GaN Wafer Level AuSn Solder Deposition

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Abstract

For GaN MMIC die attach, the 80%Au20%Sn eutectic solder is frequently used. The usual practice is to use preform AuSn to attach die to CuW or some other substrates. During this process, operator may need to cut preform to die size, then align preform, die and substrate. Because operator needs to align three tiny parts at the same time (preform, die and substrate), it is a challenging process with potential for reworks. In addition, preform is 1mil in thickness (in our case) which can result in excess solder squeeze-out that needs to be cleaned as it would impede other off-chip assembly. The whole die attach process may be time consuming. In this paper, we describe a way to sputter deposit the eutectic AuSn with eutectic composition sputtering target on GaN wafer before dies are separated. It eliminates the preform and die alignment and no excess AuSn squeeze out. By using eutectic sputtering target, it would also simplify target manufacturing. Die attach results are presented.

INTRODUCTION

Wideband Microwave GaN MMIC power amplifiers are of great interest to defense and communication applications. With device performance increases, die attach becomes important as it greatly impacts MMIC thermal budget. The 80%Au/20%Sn solder has been manufactured for semiconductor application for more than 50 years, typically as a stamped preform. However the die attach process may be tedious and time consuming due to the need to align multiple small pieces in MMIC chip and solder preform onto the carrier. Sputter deposition AuSn on whole wafer before die separation will greatly simplify the die attach process. However, the sputtered AuSn composition is critical for proper solder reflow. There is a significant composition shift between the chemistry of the AuSn sputtering target and the deposited AuSn film as the sputtering yield of Au and Sn are different [Ref. 1]. Fig. 1 below shows the Au-Sn phase diagram. By carefully controlling the sputtering parameters (power, pressure and Ar gas), we are able to deposit eutectic AuSn from a eutectic composition sputtering target. It is much easier/cheaper to manufacture an eutectic compositional sputtering target.

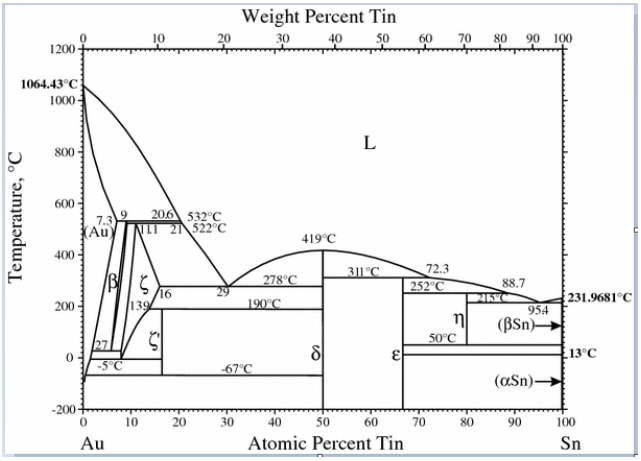

Fig. 1 AuSn phase diagram [Ref. 2]

EXPERIMENTAL DETAILS

GaN MMICs are fabricated on 4-in SiC wafers. Before AuSn sputtering deposition on the wafers, wafers are thinned to target thickness and backside processing (via etch and metallization etc) is complete. The wafers are put into a Perkin-Elmer 4450 sputtering tool for AuSn deposition. The eutectic composition sputtering target is purchased from Materion. By DOE experiments, it is found sputtering power and pressure have the greatest impact on sputtered AuSn composition. After the AuSn deposition, wafers are cut into individual dies. Then the dies are directly mounted onto substrates. This process is much simpler than with preform. Fig.2 below showed x-ray images of MMIC die attached to carriers for both sputtered AuSn and pre-form. Fig. 2 (a) showed die attach with sputtered AuSn and the film is very uniform without voids (light contrasted bubbles as seen in Fig. 2(b). Fig.2 (b) showed die attach with pre-form AuSn. In this severe example, many bubbles (light contrasted stuff) present. Voids in die attach will compromise heat transfer and make chips run hotter and degrade performance.

