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Laser Inspection for Visualizing Vibration in a Fine Structured Device†

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A real time optical metrology to detect nano-scale vibration on the surface of solid materials is presented. Comparing to the electric method checkable only whether the vibration occurred or not on the surface of device to be investigated. The real time optical metrology provides visual information how and where the vibration occurred in nano-scale. We propose a laser inspection method for real time visualizing any vibration on the surface of device or materials. The measuring limit and conditions to detect a small surface vibration are given with a function of speed and sensitivity of detector. The observed signals of interference and diffraction are analyzed by theoretical interpretation.

Key Words: Laser inspection, Nano-scale vibration, Fine structured solid material.

INTRODUCTION

Many methods of diagnosing device and material have been tried for more accurate and real time inspection[1]. Most electric metrology including atomic force microscopy and scanning electron microscopy provides comparatively reliable information for surface roughness even to nanometer scale. However, there is still a limit in visualizing real time inspection for a nanosecond pulse vibration on the surface of sample. Laser assisted detection technique was motivated by the need to visualize and image speedy vibration formed on the surface of solid materials such as silicon wafer[2].

The inspection for surface acoustic wave performance in a SAW device has been executed by an electric method which makes out the existence of surface acoustic wave. The defect of electric method is that it is difficult to find out the geometric characteristics of surface acoustic wave in SAW device because there is no more information without an answering spectrum for given signal. The optical metrology for very fine vibration on surface of solid state has been started from 1960's when the first laser developed. Including knife-edge measure, many optical processes such as diffraction, interference have been studied[3]. The factors of measurement are figured out by a function of amplitude and frequency. Comparing to the electric method, the optical metrology has a strong advantage of visualizing vibration caused by surface acoustic wave, besides sensitivity higher than other measurements. The sensitivity of optical method can be reached to 10^{-11}-10^{-8} m vibration when the laser beam focused at specific position. Sometimes even the second harmonic signal, very weak as much as 10^{-12} m, can be detected, which is comparable to the thermal vibration[4] of *ca.* 10^{-11} m.

In this study, the laser interference and diffraction has been tried for visualizing vibration of surface acoustic wave formed on SAW device. The difference in optical signals between RF input signal was permitted and not-permitted was analyzed in theory and experiments, which provided the information of local energy distribution caused by surface acoustic wave.

EXPERIMENTAL

Measurement of surface acoustic wave vibration: In optical methods for detecting fine vibration, interference, diffraction, reflection and deflection has been tried with instruments. In this study, the interference and diffraction methods with single mode laser were used for measurement of surface acoustic wave formed on SAW device.

RESULTS AND DISCUSSION

Fig. 1 depicts (a) microscopic picture and (b) frequency spectrum of signal responding of repeater filter that was used for measurement. The spacing of IDT was *ca.* 80 µm, the center frequency was 105 MHz and the band width of it was *ca.* 10 MHz.

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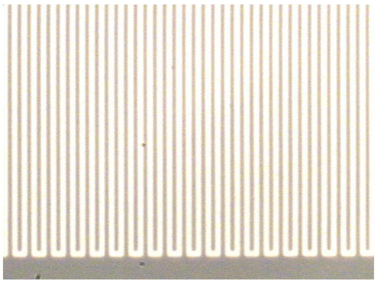
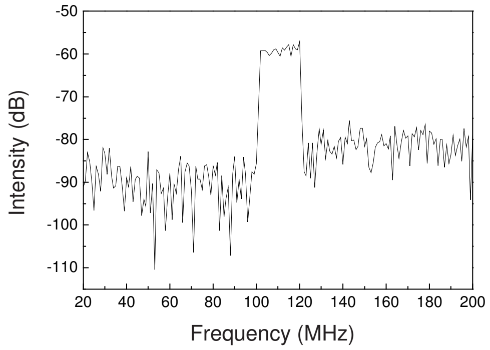


(a)



(b)

Fig. 1. (a) Microscopic picture and (b) frequency spectrum of a repeater filter

A microscopic picture shown in Fig. 1(a) is magnified 1,200 times and (b) was obtained at 30 dB input by network analyzer (Agilent).

Fig. 2 describes a comparison of interferences that obtained with and without RF signals. The detection of interference intensity with position was done along the perpendicular direction to the optical axis. RF inlet signal decreased the peak to peak intensity value of interference as shown in upper graph of Fig. 2. That is explained the increase of finess, F, which implicates the sharpness of fringe. RF inlet signal generated a surface acoustic wave, therefore lessen of a directional reflection from piezoelectric surface. The same reason caused the reduced edge intensities indicated in Fig. 2.

