Capital Investment for RHEED TRAXS Capability to Benefit Current ONR-Funded Program

Final Report

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14. ABSTRACT
The capital investment and the proof of operation of the RHEED-TRAX (Reflection High-Energy Electron Diffraction-Total Reflection Angle X-ray Spectroscopy) is complete with the conclusion of this equipment grant. The system has been custom engineered for the UHV environment and adaptive pieces engineered in order to enable real-time chemical analysis during film depostiion by molecular beam epitaxy (MBE). The full potential of RHEED-TRAX as a real time quantitative stoichiometry control tool is being investigated as part on ongoing ONR research efforts in the integration of barium hexaferrite for monolithic tunable microwave devices, the Center of Microwave & Magnetic Materials and Integrated Circuits, and the ONR EMMA MURI. The work has been part of 3 presentations to regional and national audiences and is part of 2 submitted manuscripts.

15. SUBJECT TERMS
RHEED-TRAXS, MBE, Instrumentation Development

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Summary of Benefits:
My current research of engineering the integration of functional oxides with wide-bandgap semiconductors for integrated microwave devices and next generation multi-functional devices, involves the use of RHEED, reflection high-energy electron diffraction, for real-time thin film structure development information. The advantage of reflection high-energy electron diffraction total-reflection-angle x-ray spectroscopy (or RHEED TRAXS) is that it provides real-time *chemical* analysis during growth as part of the real-time structural analysis of RHEED. Complex oxides measurably change properties with composition changes of less than 5%. The power of real-time stoichiometry control is in the potential for tuning of multifunctional oxide heterostructures in next generation military and civilian electronic devices.

RHEED TRAXS involves an external detector that analyzes the characteristic x-rays emitted from the atoms as part of the RHEED analysis. This investment will benefit the continuing effort on barium ferrite, the Center of Microwave & Magnetic Materials and Integrated Circuits, the ONR EMMA MURI, and future work in multifunctional oxide integration with wide bandgap semiconductors. In addition, the preliminary experimentation period has been invaluable in determining the criticality of both detector placement and electron beam stability. This information was presented to all Electronic Materials Program PIs at the 2007 Program review meeting at RPI.

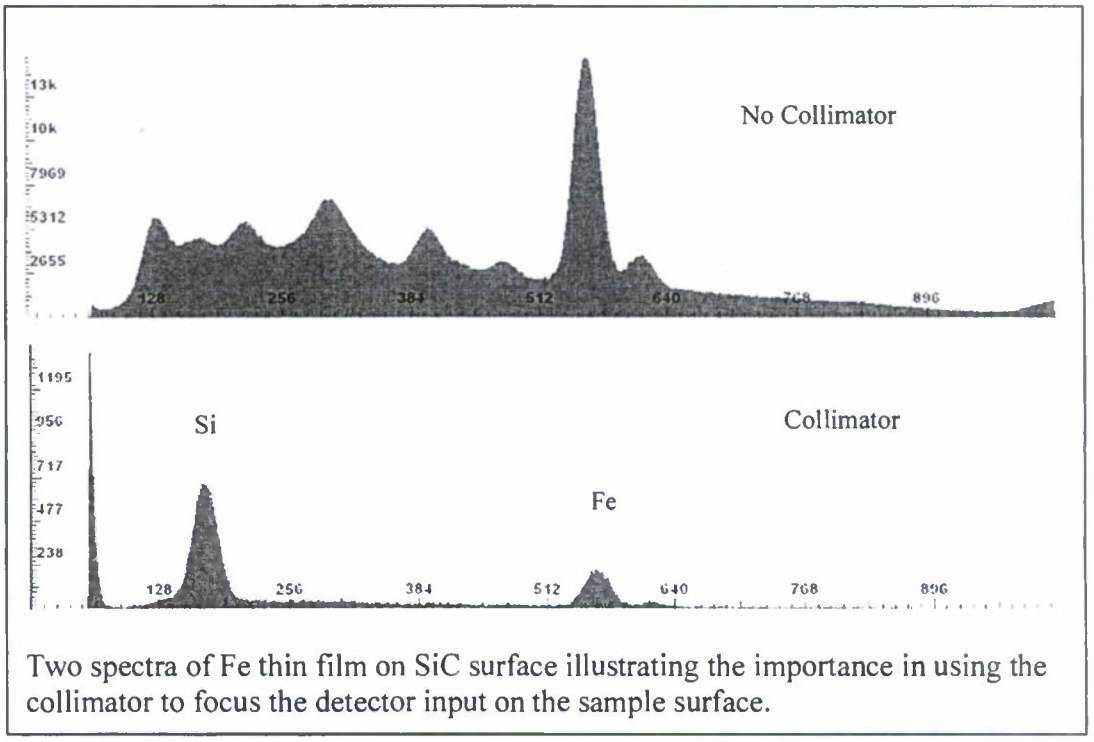
Equipment Purchased:
AmpTek equipment and electronic accessories were purchased off the shelf. As this equipment is not designed for use in a UHV in-situ RHEED-TRAX system, the chamber modifications and the interface from air to UHV was custom designed to meet the requirements of the AmpTek equipment and the laboratory research. The detailed costs are below. All purchases were capital and three bids were acquired for all work EXCEPT the AmpTek purchases. The AmpTek purchases were sole-sourced based on the experience of prior ONR-supported researchers.

