REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
03/21/2014	Final Technical	04/05/2009-03/20/2014

4. TITLE AND SUBTITLE
High K Oxide Insulated Gate Group III Nitride-Based FETs

5a. CONTRACT NUMBER

5b. GRANT NUMBER
N00014-09-1-1160

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Edgar, James H.

5d. PROJECT NUMBER
09PRE09471-00

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Kansas State University
2 Fairchild Hall
Manhattan, KS 66506-1103

8. PERFORMING ORGANIZATION REPORT NUMBER
BG1864

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Office of Naval Research
875 North Randolph Street
Arlington, VA 22203-1995

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for Public Release: Distribution is Unlimited.

13. SUPPLEMENTARY NOTES

20151007655

14. ABSTRACT
The impact of process conditions on the physical and electrical properties of high-k dielectric oxides on gallium nitride were explored. The efficacies of several cleaning procedures prior to oxide deposition by atomic layer deposition were examined. Overall, the best treatments were those that removed surface carbon with minimal surface roughening. Parameters examined included the oxide composition (Al_2O_3, TiO_2, and Ga_2O_3), the gallium nitride crystallographic orientation (c- and m-plane), and its crystal polarity (Ga- anc N-polar).

15. SUBJECT TERMS
Gallium nitride, oxides, atomic layer deposition, capitance-voltage spectroscopy

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON / 19b. TELEPHONE NUMBER *(Include area code)*
U	U	U	UU	2	James H. Edgar / 785-532-5584

High K Oxide Insulated Gate Group III Nitride –Based FETs
Grant Number N00014-09-1-1160

Because of its physical and electrical properties, the semiconductor gallium nitride is superior to silicon for high-power high-frequency electronics. To reduce leakage currents, increase the breakdown voltage and increase the power-added efficiency of its transistors, an insulating dielectric can be added to the gate to create a metal-insulator-semiconductor high electron mobility transistors (MISHEMTs). For this device to be successful, imperfections at the oxide-semiconductor interface must be suppressed to maintain the high electron mobility of the device.

This research explored several high dielectric constant gate oxides (Al_2O_3, TiO_2, and Ga_2O_3), deposited on different crystalline orientations and polarities of GaN by atomic layer deposition (ALD) to form metal oxide semiconductor capacitors MOSCAPs). Other aspects studied included the effects of pretreatment on N-polar GaN, ALD TiO_2/Al_2O_3 nano-laminate on thermally oxidized Ga-polar GaN, and a comparison of ALD Al_2O_3 on *c*- and *m*-plane GaN.

Surface pretreatments can greatly alter the morphology of N-polar GaN (it is much more reactive than Ga-polar GaN) which is detrimental to the electrical properties. Depositing ALD Al_2O_3 films directly deposited on N-polar GaN without thermal or chemical pretreatments produced the best samples with smooth surfaces (RMS=0.23 nm), a low leakage current (2.09×10^{-8} A/cm^2) and good Al_2O_3/GaN interface quality, as indicated by the low electron trap density (2.47×10^{10} cm^{-2}eV^{-1}).

In the nano-laminate study, a high dielectric constant of 12.5 was achieved by integrating a $TiO_2/Al_2O_3/Ga_2O_3$ oxide stack layer, while maintaining a low interface trap density and low leakage current.

Comparing properties of Al_2O_3 on *c*- and *m*-plane GaN showed that a smooth surface is essential to minimizing the hysteresis. The overall results indicate the promising potential of incorporation gate dielectric in future GaN devices.

This project supported two students who completed their PhD degrees in chemical engineering. They worked with scientists at the Naval Research Laboratory and Oak Ridge National Laboratory to fabricate and characterize the devices. Their work resulted in four publications with additional publications pending.