905 nm wavelength laser as a new source for in-situ end point detection of dry etching of $Al_XGa_{1-X}As$ on GaAs

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ABSTRACT

A new method has been developed for in-situ end point detection of etching of $Al_XGa_{1-X}As$ over GaAs. The results obtained with a conventional 670 nm and a new 905 nm infrared laser during etching have been compared. Light from a 670 nm laser strongly absorbed in both of GaAs and $Al_XGa_{1-X}As$ materials and no interference was detected. In contrast, incidence of 905 nm wavelength infrared laser light on the materials caused some interference with $Al_XGa_{1-X}As$, and no interference with GaAs due to absorption. The results produced a noticeable difference of signal patterns for etching of the two materials. End point detection data with 905 nm laser on various $Al_XGa_{1-X}As$ compositions (i.e. $x = 0.3 \sim 0.92$) and different types (n- or p-AlGaAs) are also reported.

INTRODUCTION

There has been a great demand for improved end point detection technologies for advanced etching of $Al_XGa_{1-X}As$ on GaAs layers. There are a variety of techniques applicable including optical emission spectroscopy (OES)(1-8), reflectometry(6-11) photoluminescence(11,12) and mass spectrometry.(2,7,14-17) Current approaches have focused on two methods. One is optical emission spectroscopy, which requires relatively a large wafer, fast etch rate and a detectable emission line from etch byproducts. Another method is based on light interference and refractive index of materials (or, band gap energy). An infrared laser source has been employed previously as an end point technique for III-V semiconductor etching because of its possible advantages over the OES method in terms of sample size and accuracy of interpretation.(1-3) However, use of conventional 670 nm laser source has difficulty in producing distinguishable interference patterns with either $Al_XGa_{1-X}As$ (where x= ~0.3, transmitting wavelength is 790 nm) or GaAs (where transmitting wavelength is 918 nm) layers due to absorption in the materials. The light from a 670 nm laser is strongly absorbed in GaAs and $Al_XGa_{1-X}As$ materials and heterostructure interferometry is limited to optically thin (< 5000 Å) layers. For etch rate monitoring of thicker layers, either specific diffraction test patterns or longer wavelength must be employed. For example, light from a 905 nm wavelength infrared laser cause some interference with $Al_XGa_{1-X}As$, and no interference with GaAs due to absorption, which will produce a noticeable difference of signal patterns for etching of the two materials. Note that the transmission wavelengths of GaAs and $Al_{0.27}Ga_{0.73}As$ are 918 and 790 nm, respectively, and 905 nm is between the two wavelengths. In this case, we can utilize a 905 nm wavelength laser as a new source for in-situ end point detection for $Al_XGa_{1-X}As$/GaAs etching.

EXPERIMENTAL

A new laser module with 905 nm wavelength was manufactured by SOFIE Instrument S. A. Inc. 0.2-2 micron thick $Al_XGa_{1-X}As$ (where x= ~0.3 - 0.92) layers were grown on bulk GaAs wafer. Plasma-Therm load-locked SLR 770 Inductively Coupled Plasma (ICP) etcher utilizing 2 MHz rf frequency was used for etching of the materials. The process chemistry employed 20 standard cubic centimeter per minute (sccm) BCl_3, 5 mTorr chamber pressure, 100 W rf chuck power and 800 W ICP source power. Etch depths were measured with Tencor profilometry after etching.

RESULTS AND DISCUSSION

Table 1 shows band gap energies and wavelengths of our GaAs and $Al_XGa_{1-X}As$ (i.e. x = 0.3 ~ 0.92) samples. Notice that bulk GaAs with band gap energy 1. 35 eV has wavelength of 918 nm while $Al_{0.27}Ga_{0.73}As$ has a bandgap corresponding to 790 nm wavelength.

Figure 1 shows in-situ monitoring results during etching of $Al_{0.28}Ga_{0.82}As$/GaAs heterostructure with a conventional 670 nm laser module. No distinguishable interference pattern was obtained. In all case, all of 670 nm wavelength laser beam was absorbed in the materials.

