A Novel Method for determining Optimum Etch Times for the One step Dry Release Process

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ABSTRACT

This paper details a novel method for determining the optimum etch times for releasing structures when using the authors' one step dry release process. By using self releasing structures known as 'waffles' the exact point when a device is released can be determined without having to etch numerous chips for different times and sectioning them. This solution allows a worker to determine when a device is released by a simple visual check.

***Keyword*:** One step DRIE dry process, STS, SOI Waffles

1. INTRODUCTION

This paper details an optimisation technique for the one step dry release process developed by the authors[1] from the work of Ranglow[2] and Ayon[3]. The authors' process facilitates the manufacture of released structures using STS Deep reactive ion etching[4,5,6,] and silicon on insulator (SOI) wafer technology[7,8] without the requirement for a second wet chemistry process step requiring the use of Hydrofluoric acid. It utilises the notching phenomena[9,10] experienced when DRIE reaches the buried oxide when etching SOI wafers. The authors developed design rules, which harness this notching phenomenon and if followed carefully can be used to release structures[1]. Initially there was a severe limitation to this process whereby any structure to be released by this process had to be bounded by a narrow trench typically 5 microns wide which was a limiting factor if a device was to achieve large actuation.

Further work led to the development of 'waffle structures'[11] which allow for the one step process to be utilised to obtain released structures now bound by large cleared areas. These waffle structures radically increase the applications for the one step process technology, which now can be used to manufacture artefacts such as large throw actuators or even large reservoirs for micro fluidics applications. It has now come to light that theses waffles can have a further application. As the waffles are removed by the same mechanism that releases structures, their removal occurs at the same time as a device adjacent to it is released. Thus they can be used to indicate when the device is released. The merits of this new application for waffles are detailed in this paper.

2.WAFFLES

A 'Waffle' is an area of silicon populated with a matrix of square holes and isolated from other design features by a perimeter trench. Figure 1 shows a micrograph of one of these sacrificial structures, 'waffles' that has been partly etched.

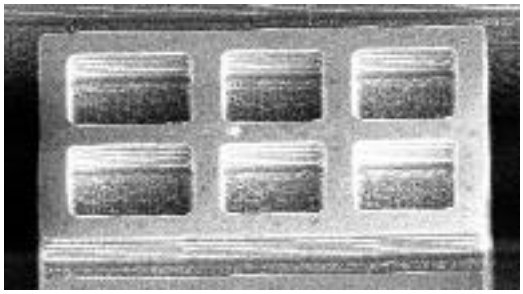

Figure 1 micrograph of a partly etched waffle (holes are 10 microns square)

Once etching is completed, the 'waffle' structures are released by the same undercutting effect [1,2,3] used by the one step process to release devices. This instigates their removal. The design rules for these sacrificial waffles are the same as those for any other feature integral to the device that needs to be released. Figure 2 Shows a waffle after it has released from the oxide layer and its removal is nearly complete.

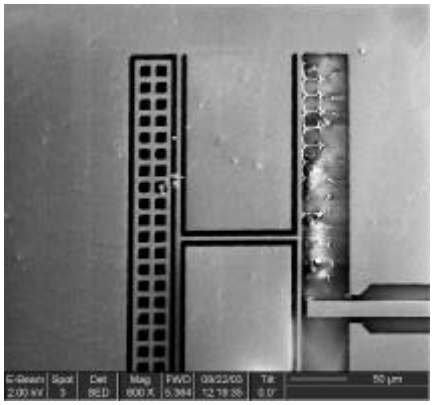

Figure 2 Waffle after it has released and dropped to the trench floor

To date the mechanism for the removal of the waffles is not fully understood. The proposed hypothesis for their removal is as follows. While a waffle is still attached to the oxide layer its orientation is assured to be perpendicular to the plasma (see Figure 3). Ion bombardment is collimated and only hits the trench floor and the top surface of the waffle, which is protected by photoresist. This orientation ensures the side walls and their passivation layers are not subject to ion bombardment and therefore they remain unetched either mechanically or chemically.

