Development of a Wet Rinse Unit-Equipped Dry Etcher for Metal Processes

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With our dry etching equipment, high density plasma (5E10–1E11/cm^3) can be generated at low pressure (0.07–13.3 Pa) by ISM (Inductive Super Magnetron) type plasma source, making it possible to achieve a uniform etching distribution using a magnet.

In this issue, we developed dry and wet composite mass production type dry etching equipment for high quality SAW filters.

A crucial feature of this device is that it is equipped with hardware that performs a combination of dry etch and wet etch processes in a low dew point environment to reduce the corrosion that is particularly likely to occur in composite metal films.

1. Introduction

The Internet of Things (IoT), which is sometimes called the Fourth Industrial Revolution, is a technological revolution that is changing the world by connecting all things and all events to the Internet. The IoT revolution is projected to create a new market of 360 trillion JPY by 2020. Japanese industry currently controls more than 50% of the global market of IoT-related sensors and electronic components.

The number of devices connected to the internet as well as the number of related sensors is expected to increase rapidly as IoT technology becomes widely used. As a result, the demand for ultra-compact and ultra-thin electronic components will also grow exponentially.

Development of new technologies is also required for communication equipment and RF devices in 5G; i. e., the next-generation communication standards considered essential for supporting the IoT.

Among RF devices, the SAW (Surface Acoustic Wave) filter, which allows only the required frequencies to pass, is a key passive component in communication equipment. As the functions of smartphones have become increasingly sophisticated, the number of SAW filters used per smartphone has increased, up to nearly 50 in some models.

While the frequencies used in current 4G smartphones are between 700 MHz and 2.5 GHz or 3.5 GHz, 5G models will use 5–6 GHz, 10–20 GHz, and even 60 GHz.

Figure 1 shows the frequency bands of RF devices and future technical trends. Even while the frequencies used are expected to become higher, currently existing platinum bands and LTE bands must still be supported, resulting in an ever-increasing number of bands as well as in the filters used in each smartphone device.

Frequency	0.8GHz	2.5GHz	5GHz
Line wide	1μm	0.4μm	0.18μm
Standard	2～3G	4G	5G
Band	Platinum	LTE	
Device	SAW	SAW	SAW/FBAR
Mass production	⇨	⇨	⇗

Figure 1 SAW filter feature trend

In addition to the expectations described above, the line width of SAW filters is being narrowed by the shift from the 4G to the 5G standard. Thus, dimensional processing accuracy plays an extremely important role in the production of SAW filters used for implementing the 5G standard.

This article introduces the NE-7800, dry etching equipment for producing high-quality SAW filters, and describes a high-reliability processing technology and the solution to the problems associated with dry/wet processing of interdigital transducer electrodes.

2. SAW filter manufacturing process

Figure 2 shows the structure of a SAW filter.

A SAW filter consists of a piezoelectric thin-film or interdigital transducer (IDT) electrodes formed with regular spacing on a substrate, for the purpoose of extracting electrical signals from a specific frequency band.

Manufacture of interdigital transducers with fine line widths requires suppression of impurities and improved processing acuracy in pattern formation.

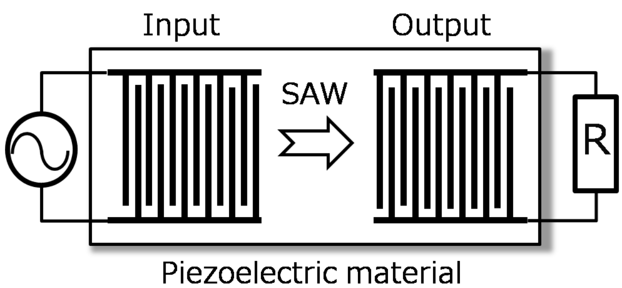

Figure 2 SAW filter structure

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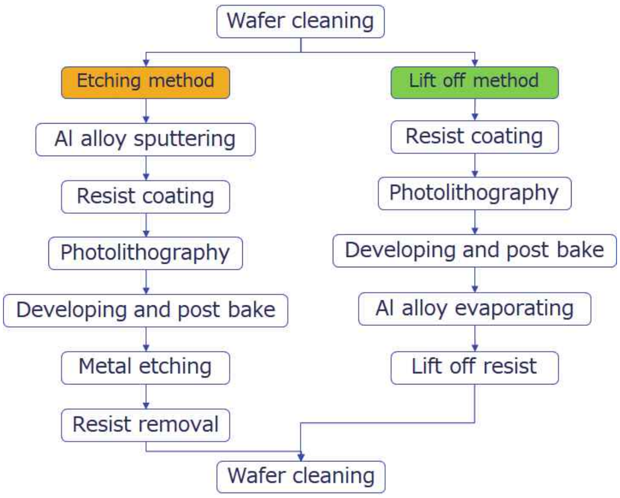

Figure 3 SAW filter front process flow

Figure 3 shows the general manufacturing process for SAW filters.

