Lift-off Challenges in using CAMP Negative Photoresist Patterning in III-V IC Fabrication

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Abstract

In III-V IC processing lift-off patterning is universally used. Historically, negative resist had issues, so that image reverse process using positive tone resist has been utilized as the main work horse. The development of new CAMP resists has made it possible to reduce cycle time and cost compared to image reverse process. However, achieving good lift off and CD control presents challenges, which are discussed in this paper.

INTRODUCTION

Gold based metallization is commonly used in III-V Power Amplifier (PA) and mixed signal integrated circuits. These metal layers are deposited by e-beam evaporation. Gold based interconnect is not amenable to dry etching of interconnect on III-V substrates. Electroplating of thick layers is also common, but evaporation combined with lift-off is most common with lower level contact, gate layer and interconnect layers. Therefore, the lift-off process continues to be the main patterning method for the interconnect layers. Even sputter deposited layers are patterned by lift-off. These can be Ti/Au type interconnects as well as TaN thin film resistors [1]. Different variations of the image reverse process using positive photo resist have been used with success for patterning thin and thick layers deposited by evaporation and even sputtering. Negative side wall angle is highly reproducible. This process has its disadvantages. Resist corners get rounded off leading to poor lift-off. This is particularly applicable to lifting of sputtered layers for resistor patterning by dielectric assisted lift-off. Fences or flags are left on the wafer. Re-deposition of lifted material is also a problem. High vapor pressure solvents like acetone may cause re-deposition. Image reverse processes cost more, in general, because more process steps and equipment is needed. Lift-off processes using negative resist have been tried earlier but were not successful for thin layers and small features because of resist swelling. New negative resists are now available that do not have these historical drawbacks. nLOF AZ2000 series is an example of CAMP negative resist that have been shown to work at sub-micron feature size with the added advantage of reduced process steps [2]. This paper will discuss the lift-off challenges using the CAMP negative photoresist.

Lift-off process relies on a good retrograde resist profile (Fig. 1). A good retrograde profile avoids metals bridging or fences. If the metal is bridging then the liftoff occurs at random locations and is dependent on where the bridge is weakest.

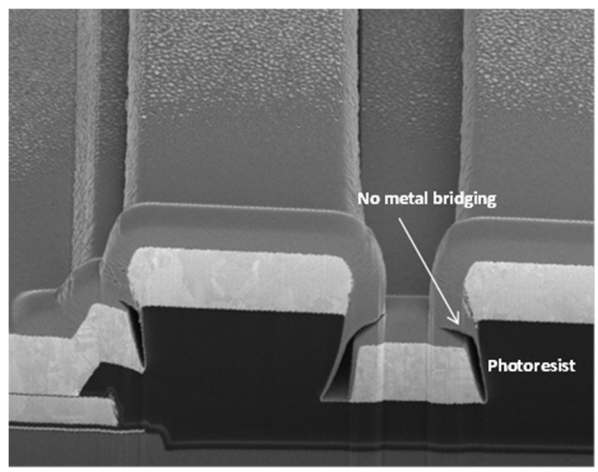

Fig. 1. No metal bridging due to good retrograde.

LIFT-OFF CHALLENGES AND RESOLUTION

CAMP negative photoresist can be planarized. Planarization causes thickness variation across different topography. In certain areas, the resist thickness is half the thickness of the deposited metal. This causes metal bridging especially if the retrograde angle is not sufficient (Fig. 2). The loading effect [2] can also result in lift-off behavior being sensitive to surrounding features. Two edges of a resist feature exhibit different side wall angles due to “Bulk effect” causing unsymmetrical metal coverage, which can be amplified by the angle of arrival of metal in the deposition system (Fig. 3). This causes the metal lines to lift during the liftoff process resulting in bent metal lines (Fig. 4).

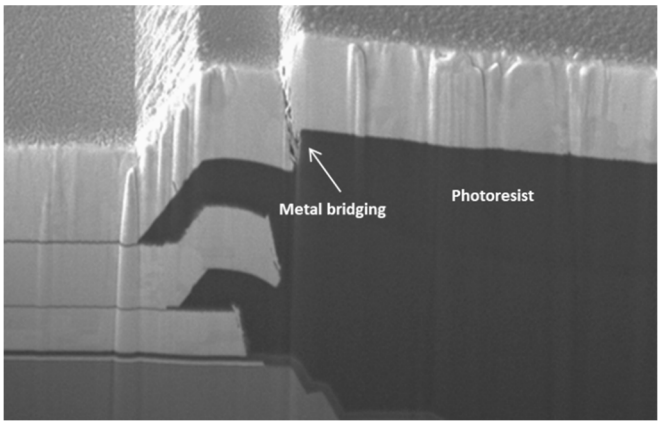

Fig. 2. Metal bridging due to resist planarization.

