Endpoint Detection Using OES in Via SiC / GaN Fabrication

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Abstract

GaN-on-SiC technology backside processes is challenging due to SiC etching and process integration. SiC via etch processing is typically done in ICP-RIE tools using Ni or ITO mask with SF6/ O2 /Ar gas mixture to achieve higher etch rate. Typically, the SiC via etch process is done in 75 - 100 um SiC thickness. The OES end point detection being used in GaAs and Si technologies improves via yield and increases process capacity. SiC etching is based on time dependence trying to stop on the GaN layer. The OES technique usually depends on the ability of monitoring byproducts of the etch process to achieve endpoint. The main critical parameter is signal / noise ratio and it is related to hardware, minimum open area to be etched and etching algorithm. This work demonstrates etching SiC with high repeatability and precision stopping on the GaN layer, using optical emission spectroscopy (OES) endpoint detection.

1. INTRODUCTION

Optical emission spectroscopy (OES) is a common method used in semiconductor technology during plasma etching processing for Endpoint detection (EPD). The method is based on measuring and tracking intensity changes in optical emission signals of the reactive species in the plasma over a period of time during the etch process. Typically, OES broadband wavelength is in the range of 200-1100 nm.

EPD methods using OES focus on identifying a single wavelength that corresponds to a chemical species in the plasma. When the etched layer is removed by the etching process, the concentration of reaction products from the etched layer is reduced and the intensity of specific wavelength will be reduced accordantly [1, 2, 3].

Typical Si / SiO_2 etch process uses fluorine gas mixture of CF_4/O_2, SF_6/O_2 but other combination like C_2F_6/O_2 could be found. In addition, Ar or N_2 can be added for mixture dilution or plasma stabilization. Typically, when OES is used for EPD detection the following wavelengths are being monitored: SiF (440.2 nm), SiO_2 (248.6nm), Si (505.6 nm), CO (482.5 nm). In this study, we have developed an EPD method for SiC etching based on following parameters: fraction of Ni mask open area and OES set up.

2. EXPERIMENTAL & RESULTS

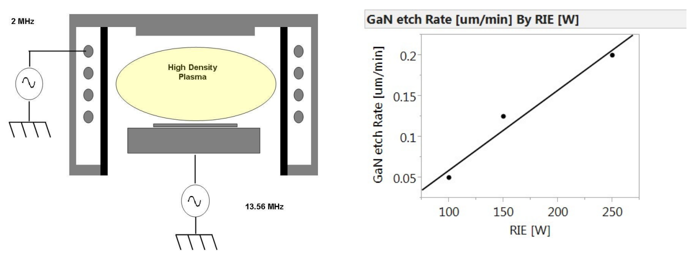


Fig.1. a) Plasma Therm ICP-RIE b) GaN etch rate vs RIE power

The SiC etch process done on a Plasma Therm ICP-RIE tool with upper 2 MHz power generator for plasma generation and bottom 13.56 MHz power generator to control DC bias voltage and OES detector. (Fig.1. (a)). The etch process is a twostep process, both steps using SF_6 /O_2/Ar gas mixture but the first process step uses higher RIE power to increase the physical mechanism of the etch process. The second process step reduces the RIE power in order to achieve better control and uniformity to stop on the GaN layer. The RIE power was pre-calibrated. Finally, it was set to 150 W. GaN etch rate vs. RIE power are shown in Fig. 1. (b)

In order to set OES wavelength to be monitored during the process, a seed layer was sputtered and ~ 4um Au electroplating was applied on the front side of 3" Si and SiC wafers, and each wafer was mounted on 4" perforated sapphire carrier.

