Seeing the World from a Drop of Water: A Novel Environment-Protecting Technique for Photoresist Strip, Metal Lift-off, and Etching Byproduct Removal

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Keywords: Water, Moisturization, Byproduct removal, Photoresist strip.

Abstract

Post etch residue and photoresist cleaning typically use several specialty solvents and multiple processing steps leading to clean the substrate. In this paper we present a novel and environment-protecting technique for photoresist and post etch residue strip process which uses DI water as main strip agent in semiconductor mass-production. This technique reduces harsh chemical and solvent usage and has remarkable performance on photoresist strip, metal lift-off, and removal of post etching byproducts. WIN Semiconductors Corp. is the first to implement this eco-friendly process into mass-production in the world. This new process establishes excellent corporate social responsibility to WINs workforce, customers, and environment.

INTRODUCTION

Photoresist cleaning and stripping is widely used in the semiconductor manufacturing industry. It needs solvent combined with reactive agents, such as NMP, DuPont™ EKC922™, acetone, IPA, etc., which are hazardous to the environment and the human body. Byproducts of plasma dry-etch is hard to remove. In this paper, we present a novel and eco-friendly technique to use DI water as the primary cleaning agent with showing remarkable performance on removal of photoresist and post etch residue, and also for metal lift-off processes.

The typical process that we use in manufacturing is to immerse batch-type wafers into NMP or DuPont™ EKC922™, and follow this with a single wafer spray with acetone and IPA to clean wafer. In the new process we immerse the batch of wafers in NMP as the first chemical treatment, then spray moisturized DI water to clean wafer. By reducing the use of the immersion bath, this is a more environmental protecting because most usage and waste of process is water, not chemical and solvent. We developed the moisturization procedure to nebulize DI water into very small droplet size, which looks like fog but with sprayed pressure. The novel process is much friendly to environment and human body. We have also found that the process tool is easier to maintain with less working hours.

HYPOTHESIS

There are three steps in the novel process to complete this strip technique, showed in Figure 1. In step 1, an immersion bath is used for a batch of wafers into NMP to do chemical treatment first, to swell the polymer such as photoresist or byproducts of plasma dry-etch. In step 2, we spray moisturized DI water to penetrate into the swelled polymer. The water will penetrate into and accumulate at the interface between polymer and substrate structure to become the water film. When the water film is in saturation, polymer would separate from substrate structure by surface tension of water and the lift-off happens, and this is step 3. [1][2][3].

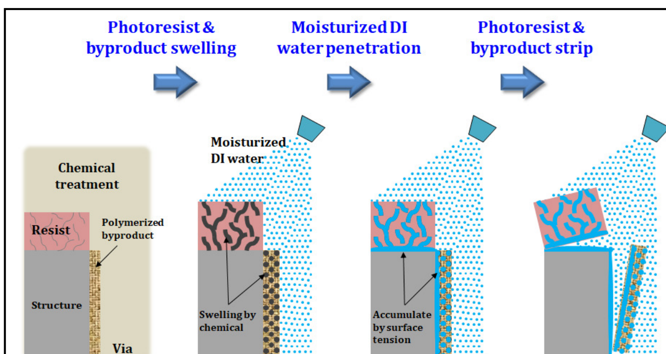

Fig. 1 Diagram of novel strip process includes "Swelling", "Penetration", and "Lift-off".

There is the counterevidence to verify the hypothesis. Figure 2 shows polymer residue remaining, which is worse case. If there is no swelling step before spraying moisturized DI water, the "Penetration" is low efficiency and hard to form water film for "Lift-off". If the moisturization is worse, the water film formation will be low efficiency. They are bad for this novel process and would cause residue remaining after moisturized spray-strip.