While the lift-off method has been conventionally used for the formation of electrode patterns, the dry etching method becomes necessary in microfabrication processes where the distance between electrodes is less than 1 µm.

ULVAC's dry etching equipment is capable of generating high-density plasma (5E10–1E11/cm^3) at low pressure (0.07–13.3 Pa) using an ISM (Inductive Super Magnetron) plasma source, and achieves uniform etching distribution due to the optimized magnetic field configuration.

Figure 4 shows the wet process following dry etching.

After the electrode material is dry-etched, the photoresist is stripped off by a wet process. Dry ashing is commonly used to completely remove the residue that cannot be stripped off in the wet process.

Figure 5 shows an example of dry and wet composite etching equipment.

3. Problems in wet rinsing and their solutions

In Al and Al alloy materials, chlorine and reaction-produced chlorides such as aluminum chloride, adhere and remain on the etched surface. They react with the moisture in the atmosphere to produce HCl, which induces surface corrosion. Figure 6 shows an example of corrosion in an IDT electrode pattern.

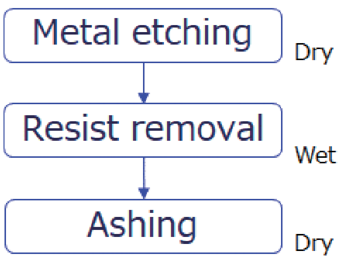

Figure 4 Wet process flow

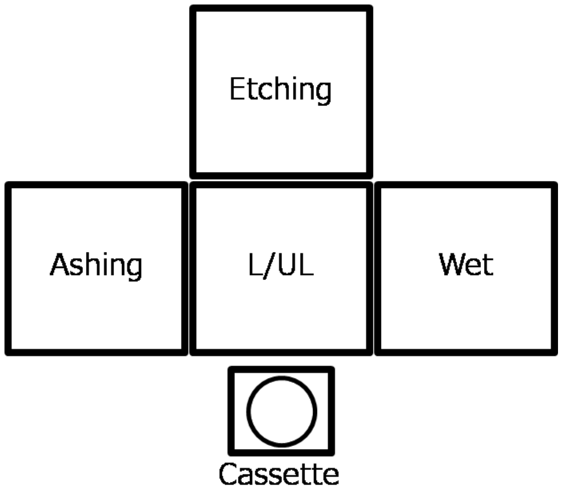

Figure 5 Dry etching tool structure

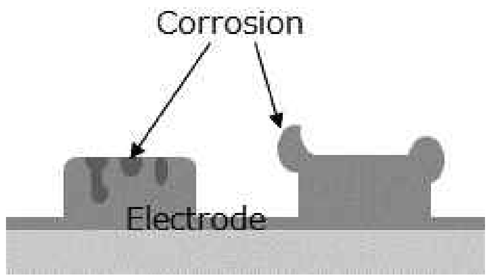

Figure 6 Corrosion of electrode

Because the occurrence of corrosion, particularly in AlCu alloys, becomes conspicuous when the Cu content is high,[1] it is necessary to optimize the post treatment method following dry etching. For this reason, the processes described below were added following dry etching and comparison experiments were conducted.

(1) O_2 plasma treatment

(2) H_2O plasma treatment

(3) Rinsing with pure running water

Figure 7 shows the results. In (1), the corrosion of the Al alloy could not be suppressed. However, following the treatments in (2) and (3), no corrosion could be observed even after the alloy had been left in the atmosphere for 6 hours, confirming that corrosion had been suppressed.

Furthermore, in dry etching of Al alloys, residue fences, such as those shown in Figure 8, often remain after photoresist removal, and must be stripped off and removed in the post treatment. Jet rinsing is sometimes used for stripping off these fences. However, the shearing strength of the LN ($LiNbO_3$: lithium niobium) substrate often used for SAW devices is less than that of Si substrates. For this reason, the jet water fluid pressure must be decreased to avoid damaging the substrate. This reduces the fence stripping margin,

Process	Result
① O_2 plasma	Not suppressed
② H_2O plasma	Suppressed
③ Rinsing	Suppressed