Figure 2 depicts monitoring results with a 905 nm laser for etching of the some heterostructure. Note that there was a clear interference pattern for AlGaAs etching and it disappeared for GaAs etching. High Al composition increased the magnitude of interference intensity for AlGaAs etching (Figure 3). Note also that the interference wavelength of the laser with 50 %, and 92 % Al composition AlGaAs during etching was quite different even though the difference was hardly noticed for etching of 28 % and 50 % Al containing AlGaAs (refer Figure 2 and Figure 3 (top)). Monitoring results of n- and p-type AlGaAs etching are shown in Figure 4. Total etch depths of p^+AlGaAs/GaAs, n^+AlGaAs/GaAs were measured as 2000 Å, 5936 Å, respectively, after etching. Use of 905 nm laser produced excellent interference patterns with both n and p-type AlGaAs etching even for relatively thin layers (p-type case).

SUMMARY AND CONCLUSIONS

We investigated a new laser source to develop in-situ end point detection techniques during etching of $Al_XGa_{1-X}As$/GaAs layers. An infrared laser with 905 nm wavelength successfully demonstrated its capability as an in-situ end point detector. More research on interaction of the laser and $Al_XGa_{1-X}As$ materials may be required for more advanced application, especially for etching of very thin $Al_XGa_{1-X}As$ layer (< 1500 Å).

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Table 1 shows band gap energy and wavelength of prepared GaAs and $Al_XGa_{1-X}As$ (i.e. x = 0.3 ~ 0.92).

	Band Gap energy at room temp. (eV)	Wavelength (nm)	refractive index (λ = 905 nm)	refractive index (λ = 670 nm)
GaAs	1.35	918	3.54	3.78
$Al_{0.27}Ga_{0.73}As$	1.57	790	3.36	3.55
$Al_{0.5}Ga_{0.5}As$	1.76	707	2.93	3.20
$Al_{0.92}Ga_{0.08}As$	2.10	592	2.64	2.70