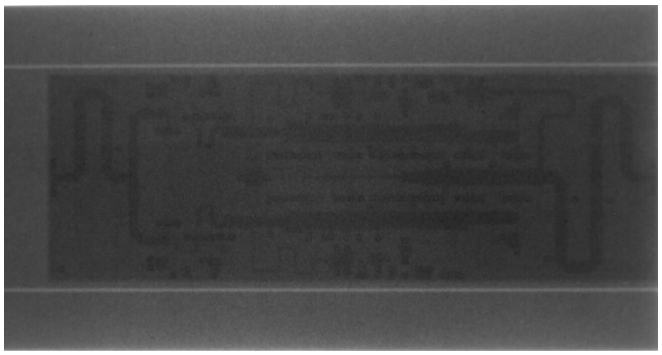

Fig. 2 (a) An example of MMIC die attach with sputtered AuSn (uniformed contrast)

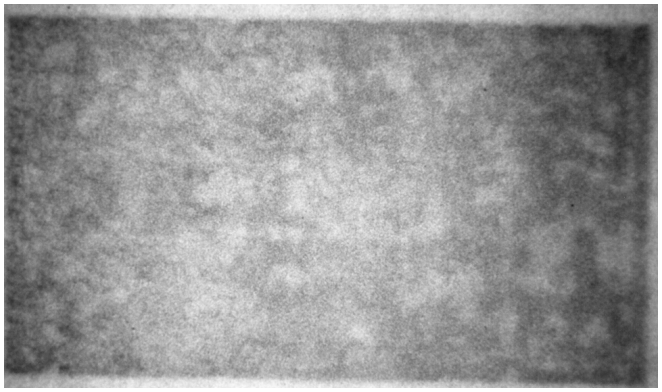

Fig. 2 (b) An example of MMIC die attach with pre-form AuSn (light contrasted areas are AuSn voids)

CHARACTERIZATION

In order to qualify this process for production, we have to test for the die attach quality. We also checked electrical performance. Fig.3 below showed die shear strength test. The die attach was good and no separation between die and substrate. Fig.3 below showed that the die (chip) didn't come off the carrier but instead it broke at edge during die shear test.

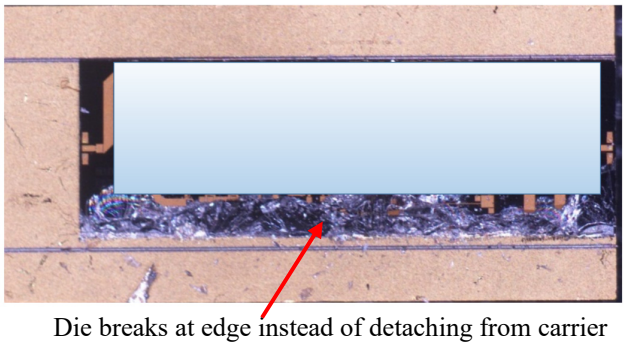

Fig. 3 showed die attach strength exceeded equipment capability

Pulsed IV characterization is carried out on devices before and after sputtered AuSn. Fig. 4 showed an example of the pulsed IV curves. They are right on top of each other. No electrical degradation is found. Full RF test on MMIC also showed no change before/after AuSn deposition.

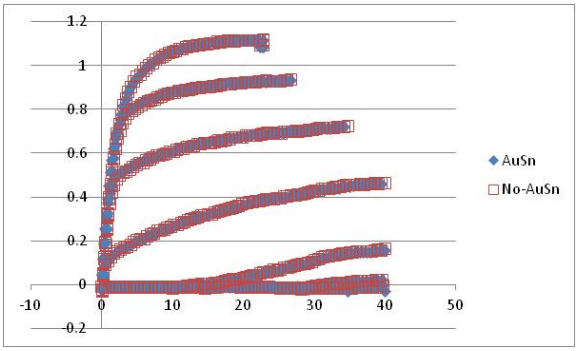

Fig. 4 pIV curves before/after sputtered AuSn deposition

CONCLUSIONS

In this paper, we presented results on sputter deposition of AuSn on GaN MMIC chips with a eutectic composition sputtering target. The developed process greatly simplified die attach process. Equally important, we are able to use a eutectic composition target, which also simplified the process.

ACKNOWLEDGEMENTS

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References

[1] Heiner Lichtenberger, et al. Mantech Confereence, 2013

[2] Phase Diagram of AuSn from Springer.com

Acronyms

MMIC: Monolithic Microwave Integrated Circuit
AuSn: 80%Au 20%Sn by weight
Eutectic: single melt point
Au: Gold
Sn: Tin
GaN: Gallium nitride