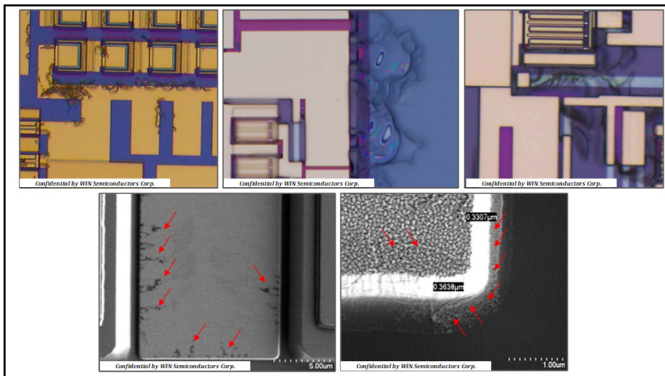

Fig. 2 Remained residue is caused by non-swelling or worse moisturizing.

REMARKABLE PERFORMANCE

Considering the impact to the environment and the human body, we summarize and normalize the usage for two mass-production processes, typical one and novel one. Figure 3 shows total usage for chemical and solvent, which is normalized to one wafer. There is almost 10 L of chemical and solvent used since from first process layer to the end process layer in cleaning tool, normalized to every wafer which is an average value. Compare with typical process, it is a benefit to reduce total 90.7% usage for each wafer in novel process. We also note that using DI water as main strip agent is easier to maintain equipment. The typical process takes 1.1% working hours per year in tool maintenance, but the novel process only needs 0.49% working hours per year which is 55% reduction.

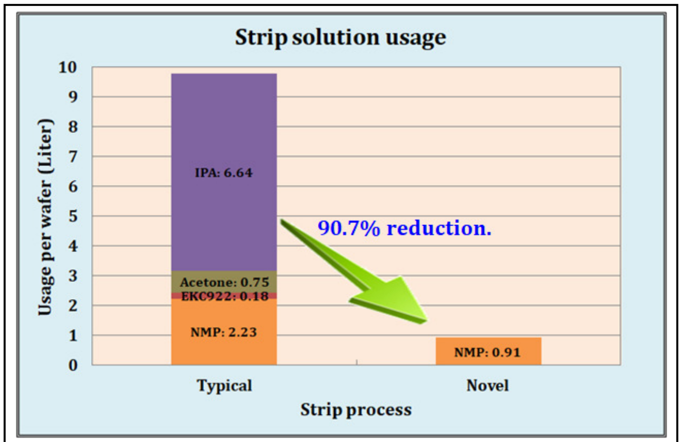

Fig. 3 The novel process can reduce about 90.7% usage than typical process, normalized to each wafer.

For byproducts removal of plasma dry-etch on polyimide structure, there is a very excellent result with novel process. Typical process has very thick and polymerized byproducts remaining on sidewall and it becomes a fence and then peels down making it unable to be effectively removed in Figure 4 (a). This is a wafer defect and would cause reliability and electrical fail. Figure 4 (b) shows novel process has excellent result to remove polymerized byproducts on same structure. To swell byproducts first and spray moisturized DI wafer to penetrate into to form water film at the interface between polyimide structure and polymerized byproducts. Then complete "Lift-off" by water surface tension. This great result also proves our hypothesis is correct.

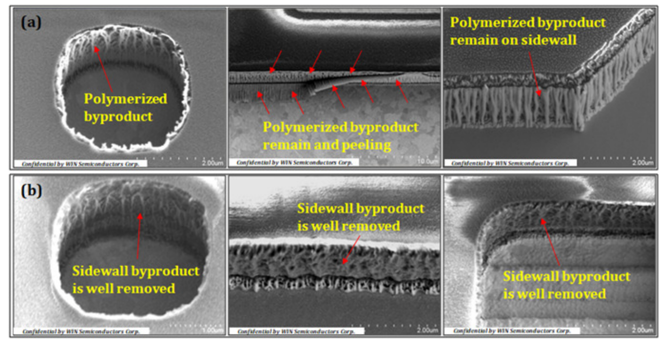

Fig. 4 a) Typical process is hard to remove polymerized byproducts after plasma dry-etch on polyimide via and structure; b) Novel process can easily remove same byproducts and the wafer is well-cleaned.

