling. In 1870s, Abbe discovered that when an object is observed by optical devices such as microscopes or telescopes, the features smaller than half of the wavelength of light are not resolvable because of diffraction phenomena [1]. Due to diffraction limit, resolution achievable by using conventional optical microscope is intrinsically limited to approximately two hundred nanometers in visible light. Realizing microscopes with higher resolution have been active research area. At 1930s, microscopes using electrons such as scanning electron microscope (SEM) [2] and transmission electron microscope(TEM) [3] were invented. Those two microscopes have much higher resolutions of tens of nanometers compared to the typical optical microscope due to the shorter de Broglie wavelength of electrons. We have already reported the application of (PIMI) system under the sample of graphene layers[4].It is well known that the resolution and evaluation of the image quality technique is important for imaging system assessment such as radar[5],Atomic force microscope CT[4].etc. We have review our study in image resolution with different methods [8-10].In the present paper, resolution of pattern GaN sample has been studies with the help of parameter of indirect microscopy, which is better as compare to reported before. The details sections are described below.



2. Theory:

With the help of geometric optical coordination system, polarization orientations illustrated and the Jones model [11-14], one can find that during polarization sweeping, the pixel intensity (I_i) depending on the vector addition of two wave fronts of unlike polarization states from the inherent structural anisotropy of the samples under measurement (SUM), varies with input split angle α . This hope can be described by Eq. (1) in a basic form, where I_{dp} is the average intensities over all polarization status transmitted through or reflected from each field points of the SUM, so its value least affected by

scatterings near field change of polarization status, $a_0 = \frac{1}{2}$, $a_1 = \cos 2\phi \sin \delta$, $a_2 = \sin 2\phi \sin \delta$ and $\sin \delta$ is the sine of phase difference between two orthogonal polarization states, ϕ is the polarization angle of the slow axis. Therefore the ratio between pixel intensity (I_i) and average intensity (I_{dp}) is given in below equation-1.

$$\frac{I_i}{I_{dp}} = a_0 + a_1 \sin 2\alpha + a_2 \cos 2\alpha \quad (1)$$

The field intensities at individual pixel of the CCD matrix were recorded while wide the polarization which is achieved by rotating a linear polarization disc in a manage component. The intensity difference with parameters, such as the split phase and angles were fit to Eq. (1). From the derived equation, the values of the parameters such as I_{dp} , $\sin \delta$ and ϕ can be extracted. From the above polarization parameters, using the relationship between Jones's and Mueller's model, the Stokes parameters, S_0 , S_1 , S_2 and S_3 can be further calculated with Eq. (2).

$$\begin{pmatrix} S_0 \\ S_1 \\ S_2 \\ S_3 \end{pmatrix} = \begin{pmatrix} E_x E_x + E_y E_y \\ E_x E_x - E_y E_y \\ E_x E_y^* - E_y E_x^* \\ i(E_x E_y^* - E_y E_x^*) \end{pmatrix} = \begin{pmatrix} I_{dp}(1 + \sin \delta) \\ I_{dp}(1 + \sin \delta) \cos 2\phi \\ \sqrt{2} I_{dp}(1 + \sin \delta) \sqrt{\sin 2\phi} \cos \delta \\ \sqrt{2} I_{dp}(1 + \sin \delta) \sqrt{\sin 2\phi} \sin \delta \end{pmatrix} \quad (2)$$

Where E_x and E_y are the X and Y optical field components, S_0 , S_1 , S_2 , S_3 are Stokes parameters along with the depolarization intensity, I_{dp} , phase difference, $\sin \delta$, and polarization angle, ϕ can be retained to each pixel coordinates in the sensor space to form individual parameter maps, or indirect images as we call them, with the contrasts not built by the optical intensity but the spatial polarization parameters related to near field characteristics.

3. Parameter of Indirect Microscopy (PIMI) Setup for Measurement

Based on the above theory [4] we have designed an experimental setup (PIMI) which is shown in fig.1.

