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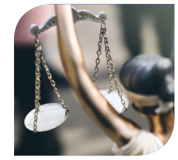

# SIMS Analysis of Al and Ga Diffusion into Si Substrate in GaN on Si HEMT Structure

**Secondary Ion Mass Spectrometry (SIMS) is an analytical technique that detects very low concentrations of dopants and impurities. It can provide elemental depth profiles over a depth range from a few nanometers to tens of microns.**

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).

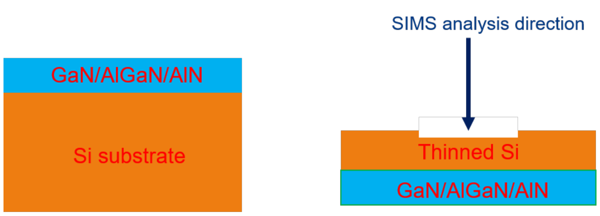


*Figure 1: Sample preparation for SIMS analysis from backside (Si side)*

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).

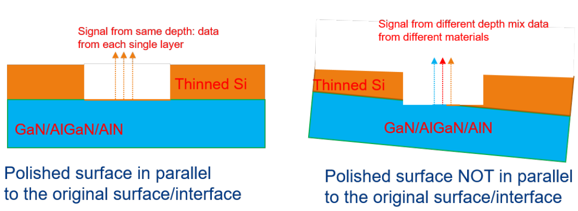


*Figure 2: Sample preparation requirement for backside SIMS*

## 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.

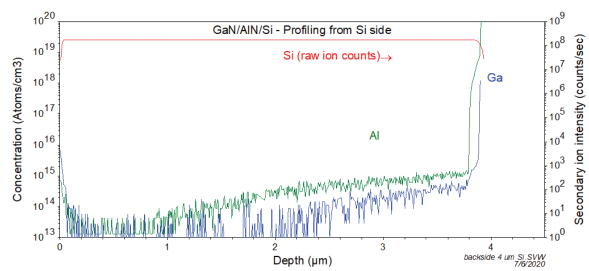


*Figure 3: Al and Ga profiles from Si side with ~4 µm Si remaining*

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. The pin hole defects will create a distorted interface which incorrectly shows 1E18 atoms/cc concentration of Al diffused into the Si substrate.

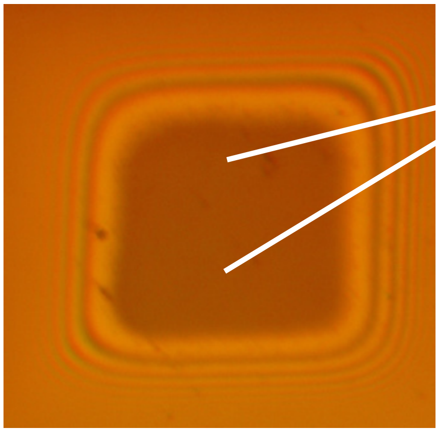


*Figure 4: Optical image of SIMS crater at Si/AIN*

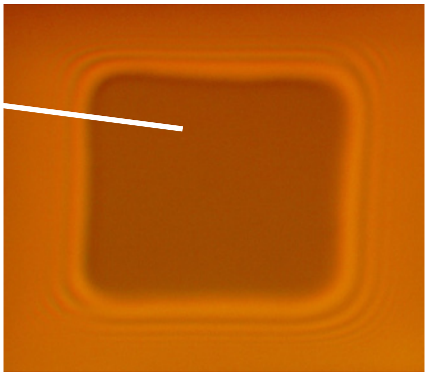


*Figure 6: Optical image of SIMS crater at Si/AIN interface*

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

Figure 5 shows the results of the same sample with additional polishing to reduce Si thickness to ~ 2 µm. The Al and Ga profiles at interface shown sharp increase at interface region. Image taken at Si/AIN 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.

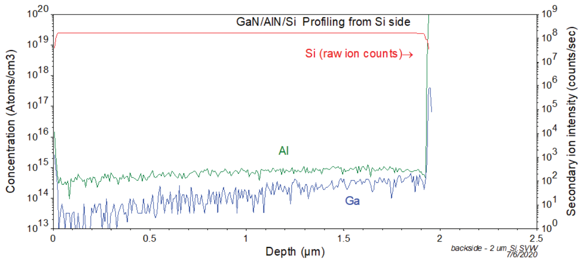


*Figure 5: Al and Ga profiles from Si side with ~2 µm Si*

## 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..

## SIMS Analysis at EAG

EAG is the industry standard for SIMS analysis, offering the best detection sensitivity along with accurate concentration and layer structure identification. No other analytical laboratory can match EAG's depth of experience, as well as dedication to research and development in the SIMS field. We have the highest number of SIMS instruments worldwide (more than 50 SIMS instruments), highly qualified scientists, and the world's largest reference material library of over 6,000 ion-implanted and bulk-doped standards for accurate SIMS quantification. EAG has been doing SIMS for over 40 years; longer than any other commercial laboratory.