# Defects ('Seams') Caused By Clear Field Mask Chrome Dimensions

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**ABSTRACT**

Seams are an anomaly that occurs when the chrome boarder of a clear field mask is "smaller" than stepping distance during exposure. Both positive tone and image reversal resist processes are susceptible to this phenomenon. However, the result is different in either case. On the surface, it may 'seem' benign, but could have an impact on yield and cause issues with unconventional masking layers, specifically those that use field stitching. We have found that the stepping distance and the chrome boarder size play a large role in the seam formation. In this paper, we will address this issue and examine the ways to both fix the problem and mitigate its impact on current processes.

**INTRODUCTION**

Photolithography is the hub of any semiconductor manufacturing process from simple 5 masking layer LEDs to complicated 20+ layer CMOS devices. The photo area sees these lots numerous times whether the need is for a temporary layer for etch protect or metal lift off to permanent coating of polyimides and SOGs. The most expensive tool is the exposure system. Whether it is an I-line stepper, DUV step and scan or the latest in emersion or EUV systems, these tools are the work horses in the processing of any type of device. There are 2 interactive components that are typically taken for granted; the chrome boarder on the mask and the stepping accuracy of the exposure tool. SPC data is taken and PM activities verify that the tool is performing as it should. But what about the clear field chrome opening? How is it measured and controlled? And what kind of impact could it have if the size were not correct?

**PROBLEM**

*Seams* are defined as the small lines that are optically detected at the edges of the exposure field (Fig. 1). Seams, for the most part, are benign. For the image reversal process, a trench (Fig. 2) is formed in this region along the field borders. However, in the corners there are openings that reach the substrate. These areas could potentially result in small metal poles or spikes remaining on the surface depending of the type and method of deposition. These posts probably do not survive the lift off process, however they could 'pop' off and redeposit onto the wafer or impact future layer processing if they remain.

In the positive tone mode, a small thin resist line remains along the field edges (Fig. 3). The effects of a seam in this mode could be worse. During etch steps, where positive resist is more widely used, a small unetched material barrier would remain. Again, this would be located in the streets but easily visible during optical inspection flagging the lot for additional defect review, slowing its progress.

In conventional device processing, seams are not a problem due to the location, in the street. However, other devices, like MEMs, antenna and wave guide processing where field stitching is necessary, these seams can cause problems. Some metals in these processes are deposited as a blanket film then patterned and etched. Seams in the resist would block the etch and result in bridging of these features rendering the device useless. In areas that are not stitched, these metal stringers would have the potential to pop off and bridge other devices, again rendering them non-functional. In general, a positive seam used during an etch process can result in added defects on the wafer.

**BRAINSTORMING ROOT CAUSES AND EXPERIMENTATION**

We were able to replicate the seams on processed wafers with a dose matrix and those reticles. A significant under dose of the resist (Fig. 4) showed distinct seams. This gave us a test bed to develop and test solutions to understand and resolve the issue. During a brainstorming activity, several items were identified as possible causes: stepper blade location, stepping distance, magnification, exposure, and chrome boarder field size. Experimentation was done to either validate or exonerate these potential root causes. A result from one experiment showed that if the exposure was increased, the seam was minimized significantly.

After all solutions were tested, the root cause was determined to be that the chrome border size on the mask was too small. If the chrome boarder is smaller than the expected field size and stepping distance, there will be no field to field overlap resulting in unexposed regions between steps. There will be some light diffraction that will expose some regions of the resist but the intensity will not be enough to cause a significant reaction (Fig. 5 and Fig. 6).

**CONCLUSION**

For current masks in house, increasing the dose by 200J/m² + (depending on resist thickness and substrate material) eliminated the seam for both processing modes (Fig. 7). However, some additional optimization will be needed for layers with sensitive critical dimension. With the help of our mask vendor, clear field border measurements were gathered and several experiments were repeated to show that the chrome boarder on the mask must be at least 0.5µm larger than the desired field size to eliminate the seam. This translates into a 0.1µm larger field size at the wafer using a 5x reduction stepper. Finally, all new clear field masks will need to be ordered with a larger boarder to prevent this issue.

