Oxide Materials and Devices

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Primary CNF Tools Used: Autostep i-line stepper, SC4500 odd-hour evaporator, PT770 etcher, P10 profilometer

Abstract:

In order to approach our research of gallium oxide lateral structure microdevices, we have worked at CNF for six months to get familiar with the gallium oxides metal oxide semiconductor field effect and fin field effect transistor processing.

Summary of Research:

In this past six months, we have been working on processing gallium oxide lateral structure microdevices, including metal oxide semiconductor field effect transistor (MOSFET), fin field effect transistor (FinFET).

MOSFET. To avoid the gallium oxide sample loss due to misoperation, an old gallium nitride (GaN) sample was used to be familiar with the standard processing. The GaN sample went through the mesa-isolation, drain and source metal deposition and metal contact annealing, shown in Figure 1a. The mesa-isolation involved photolithography and plasma etching. The metal deposition was completed by electron beam assistant physical vapor deposition. Metal contact annealing was done by the rapid thermal anneal. After the ohmic contact test, it appears that the resistance of the contact was much higher than expected. The reason could be unexpected oxidization of metal contact during the annealing shown in Figure 1b. In the rapid thermal anneal chamber, the temperature didn't reach the desired value and the ambiance didn't maintain as nitrogen along with the annealing.

With the previous experience in mind, a gallium oxide sample was processed with the same procedure. However, due to the brittle property of gallium oxides, the sample was broken during the sonication cleaning in glass beaker shown in Figure 2.

With the experience from the last two failures, the second gallium oxide sample (shown in Figure 3) was successfully processed. It was cleaned in a Teflon® beaker during sonication. We repeated the same procedure as the GaN sample. However, during the annealing process, the ambiance and temperature of the chamber were carefully controlled in a nitrogen atmosphere.

This sample showed acceptable ohmic contact of drain and source metal. The sample has deposited a layer of the dielectric layer by atomic layer deposition. The gate metal was deposited with an electron beam assistant physical vapor deposition. The contact hole was done by the wet etching.

During this processing, it's vital to ensure the photolithography alignment of building each layer. In order to achieve good alignment, the manual operation on i-line stepper was practiced several times.

FinFET. In order to study the property of FinFET with gallium oxides, one gallium oxide sample was processed with a newly designed procedure. In order to identify the electron-beam dose of the electron-beam lithography, a control sample went through the same designed procedure as the official sample, mesa-isolation, and recess etching. The mesa-isolation involved photolithography, metal deposition, and plasma etching. Ion milling, metal deposition, and electron-beam lithography consisted of recess etching.

Due to the lab closing for COVID-19, the official sample needs to be completed in the future.

Conclusions and Future Steps:

During the six months of work in the CNF, we mastered the basic processing techniques of gallium oxide MOSFET and FinFET, including photolithography, plasma etching, metal deposition, dielectrics deposition and wet etching. In the future, in order to complete this research of gallium oxide FinFETs, we plan to master more characterization techniques (such as atomic force morphology, scanning electron microscopy), and electron-beam lithography.

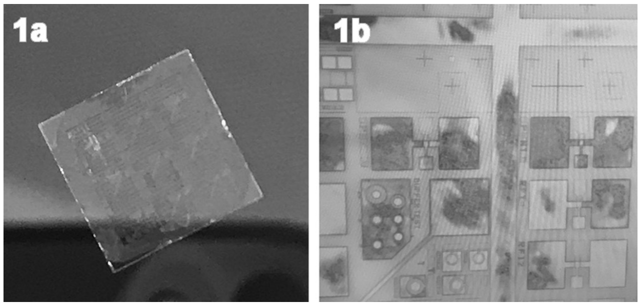

Figure 1: After mesa-isolation, drain and source metal deposition and metal contact annealing, a) contact metal turn to a greenish color, b) oxides under the microscope.

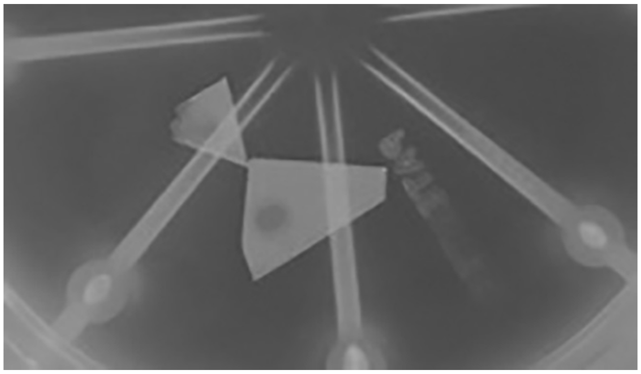

Figure 2: First gallium oxides sample after sonication clean.

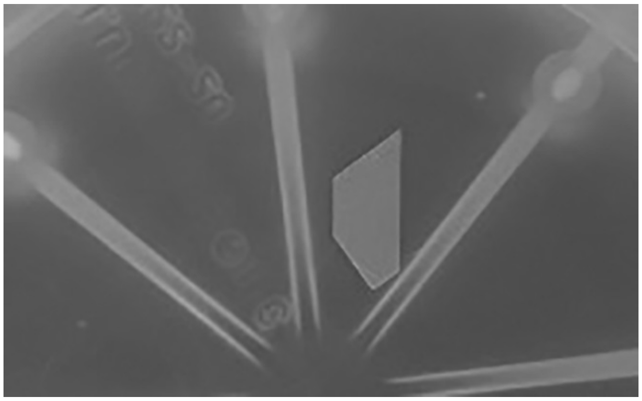

Figure 3: Second gallium oxide sample after sonication clean.

PROCESS & CHARACTERIZATION