Proposed Capital Costs:		
AmpTek X-ray Detector XR-100CR 25mm2/500µm		$3,900
PX4 Digital pulse Processor, MCA, and power supply		$5,950
EXVC Collimator Kit		$1,700
EXV9 9" vacuum extension		$1,200
vacuum feedthrough and cables		$700
Special tube with Be window		$5,000
3.75 UHV xyz stage manipulator		$8,300
LabView Program for data acquisition		$1,195
PCI-GPIB IEEE 488.2 interface card		$715
Chamber add ons & Modifications*		$1,340
Total:		**$30,00**
Proposal amount:		**$26, 126**
Actual Capital Costs:		**$25,957**
Difference in actual spent amount due to not needing software		

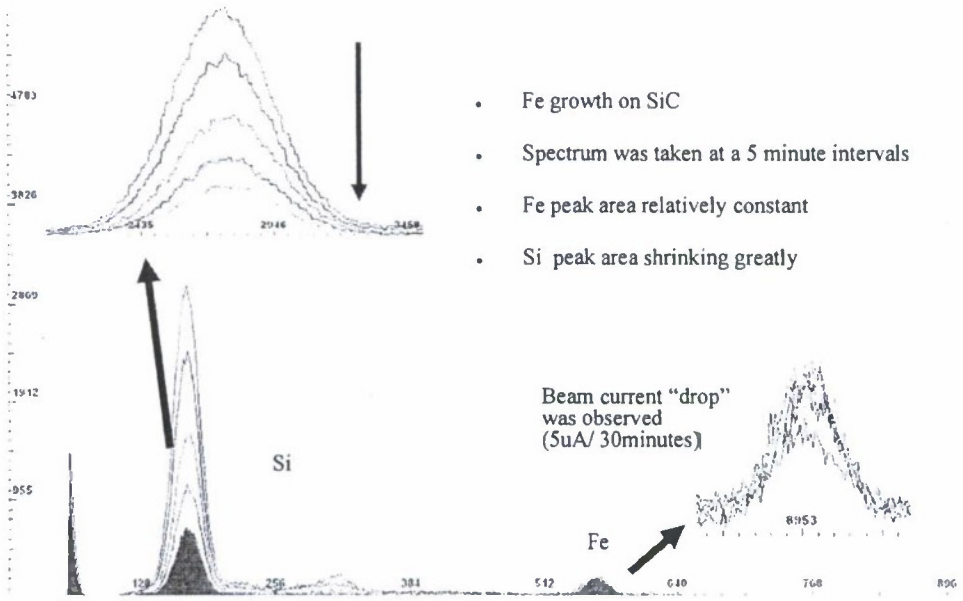
The custom design for integration of the AmpTek pieces into the UHV chamber included the following considerations:

- Different aperture sizes for flexible control of the incoming flux
- In-situ renewable protection of beryllium window from material deposition during film growth
- Precise control of incident angle for critical angle analysis and quantitative spectrum analysis (+/- 1 inch movement of X-Y stage, total 5.1 degree of adjustment available, including tilt for line-of-sight aiming)
- Continual pumping of detector environment and flexibility to remove RHEED-TRAX for maintenance and improvements without interrupting chamber operation

Sample of Results:



Two spectra of Fe thin film on SiC surface illustrating the importance in using the collimator to focus the detector input on the sample surface.



Time study of Fe film deposition on SiC. While the decrease in the area of the Si peak corresponds well to increased monolayers of Fe deposition, the change in area of the Fe peak fluctuates with beam current in the RHEED gun. This illustrates one of the many challenges remaining in transitioning the RHEED-TRAX from a qualitative to a quantitative stoichiometry control tool.

Future Work:

The capital investment and the proof of operation of the RHEED-TRAX is complete with the conclusion of this equipment grant. The full potential of RHEED-TRAX as a real time quantitative stoichiometry control tool is being investigated as part on ongoing ONR research efforts in the integration of barium hexaferrite for monolithic tunable microwave devices, the Center of Microwave & Magnetic Materials and Integrated Circuits, and the ONR EMMA MURI.