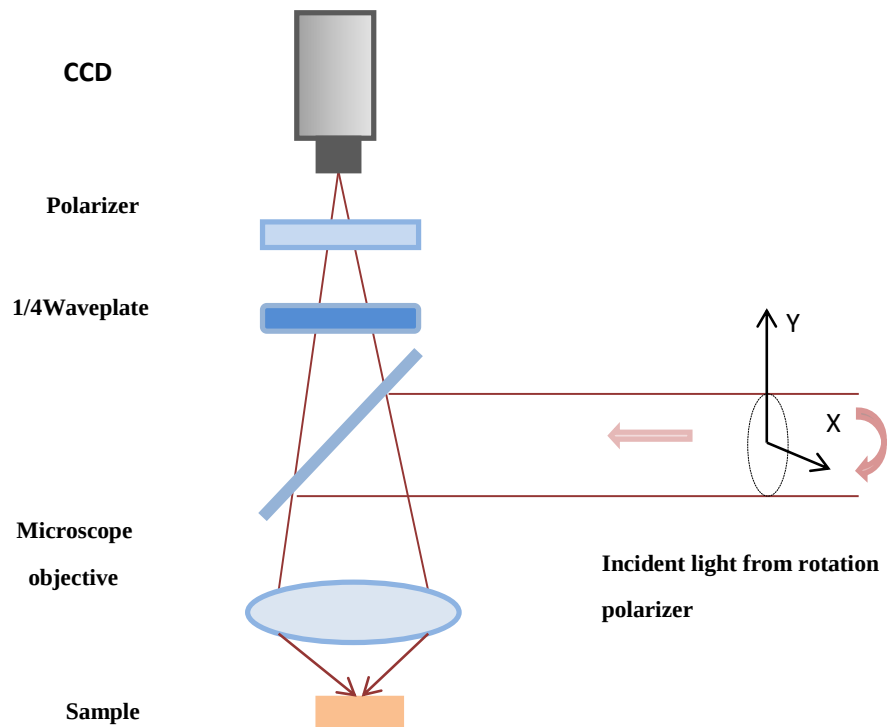


Fig.1. Diagram of modulated polarization parameter imaging system with a tilted sample.

PIMI system was built by the same as Olympus reflection microscopic system BX51M[4]. And the microscope objective is 0.9 Numerical Aperture (NA) 100X magnification under the narrow-line width(<20nm) 532nm illumination and CCD with pixel size of 3.4 micron and output range of 12 bits. The incident light with the polarizer rotating lead to the polarization of its sweeping, while the CCD images were synchronized with the position and movement of rotation polarizer automatic control. In this way, the measurement of the GaN sample with the tilted small angle has been established. As expected, (SUM) will be imaged by part of picture inside or outside focus and another part in focus. Whatever inside and outside focus is out of focus, which can lead to optical blur. In order to the standard test, the SUM on focus will be used by ensuring the existence of the imaging of focus plane, which is clearer. Furthermore, the PIMI has the sub 100 nm resolution, which is capable of wide view-field and far field measurement comparing with the Scanning Electron microscopy(SEM).

4. Results and Discussion

We have take the images of the sample through the indirect microscopy(PIMI) in different magnifications. The image results are shown in below figs.(2-4).