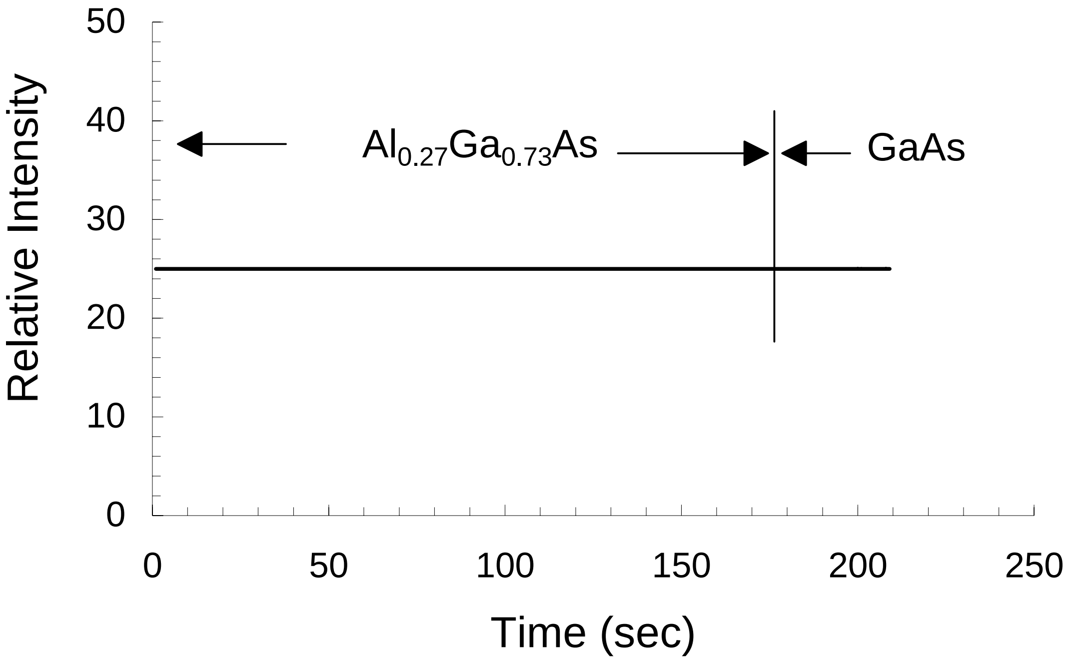
FIGURE CAPTIONS

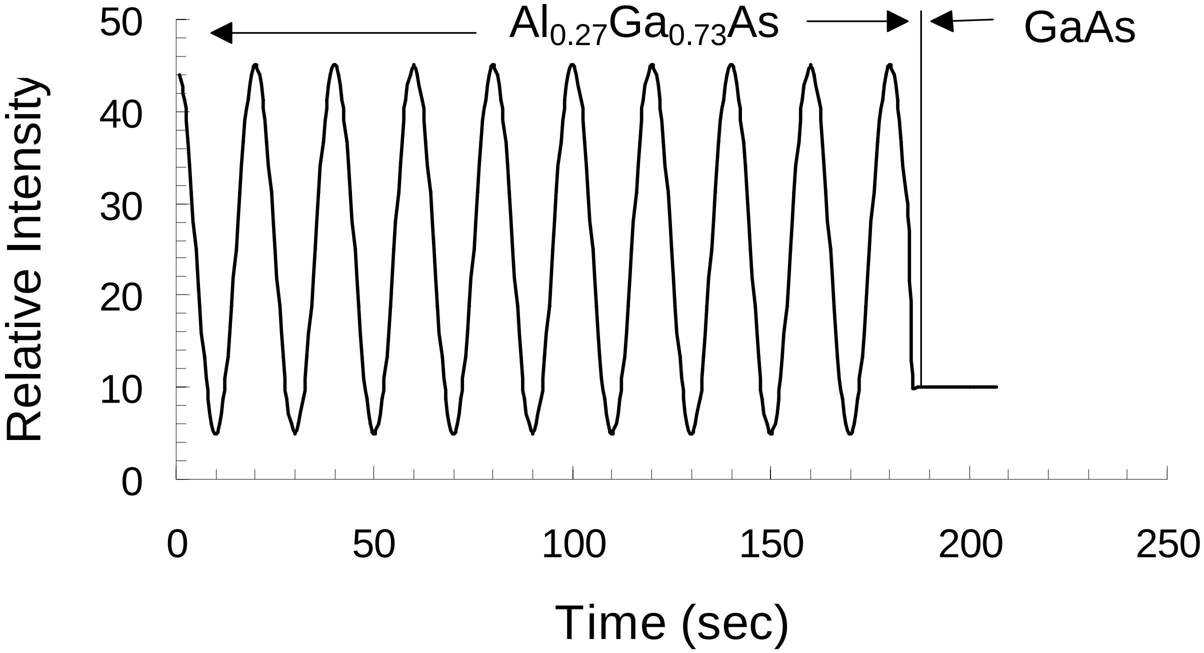
Figure 1. A signal pattern from $Al_{0.27}Ga_{0.73}As$ layer with incident 670 nm wavelength laser during dry etching.

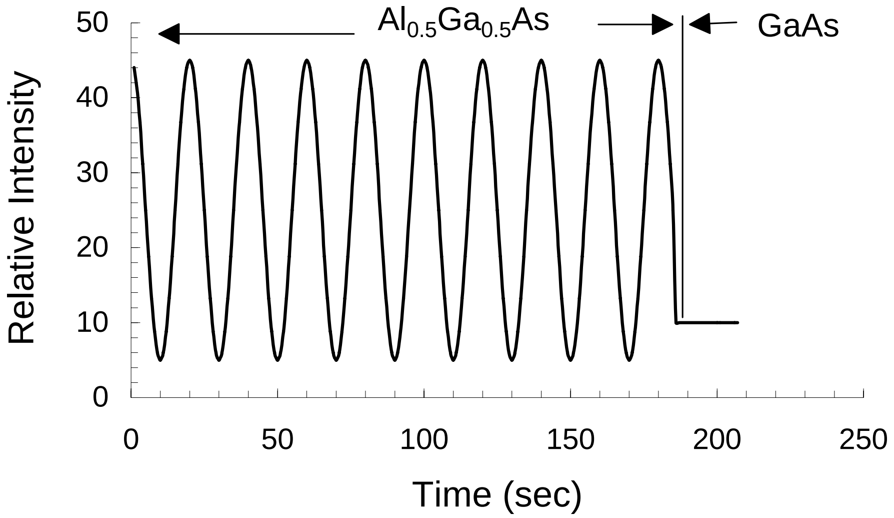
Figure 2. A signal pattern from $Al_{0.27}Ga_{0.73}As/GaAs$ layer with incident 905 nm wavelength laser during dry etching.

