EAG LABORATORIES | Eurofins Materials Science

APPLICATION NOTE

SIMS analysis of Al and Ga diffusion into Si substrate in GaN on Si HEMT structure

INTRODUCTION

During fabrication process of GaN on silicon HEMT device, Al and Ga can diffuse into Si substrate. As p-type dopants in Si, Al and Ga can form parasitic conduction channel at Si interface region. Understanding and control of Al and Ga diffusion into Si is important in manufacturing high performance GaN/Si HEMT devices.

SIMS analysis from Si side has been used to study the diffusion of Al and Ga.

SAMPLE PREPARATION

To detect low level Al and Ga diffusion, samples need to be analyzed from Si substrate side. This requires mechanical polishing to thin Si substrate to a few micrometers (fig. 1).

In addition to have mirror finish (< 2Å), the polished surface also need to be in parallel (<0.02°) to the original surface to avoid signal collection from different depth in SIMS analysis. (fig. 2)

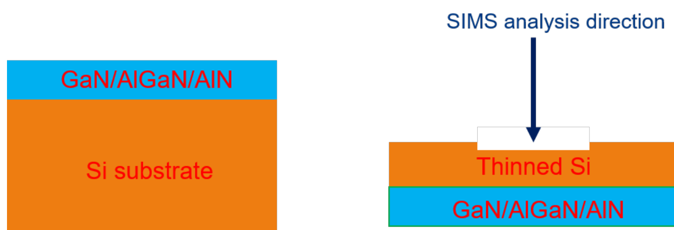

Figure 1. Sample preparation for SIMS analysis from backside (Si side)

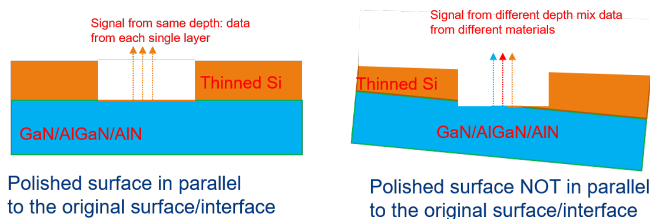

Figure 2. Sample preparation requirement for backside SIMS

SIMS ANALYSIS RESULTS AND POTENTIAL ARTIFACT

Figure 3 is Al and Ga depth profile from thinned Si surface (backside), with ~ 4 µm Si remaining with intention to capture the entire Al and Ga diffusion profiles. The Si raw ion counts profile is also plotted (referred in right hand axis) to mark the end of Si layer when Si intensity drop.

SIMS results shown both Ga and Al diffused to Si substrate with different diffusion depth when reaching SIMS detection limits (~ 1E13 atoms/cm3): ~ 3 µm for Al and ~ 2 µm for Ga.

But sputtering Si with oxygen primary beam to a depth greater than > 3µm can result sputtering induced roughness that will result pin holes at near Si/AlN interface (fig 4). The pin hole will create artificial tails as shown in fig. 3.

By reducing thickness of remaining Si layer to <2.5 µm, the artifact of sputtering induced roughness can be avoided.

Figure 5 shown the results of the same sample with additional polishing to reduce Si thickness to ~ 2 µm. The Al and Ga profiles at interface shown shape increase at interface region. Image taken at Si/AlN interface of SIMS sputtering crater (fig 6) shows smooth interface – no pin holes.

The drawback is that due to thinner Si layer, SIMS profile did not capture entire Al diffusion profile.

SUMMARY

Combined with parallel polishing, SIMS depth profile from Si side is a great tool to understand Al and Ga diffusion into Si for GaN/Si HEMT structure.

If remaining Si thickness is greater than ~ 3 µm, sputtering induced roughness can results artificial tails at Si interface region.