## FIGURES

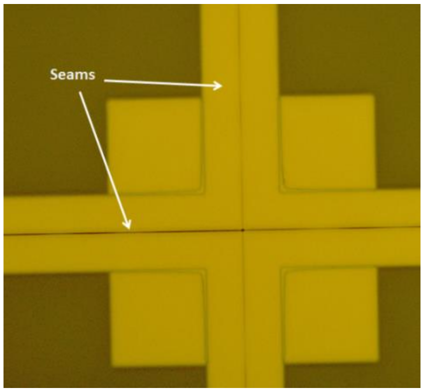


Fig.1 Optical image of a resist seam using Image Reversal Process

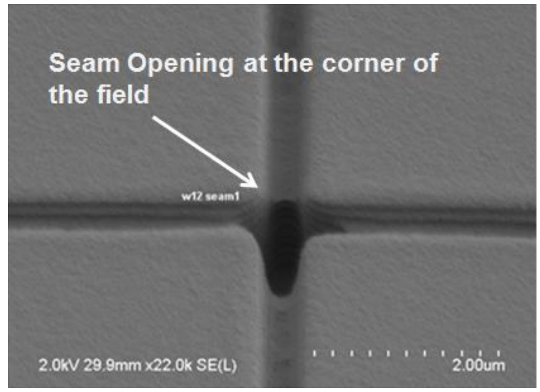


Fig.2 SEM image of an Image Reversal resist seam

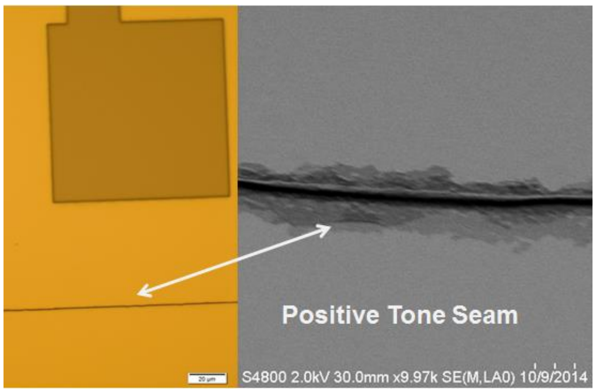


Fig.3 Optical and SEM image of a Positive Tone resist seam

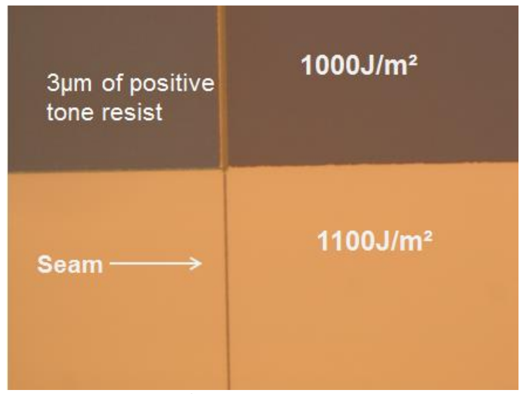


Fig.4 Optical image of a replicated seam in Positive Tone resist.

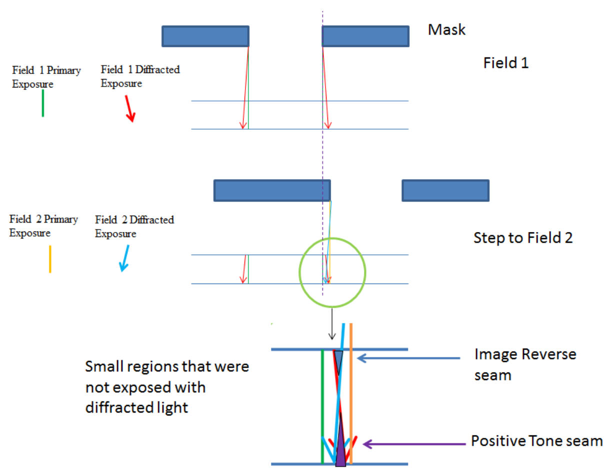


Fig. 5 Diffraction of light between 2 adjacent exposure fields

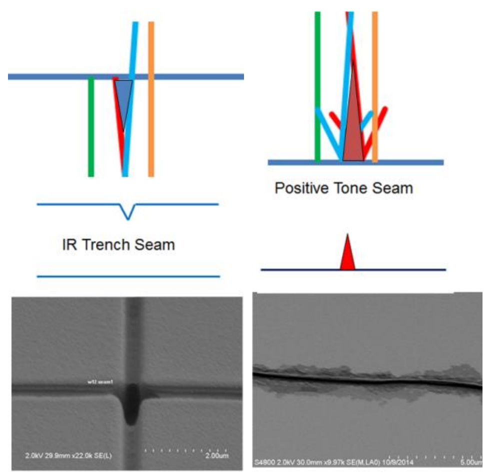


Fig. 6 Results of diffracted light on IR and Positive Tone Seam generation

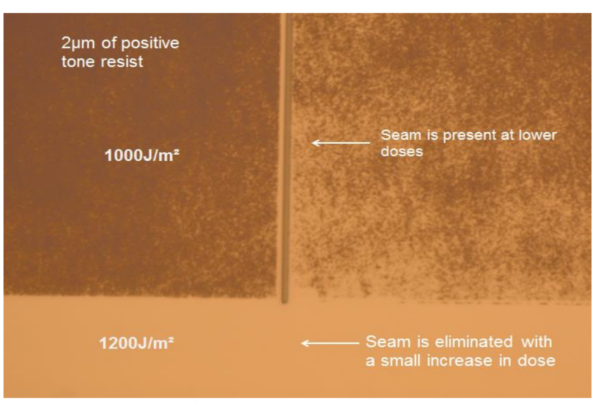


Fig.7 Optical image of exposure impacts on the seam