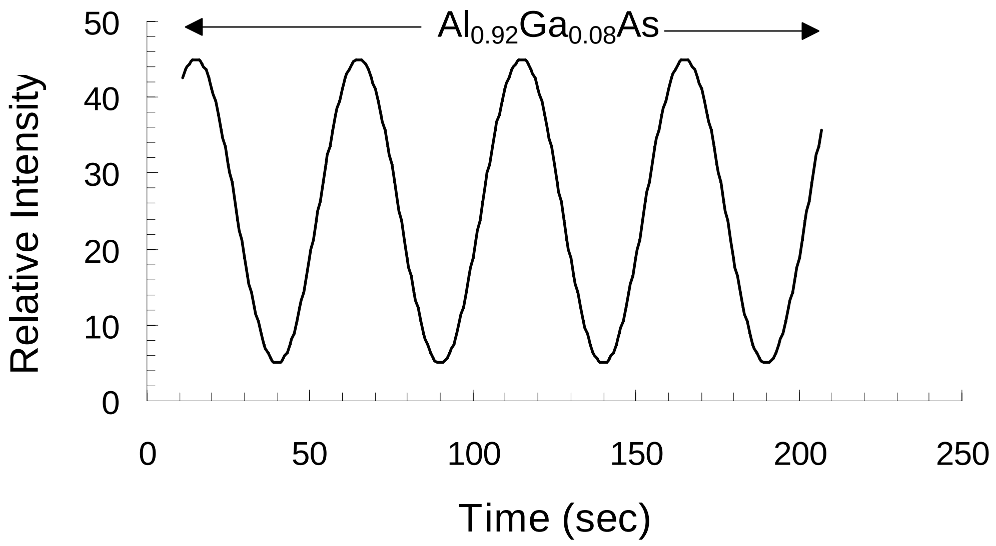
Figure 3. A signal pattern from $Al_{0.5}Ga_{0.5}As$ /GaAs (top) and $Al_{0.92}Ga_{0.08}As$ (bottom) layer with incident 905 nm wavelength laser during dry etching.

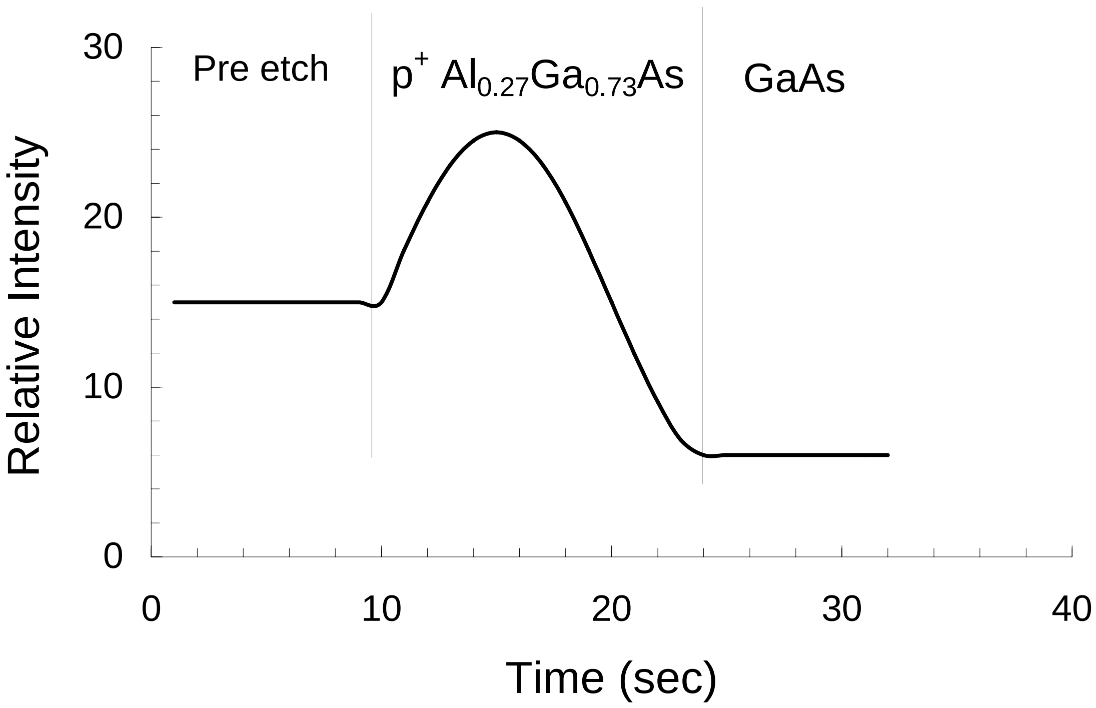
Figure 4. A signal pattern from $p^{+}Al_{0.27}Ga_{0.73}As$ /GaAs (left) and $n^{+}Al_{0.27}Ga_{0.73}As$ /GaAs (right) layers with incident 905 nm wavelength laser during dry etching.