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SIMS artifact due to formation of pin holes

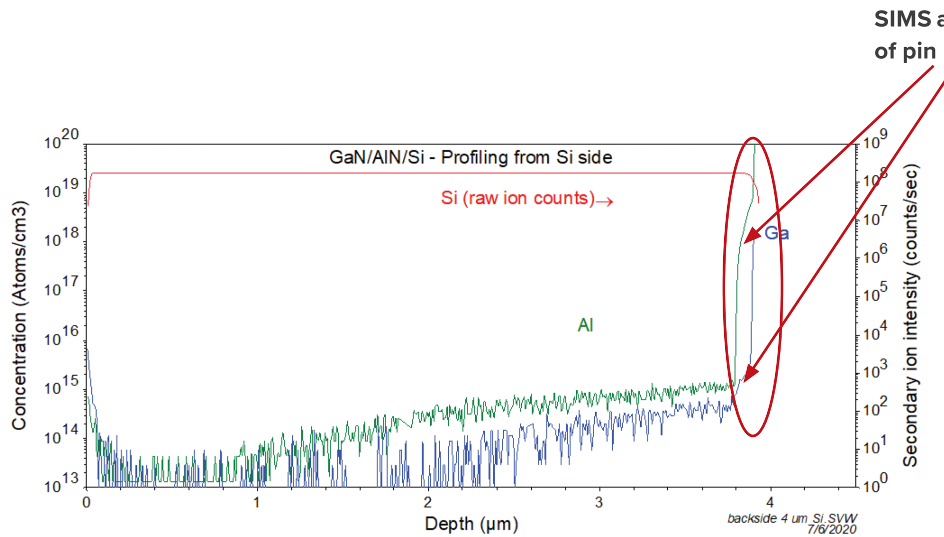

Figure 3: Al and Ga profiles from Si side with ~ 4 µm Si remaining

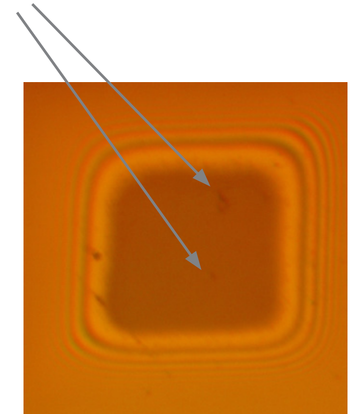

Figure 4: Optical image of SIMS crater at Si/AlN interface

Si/AlN interface region - no pin holes observed

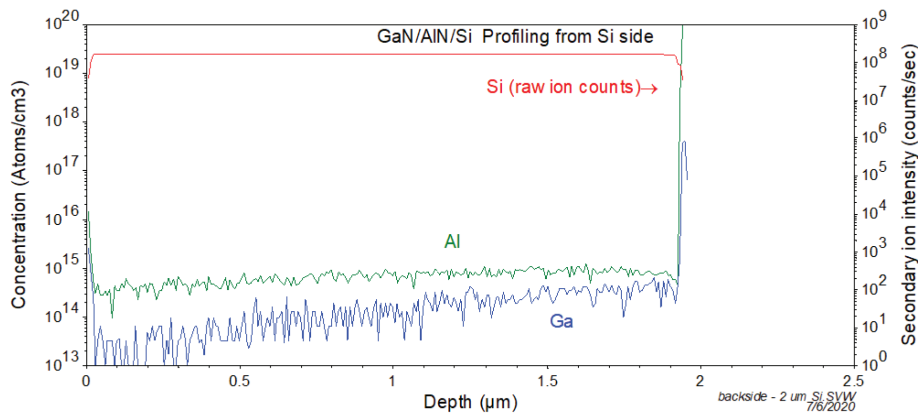

Figure 5: Al and Ga profiles from Si side with ~ 2 µm Si remaining

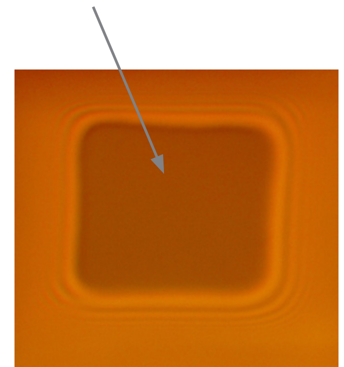

Figure 6: Optical image of SIMS crater at Si/AlN interface

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