Through-wafer-via etching is a commonly used process. The byproducts after plasma dry-etch is hard to remove in deep via and becomes a side effect to interconnection. In Figure 5 (a), there is thick and polymerized byproducts adhere to sidewall of deep via and unable to be removed by typical process. It is very serious at the bottom of deep via and easy to remain and peel to induce reliability and electrical fail. When WIN implemented the novel process to same via structure and the result is perfect which is in Figure 5 (b). The byproducts no matter on via sidewall or at bottom of via is all well-cleaned. Of course, the quality of photoresist removal after plasma dry-etch is same as typical process for sure.

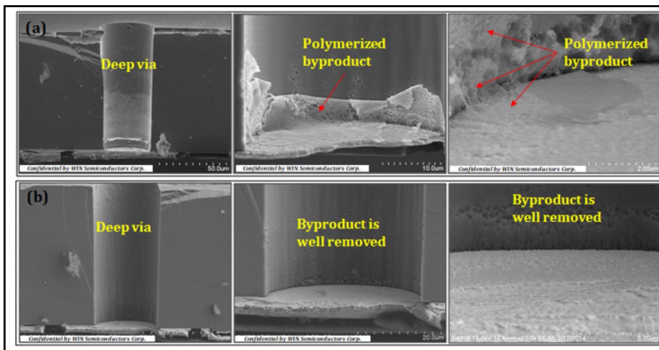

Fig. 5 a) Typical process is hard to remove polymerized byproducts after through-wafer-via plasma dry-etch; b) Novel process can remove same byproducts, no matter on via sidewall or at bottom of deep via.

There is one more benefit contributed by novel process. Figure 6 (a) is the result of typical process on photoresist strip and metal lift-off. There are silk remains and unable to be cleaned well after re-work. Novel process can avoid this defect happens on same structure, showed in Figure 6 (b).

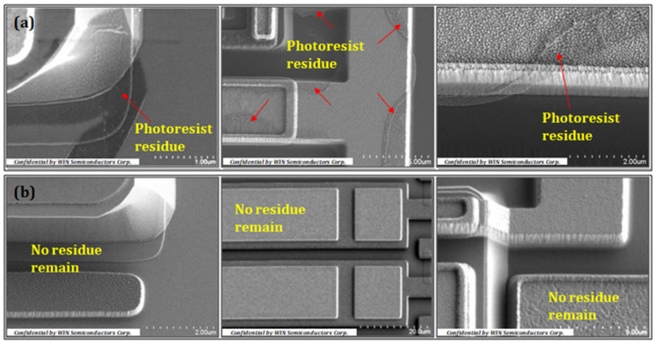

Fig. 6 a) Typical process has silks remain and unable to be cleaned after re-work; b) Novel process can avoid silks defect happens on same structure.

CONCLUSIONS

WIN Semiconductors Corp. is the first to implement novel and environment-protecting strip process which uses DI water as main strip agent to mass-production in the world. This process establishes excellent corporate social responsibility to WINs workforce, customers, and environment. It achieves remarkable performance to remove byproducts and photoresist, and also reduces chemical and solvent usage.

REFERENCES

[1] Song, Jae-Inh, et al. "*Using an ozonated-DI-water technology for photoresist removal*", Micro Magazine (2001).

[2] Rudolph, Matthias, et al. "*Introduction of an innovative water-based photoresist stripping process using intelligent fluids*", Advances in Patterning Materials and Processes XXXI., Vol. 9051, International Society for Optics and Photonics (2014).

[3] Rudolph, Matthias, et al. "*Evaluation of water based intelligent fluids for resist stripping in single wafer cleaning tools*", Advances in Patterning Materials and Processes XXXIII., Vol. 9779, International Society for Optics and Photonics (2016).

ACRONYMS

DI water: De-ionized water.
EKC922™: DuPont's universal photoresist remover.
IPA: Isopropyl alcohol.
NMP: N-Methyl-2-pyrrolidone.