All wafers were grinded to 50 um thickness and processed for full SiC etching using second etch process step parameters. During the last 10 min of the etching process the OES detector was switched on. In order to choose the wavelength with the higher signal difference between end to start, the wavelengths between 200-1100 nm were recorded. The signal of SiF (440.2 nm wavelength) was chosen for process monitoring, which is one the etching products that has and good signal difference. Shown in Fig.2

When SiF (440.2 nm wavelength) peak was significantly reduced, the process was manually stopped. Visual inspection of bare Si and SiC wafers revealed 100% etch. The above results showed good potential for making endpoint detection using SiF(440.2 nm) signal.

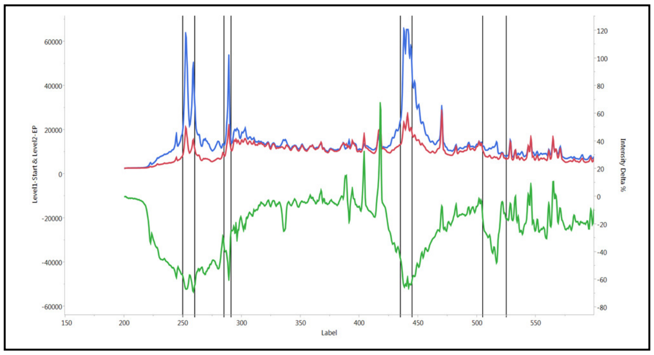


Fig.2. Bare SiC OES wavelength monitoring. **Blue** – Starting point signal, **Red** – end point signal, **Green** – delta (EPD – Start)

3. OES SIGNAL / NOISE CALIBRATION

In order to obtain high signal to noise ratio for EPD, the OES signals (200-1100 nm) were recorded for 3 different wafers: Si without mask (100% open area), SiC 100% open area & SiC with 2% opening area of Ni mask. All wafers had the same etching process parameters: ICP and RIE power, pressure, gas flow etc. While observing the difference of OES signature between 100% open area of Si (Blue) and SiC (Red), one can see intensity reduction of ~50% in the range of 200-330 nm wavelength, and ~33% in the range of 400-600 nm wavelength, shown in Fig 3.

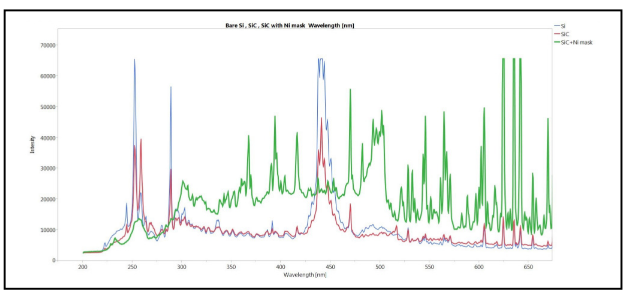


Fig.3. **Blue** – Start signal of OES on Si wafer,
Red – Start signal of OES on SiC wafer,
Green - Start signal of OES on SiC wafer with 2% open area.

This result probably was caused by the nature of byproducts related to crystal material differences (Si vs SiC). But when comparing 100% open area of SiC (Red) to 2% open area of SiC (Green), one can see signal reduction of ~ 75% in the range of 200-330 nm and 100% in the range of 400-600 nm, making endpoint detection using SiF(440.2 nm) impossible. On the other hand, tests with 20 % opening area of Ni mask were able to achieve good EPD, shown in Fig.4. Typical via open area is less than 1%, so in order to achieve good EPD it was clear that we have to increase signal to noise ratio. New hardware was installed and a new algorithm was developed for better sensitivity, those solutions helped to overcome the problem and make the EPD applicable.