Once the waffle is released it loses this perpendicular orientation when it falls to the oxide layer. This is believed to be due to irregularities in the underside of the waffle occurring as a result of the release process. Subsequent etch steps expose the sidewalls of the waffles to ion bombardment removing the protective polymer layer (see Figure 3), mechanically etching them and then leaving them exposed to chemical etching. In this work the waffle walls are only 5 microns thick and the etch rate for the DRIE process is 3 microns per minute. In these conditions a disorientated waffle would only last approximately 1.5 minutes. This would explain why once a waffle is released its failure is radical and catastrophic.

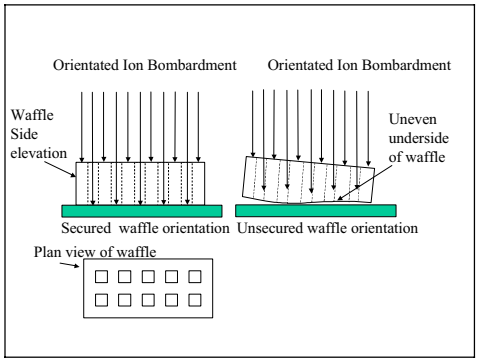

Figure 3 Proposed method for waffle removal

As previously stated these waffles have only been used to clear larger areas in close proximity to a released structure. Figure 4 shows a patterned wafer prior to etching containing a structure surrounded by waffles and then in figure 5 a micrograph of the device after its release and the waffles have been removed.

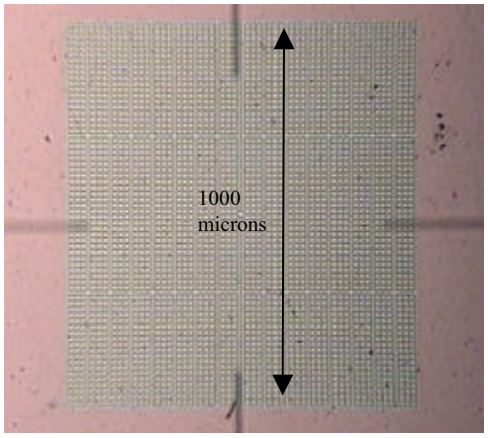

Figure 4 Optical Micrograph of the design with waffles prior to etching

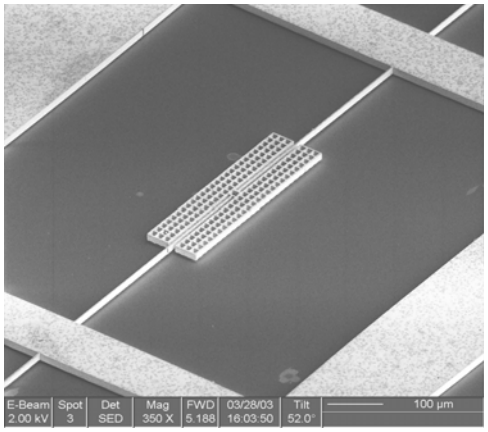

Figure 5 A micrograph of a device released and its surrounding area cleared using waffles.

3. NEW PROPOSED USE FOR WAFFLES

This paper details work that successfully illustrates how these waffles can be used for another purpose, to determine when a structure is released. When the one step process was being developed, determining when a structure had been released required sectioning of the sample and checking visually using an SEM. This method was time consuming and wasteful of chips.

It was then decided that the waffle structures could be utilised for an additional purpose. By placing a waffle in close proximity to a structure its removal could be used as an indicator as to when the released structure was released. As their removal is so radical and catastrophic it also allows the workers to accurately judge when structures are released. This allows for the production of released structures with a minimum notch size, and hence an optimum released structure.

The following micrographs show an example of a structure as it releases which is indicated as the waffle releases, fails and is finally cleared. Figure 6 shows a micrograph of a dual beam resonator after it has been etched for 8 minutes. To the side of it can clearly be seen the release indicating waffle still intact and unreleased there fore indicating the device is still unreleased (see also figure 7 for close up). Figure 8 shows micrograph of the same device after etching for a further minute and it can be seen that waffle removal has begun indicating that the device is releasing. Finally figure 9 shows the device and the complete elimination of the waffle indicating the device is fully released after a further 30 seconds of etching.