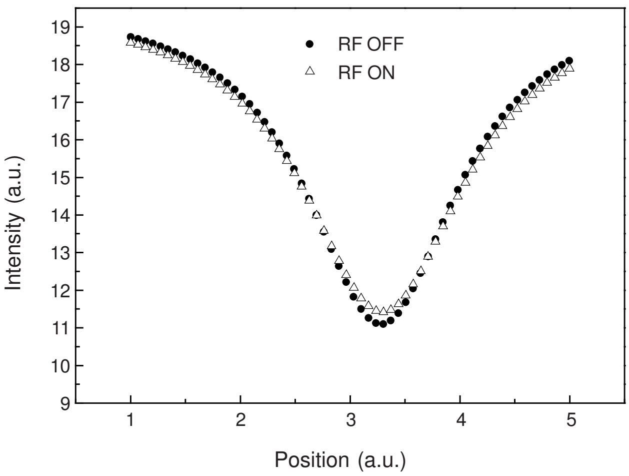
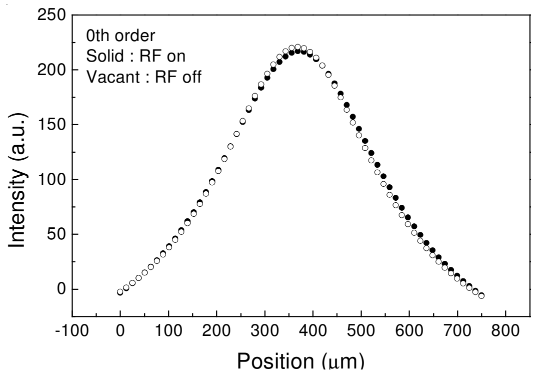
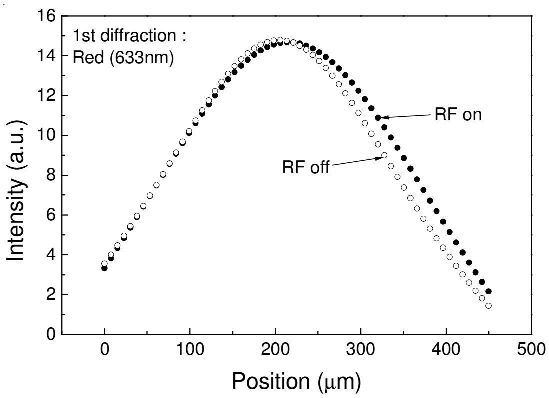


Fig. 2. Comparison of interferences that obtained with and without RF signals

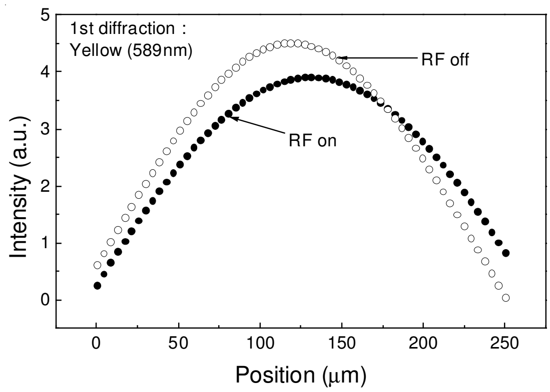
Fig. 3 is a experimental results of diffraction. Fig. 3(a) is for the 0th order reflected beam and (b)-(d) are for the 1st order diffracted beam. The difference could not be found in 0th order reflected beams between optical intensity distributions whether or not RF signal biased regardless of laser wavelength. Fig. 3(a) is for the red light of 633 nm laser probe beam. However, the 1st order diffracted beams showed differences in distribution and position as shown in Fig. 3(b)-(d). It is believed that the difference was caused by gradient of surface acoustic wave. The reason why the 0th order could not show the difference like 1st order diffracted beam distribution was that most probe beam light experienced reflection and pointed the same angle of incident angle by the law of reflection. As a result, the effect of deflection was much smaller than reflection in 0th order. The difference in light distribution in 1st order diffracted beam was larger at shorter wavelength of probe laser beam as shown in Fig. 3(b)-(d). It is also explained that the longer wavelength is, the larger angle diffracted. The larger angle of diffraction makes it difficult to detect the difference in light distribution.



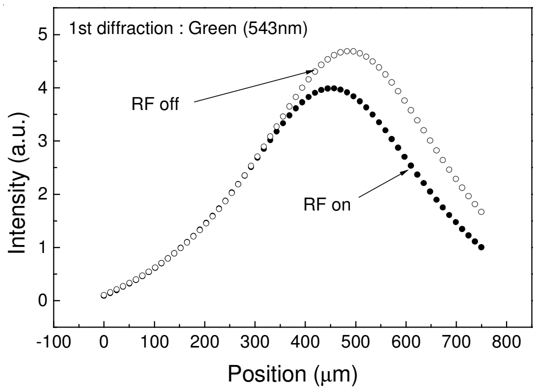
(a)



(b)



(c)



(d)

Fig. 3.

Conclusion

In this study, the optical methods of visualizing positional surface acoustic wave were suggested for inspecting complex module of multi-function, which provides an important technical solution for analyzing structure of IDT and disposition of absorber and isolator.

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