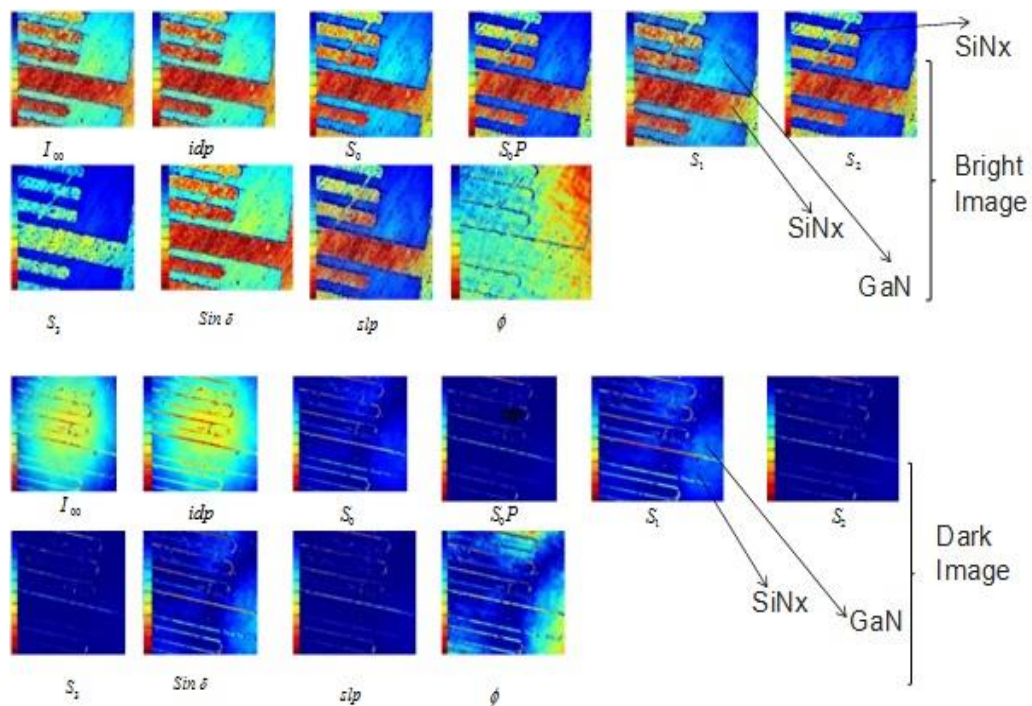


Fig.2: 10 X magnification in the same position

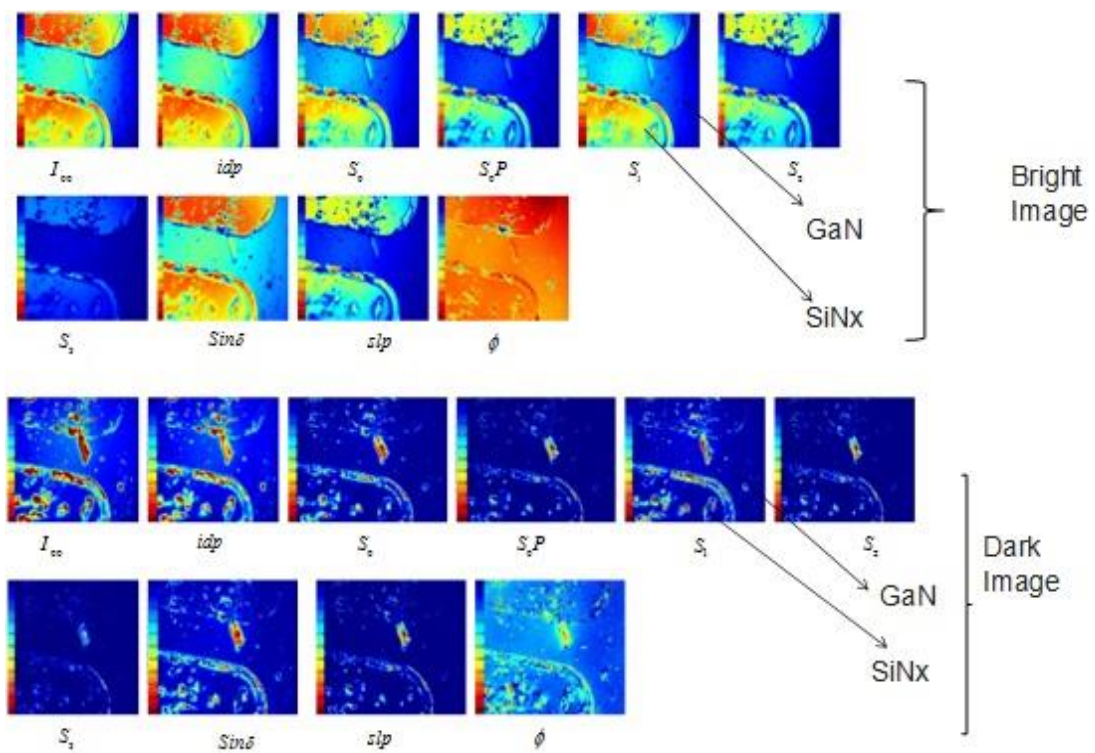


Fig.3: 50 X magnification in the same position