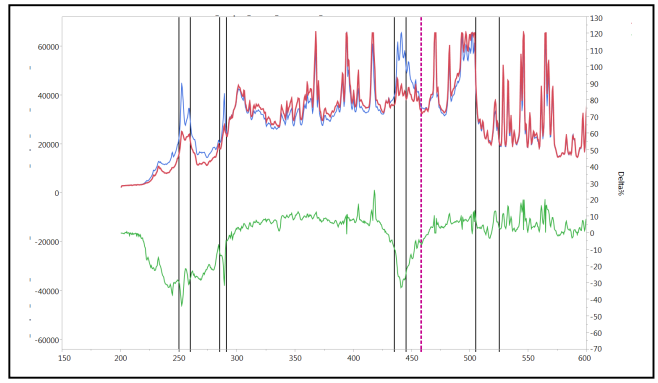


Fig 4. OES on SiC wafer with 20% open area, **Blue** – Starting point signal, **Red** - end point signal, **Green** – delta (EPD – Start).

4. RESULTS of NEW EPD PROCESS

100 mm SiC wafers with full front metallization were mounted on perforated sapphire, wafers then grinded to 100 um thickness and Ni masks (~10 um) with different open areas (down to 0.5% mask open area) were tested.

SF_6 / O2 gas mixture was used during the etching process and SiF (440.2 nm) was monitored, shown in Fig.5 and Fig.6. All wafers were passed visual inspection (VI) and showed 100% yield of stopping on the GaN layer, shown in Fig7.

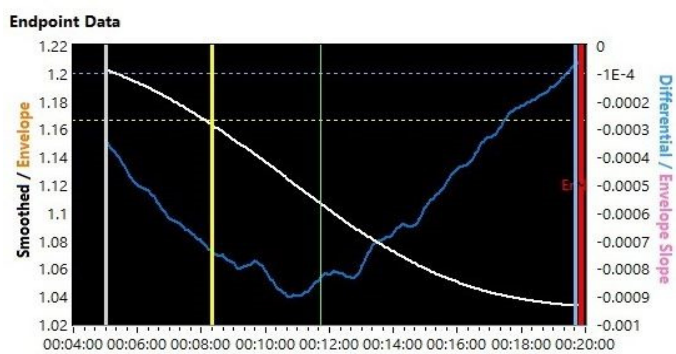


Fig.5 OES of 2.4 % open area during the etching process. **White** signal of new monitor function (f), Blue – df/dt

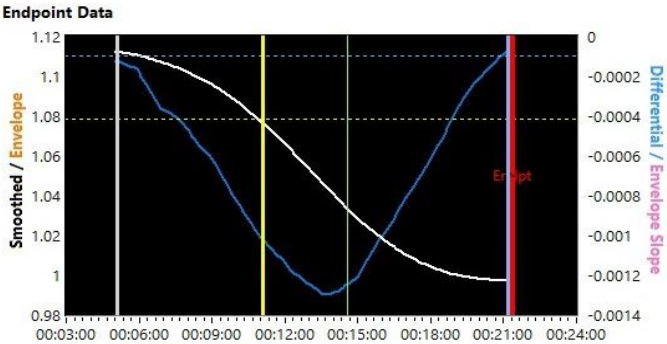
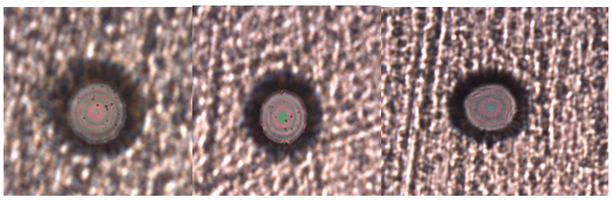


Fig.6 OES of 0.5 % open area during the process. **White** signal of new monitor function (f), Blue – df/dt



a) Top b) Center c) Bottom

Fig. 7. EPD on 0.5 % opening, VI test across the wafer showing 100% yield stopping on the GaN layer.

5. CONCLUSION

In this study, we have showed the reduction of OES signals when Ni mask was applied on SiC wafer. New hardware was installed and a new algorithm was developed for better sensitivity. We successfully demonstrated that EPD using OES for a SiC via process can be achieved for Ni mask open area down to 0.5%.

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ACRONYMS

OES: Optical emission spectroscopy
EP: End Point
EPD: End Point Detection
SiC: Silicon Carbide