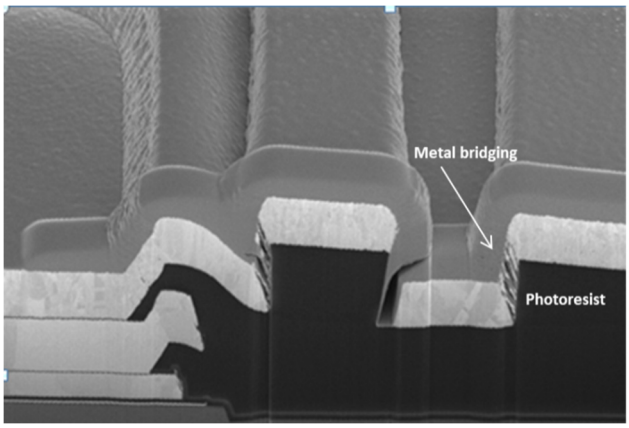

Fig. 3. Metal bridging due to lack of retrograde angle of the resist profile.

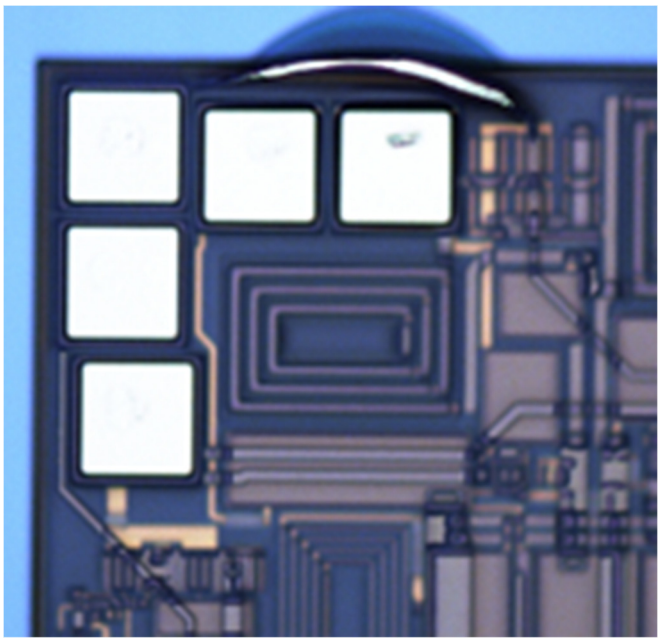
Fig. 4. Bent metal line due to metal bridging

An initial investigation into the bent metal lines was pointing to the liftoff tool. The liftoff process uses a high pressure spray tool and the suspicion was the high pressure spray was causing the bent lines. A design of experiment (DOE) was performed on the lift tool using low pressure spray. Further investigation still showed metal bridging. The metal bridging, combined with subpar adhesion of metal to the underlying layer, caused the metal lines to bend. The next step in the investigation was to figure out how to improve the resist sidewall retrograde across of the different features. A focus matrix was done by the photo team to determine if a good retrograde could be obtained for all features. The experiment results showed that the focus was not the only knob to improve the profile. The next step was stepper illumination optimization. A DOE was performed by the photo team and results showed the knob for sidewall retrograde improvement was the illumination setting (Fig. 5). Subsequent lift-off runs were performed with the new illuminator setting and none of the lift-off results showed the metal bridging issue.

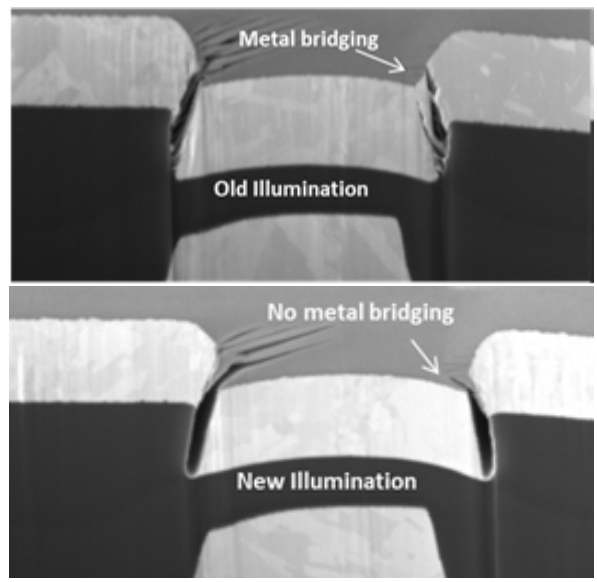

Fig. 5. Comparison of old illumination versus new illumination on exposure tool.

CONCLUSION

In Summary, the new illumination setting for the exposure tool improved the sidewall retrograde of the nLOF resist. The new illumination helped eliminate the metal bridging issue and improved the lift-off process

ACKNOWLEDGEMENTS

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REFERENCES

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[2] S. Kulkarni et al., "Impact of Loading Effect on Retrograde Profile of CAMP Negative Photoresist in Metal Lift-off Applications", CSMANTECH (2018)

ACRONYMS

CAMP: Chemically Amplified Photoresist
HBT: Heterojunction Bipolar Transistor
TDMA: Time Division Multiple Access