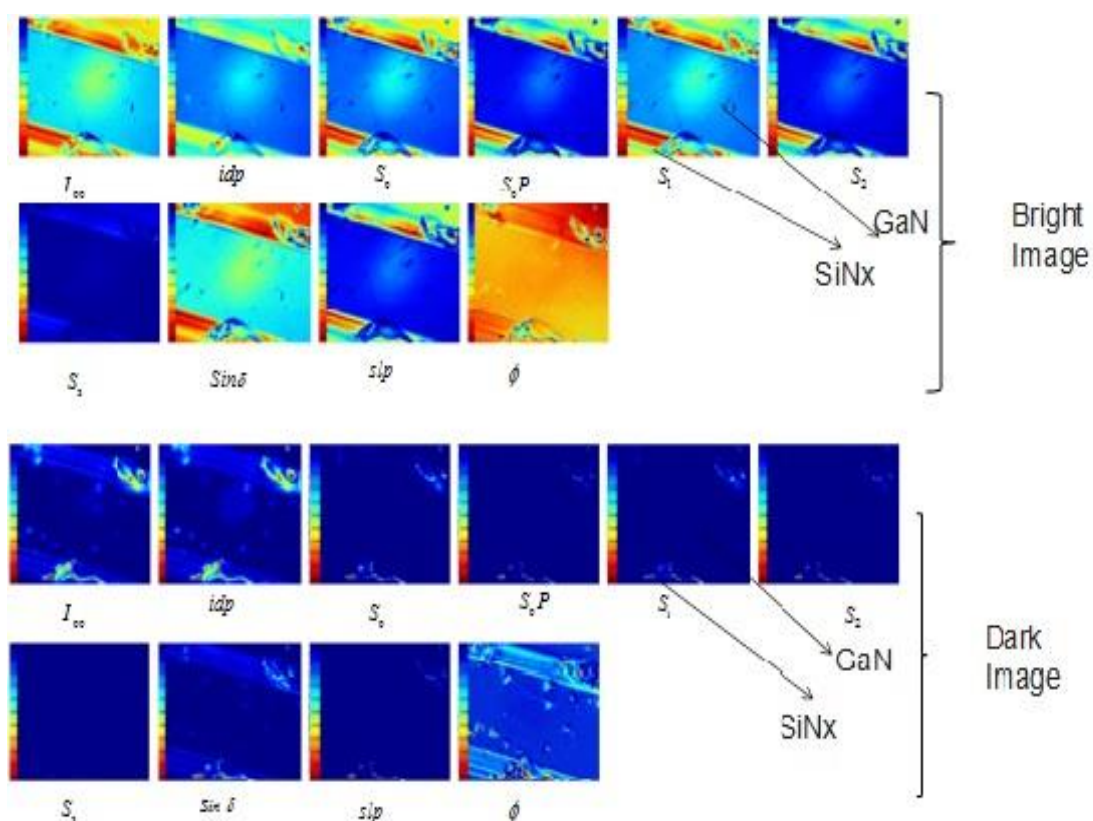
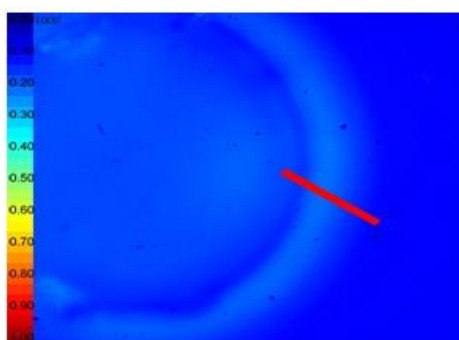


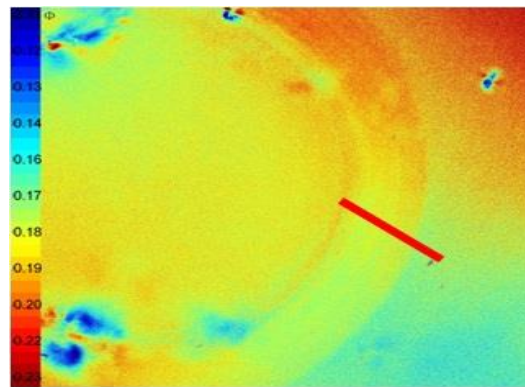
Fig.4: 100 X magnification in the same position