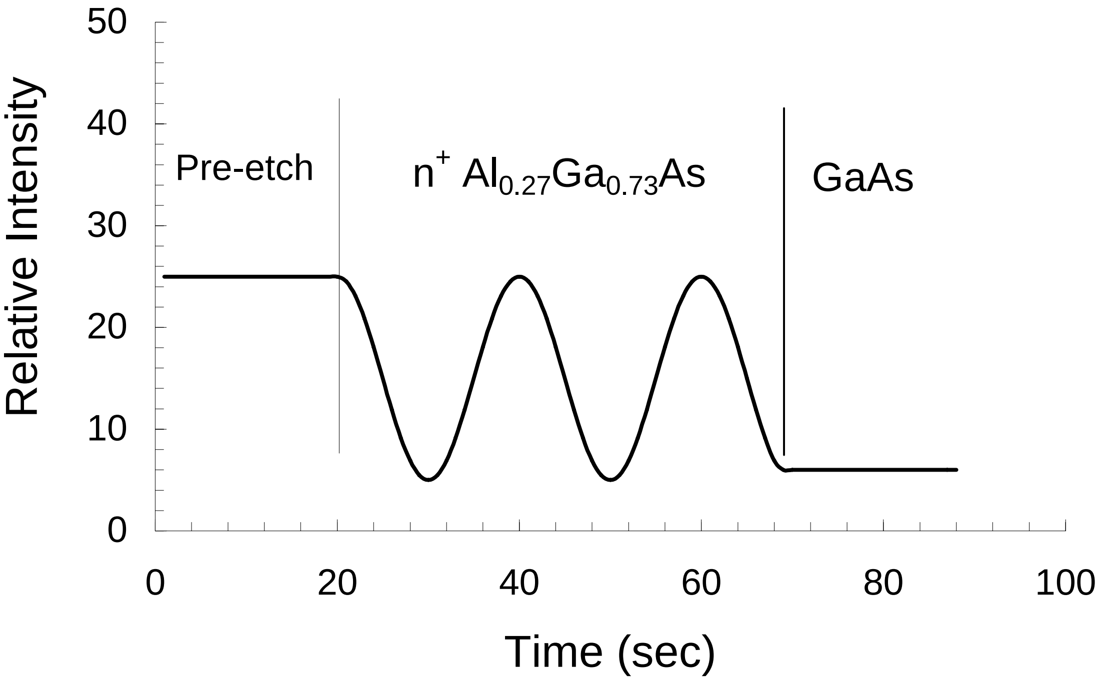

Relative Intensity
50
40
30
20
10
0
0
50
100
150
200
250
Time (sec)
$Al_{0.27}Ga_{0.73}As$
GaAs


$Al_{0.27}Ga_{0.73}As$
GaAs
Relative Intensity
0
10
20
30
40
50
0
50
100
150
200
250
Time (sec)


$Al_{0.5}Ga_{0.5}As$
GaAs
Relative Intensity
0
10
20
30
40
50
0
50
100
150
200
250
Time (sec)


$Al_{0.92}Ga_{0.08}As$
Relative Intensity
0
10
20
30
40
50
0
50
100
150
200
250
Time (sec)


Relative Intensity
Time (sec)
Pre etch
p^+ $Al_{0.27}Ga_{0.73}As$
GaAs
0
10
20
30
0
10
20
30
40


Relative Intensity
Time (sec)
Pre-etch
n^+ $Al_{0.27}Ga_{0.73}As$
GaAs
0
10
20
30
40
50
0
20
40
60
80
100