Figure 7 Corrosion after dry etching

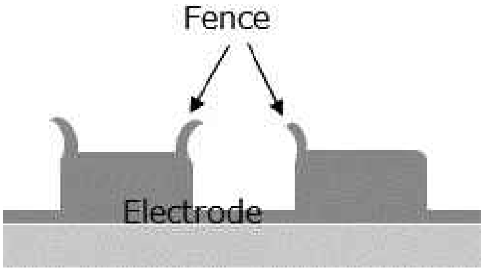

Figure 8 Fence of electrode

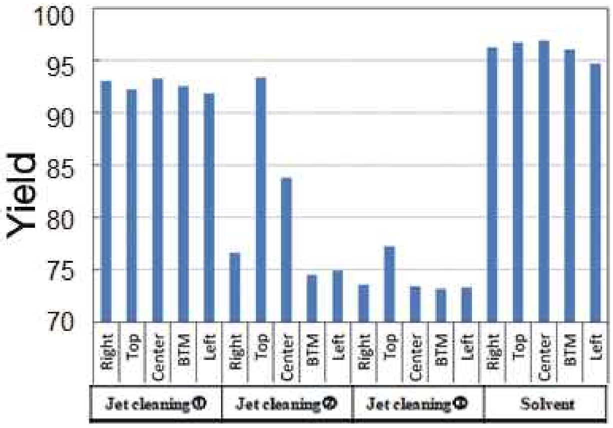

Figure 9 Yield in the substrate

Process	Result
① O_2 plasma	Incomplete
② H_2O plasma	Incomplete
③ Rinsing	Complete

Figure 10 Side wall deposition peeling result by chemical treatment

making it difficult to improve the yield. Therefore, we used a dedicated stripping solution and confirmed a yield improvement within the substrate surface, as shown in Figure 9.

However, as shown in Figure 10, the fence-removing process using this stripping solution encountered a problem. When the substrates went through the above-mentioned (1) O_2 plasma treatment and (2) H_2O plasma treatment, the fence-removing process oxidized the Al, the main component of the fences, resulting in incomplete removal of the fences. In contrast, in (3) the running water rinse, no oxidation occurred and complete fence removal was confirmed. Therefore, this treatment was judged to be optimal.

Since the above-mentioned treatment (3) is a wet treatment, a dry treatment is carried out in a vacuum, and then the substrate is exposed to the atmosphere. As shown in Figure 11, the degree of corrosion occurrence is greatly affected by the duration of time that the substrate is exposed to the atmosphere following etching, and corrosion cannot be completely suppressed even if the exposure time is as short as 3 seconds. Assuming the cause of this to be the effect of moisture in the atmosphere, when we controlled the dew point of the atmospheric environment to which the substrate was exposed at -35°C or lower, we found that we could completely suppress corrosion as shown in Figure 12.

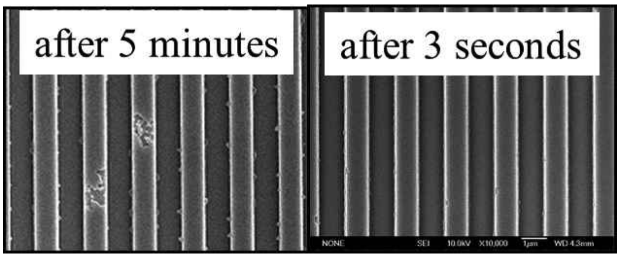

Figure 11 Atmosphere exposure time dependent of corrosion

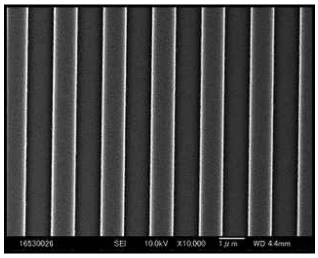

Figure 12 Corrosion suppression by dew point control

The above results demonstrate that we solved these problems by carrying out dechlorination using wet treatment under a controlled environment as well as a separate fence removal process, both as part of the post treatment method following dry etching.

Figure 13 shows the improved wet process.

Since it is important to manage the dew point during the translocation period from dry etching to wet rinse, the newly developed equipment has specifications that make it possible to control the dew point inside the robot-based transfer space.

Figure 14 shows the external appearance of the new equipment.

The two wet process mechanisms and the atmospheric transfer robot are designed to be operated under a low-dew-point environment (-35°C) inside a nitrogen atmosphere. The newly developed equipment makes it possible to achieve yield improvement and automation, and has greatly contributed to mass production of high-quality SAW filters.

Figure 13 Wet process flow

Figure 14 New dry etching tool

4. Conclusion

By optimizing the wet process following chlorine-based dry etching under a low-dew-point environment, we were able to solve the problems of corrosion and fences, and to develop mass production equipment capable of a low processing defect rate.

Furthermore, the newly developed equipment adopts an optimally designed antenna and a homogenization ring to optimize the etchant concentration inside the processing chamber, thereby achieving enhanced processing dimension uniformity over the entire wafer surface.

We hope to market the newly developed equipment widely to manufacturers of RF devices worldwide, whose number is expected to increase in the future, and we hope to expand its application to other devices as a differentiated high-performance metal etcher.

References

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