Table-1

Sample-1	OCL	MSE	OCL/MSE	RMSE	OCL/R MSE	Contra st
I ₀₀	0.2481	3.2021 E-04	774.8652	1.79E-0 2	13	0.02
Phi	0.2492	8.1357 E-04	306.2633	2.56E-0 2	9	0.04



(a)(100)



(b)Phi

Fig. 5: PIMI Image with line (a) I00 (b) Phi

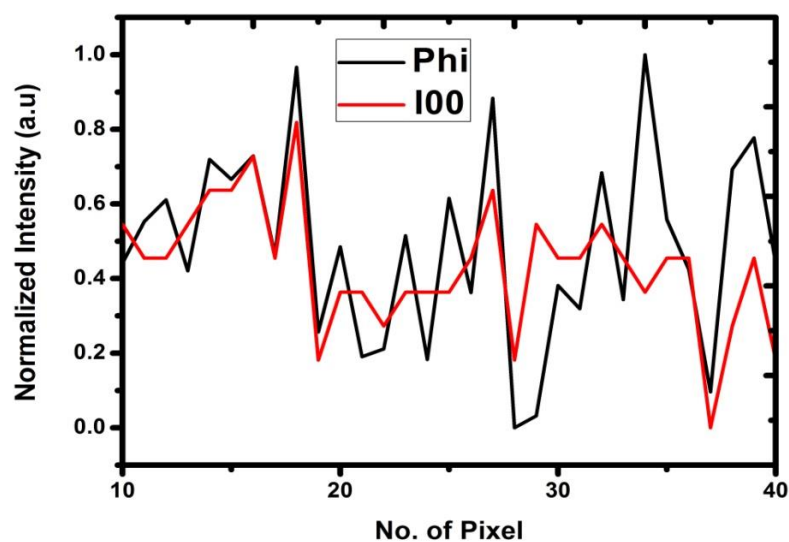


Fig.6: Image quality and contrast variation between Phi and I00 PIMI Image.

With the help of all PIMI images, first we would to see whether the etched part is fully etched without SiNx. You may see the pattern with 5 fingers (fig.2) and one can see the area between fingers to see whether there is SiNx left or not?.And check the difference on the fingers and between the finger, if there is SiNx on the finger, there should be no SiNx between finger, or its opposite. According to all issues, we have done the measurements of this sample through PIMI on 10X,50X and 100X magnification both bright and dark fields.I00 is image of conventional images and from S_0 to ϕ are the stokes parameter of the PIMI. From the above results of GaN images, it will be easy to confirmed that if SiNx on the fingers in sample then GaN is between the fingers or its opposite. Form figs. 2 to 4, you can see the PIMI images with different magnifications of the same sample. In dark images has

more resolution as compare to bright images. The confirmation of this new idea, we have draw a line in PIMI image of Phi and I00 shown in fig.5 and also calculated the MSE, RMSE and contrast in table-1. Further, we have draw the curve between Phi and I00, which can seen in fig.6.. Finally we got the contrast of phi images is better than I00 images, and we have also compared the results between bright and dark field, found that the resolution of PIMI is more accurate is near about 80 nm. And we achieve the resolution of the conventional microscopy is 322.47nm for GaN sample whose ideal resolution is 296nm using the same objective parameter. In this way, we can also calculate the resolution through the line methods of any of the sample images.

5. Conclusion:

In this paper, we discussed how GaN have been used for better imaging surpassing and complementing the currently available optical microscope (PIMI). GaN have shown ability to control electromagnetic wave at the nanoscale, allowing nanometers order of imaging resolution to come true. Therefore, with the development of nanofabrication and nano manufacturing methods, and the integration of new creative ideas, overcoming the results and limitations mentioned in this paper will be the continuous efforts to make GaN-based imaging techniques to be a next generation of imaging technology replacing current optical microscopy, which thus can be called nanoscopy.

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