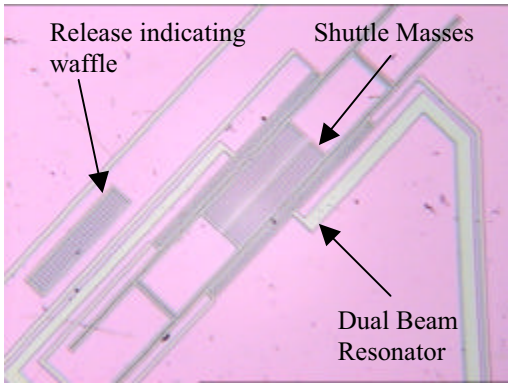

Figure 6 Micrograph of complete device after 8minutes of etching (device is 800 microns long)

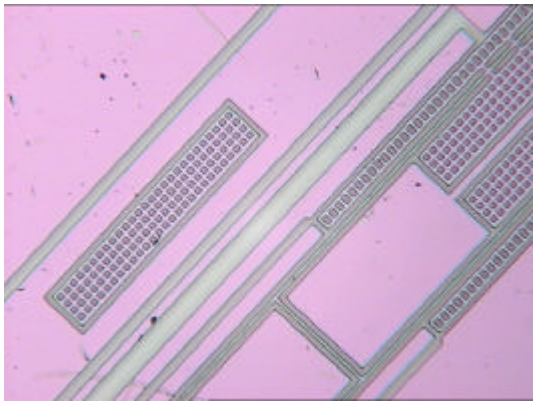

Figure 7 Close up of release indicating waffle (after 8 minutes etching)

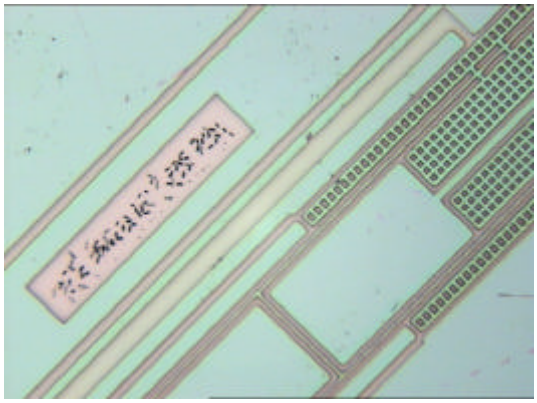

Figure 8 Release indicating waffle after catastrophic failure has commenced (after 9 minutes of etching)

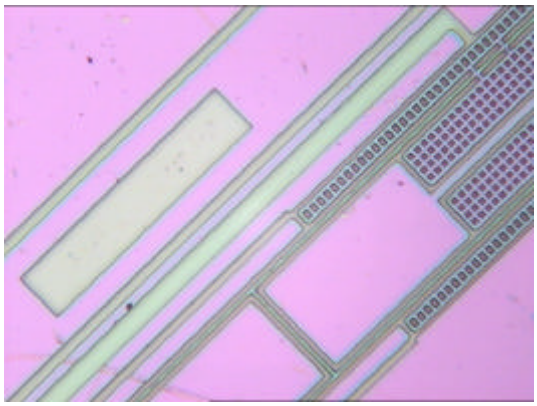

Figure 9 Release indicating waffle has been completely eradicated indicating that the device is completely released. (after 9.30 minutes)

To date the resonator has been excited using a piezoelectric device to prove it was in fact released.

From this work further information can be drawn to reinforce the hypothesis offered by the authors for the removal of the waffles. The time taken for them to be removed directly correlates to the time predicted by the hypothesis.

For production environments larger areas of these waffles that can be seen with a simple unmagnified visual check could be placed at various locations on a wafer. This would allow global releasing of devices across a wafer to be checked visually from the observation window of the STS DRIE. This could be a valid control check for a production environment, which would not involve costly downtime if removal of the wafer from the etching chamber were required. It can also be used by anyone already running an STS DRIE facility without the need for new and potential costly additional equipment.

4. CONCLUSION

This paper presents a technique that further improves the case for using the one step process over the traditional two step process.

The dry one step process has now a number of advantages over the more traditional two-step process. The first is the elimination for any wet bench chemistry, often a costly facility to install and often hazardous. It is able to clear large areas on a wafer, in fact its only limitation is the wafer area itself! Not only is it able to do this it does it without encountering grass formation[12] in these larger features that is encountered when using the two step process. It now has the facility to indicate when a structure is released. In addition to the previously known advantages, this new application of the waffle technique is a novel and valid asset to anyone wanting to take advantage of the new and vibrant one step dry process.

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