5-1-00

A Renewal Proposal

DEVELOPMENT OF IMAGE REJECTING MIXERS

Submitted to:

National Radio Astronomy Observatory
Edgemont Road
Charlottesville, VA 22903-2475

Attention:

James L. Desmond
Associate Director, Administration

Submitted by:

A. W. Lichtenberger
Research Associate Professor

SEAS Proposal No. EE-NRAO-0356-00
May 2000

DEPARTMENT OF ELECTRICAL ENGINEERING
UNIVERSITY OF VIRGINIA
SCHOOL OF ENGINEERING & APPLIED SCIENCE
351 MCCORMICK ROAD, P. O. BOX 400743
CHARLOTTESVILLE, VA 22904-4743

CONTRACTUAL INFORMATION

A Renewal Proposal Submitted to National Radio Astronomy Observatory

Title: Development of SIS Image Rejecting Mixers

Proposal Number: EE-NRAO-0356-00

Date Submitted: May 2000

Offeror: University of Virginia

Business Office/
Administrative Contact:

Office of Sponsored Programs
P.O. Box 400195
Charlottesville, VA 22904-4195
Michael G. Glasgow, Jr., Director
Phone (804) 924-4270
Fax (804) 982-3096
E-mail: mgg5e@virginia.edu

Principal Investigator/
Technical Contact:

A. W. Lichtenberger
Department of Electrical Engineering
School of Engineering and Applied Science
351 McCormick Road, P. O. Box 400743
Charlottesville, VA 22904-4743
Phone (804) 924-7454
Fax (804) 924-8818
E-mail: awl1l@virginia.edu

Duration: July 1, 2000 – June 30, 2001

Amount: $150,000

Approvals:

UNIVERSITY OF VIRGINIA

_____
Michael G. Glasgow, Jr., Director
Office of Sponsored Programs
Date:_____

PRINCIPAL INVESTIGATOR

_____
A. W. Lichtenberger
Research Associate Professor
Date:_____

DEPARTMENT OF ELECTRICAL ENGINEERING

_____ Date:_____

J. H. Aylor
Professor and Chairman

SCHOOL OF ENGINEERING AND APPLIED SCIENCE

_____ Date:_____

Haydn N. G. Wadley
Associate Dean for Research

Liaison:

Requests for additional information and assistance may be referred to:

Preaward Research Administration
School of Engineering and Applied Science
University of Virginia
351 McCormick Road, P. O. Box 400743
Charlottesville, VA 22904-4743
Attention: Ms. D. E. Van, Grants Administrator
Phone: (804) 924-6272
FAX: (804) 924-6270
E-mail: dev@virginia.edu

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II. Proposed Development

Introduction

In the past year we continued to examine our fabrication process in light of the need for smaller area SIS junctions and sharper electrical characteristics. This investigation was primarily undertaken with respect to the deposition of the trilayer films and the stress of these films. In this period we also continued our investigation of potential technologies for deep micro machining of quartz and wafer thinning processes. Finally, we have continued our investigation of thin film resistors for image rejecting mixer designs.

The film stress of Nb has been shown empirically to play a critical role in the quality of electrical characteristics of SIS junctions. In our laboratory, film stress is obtained with a laser based tool which is used to measure the curvature of a Si wafer prior to and after film deposition. The profiles are subtracted and fit with a theoretically generated curve, from which the film stress value is extracted. We had previously found that the stress of our 200nm thick Nb films from the trilayer system was fairly stable and changed moderately as a target is eroded with use. Reports from other researchers indicated similar results, though the reported rate of stress change with target use varies widely from system to system. We also found that the stress values for different material systems such as Si/Nb and Si/Nb/Al(thin)/Nb varied greatly for a given pressure. This result puzzled us for some time. After considerable experimentation, it was discovered that the measured film stress depended on film thickness. Ideally, intrinsic film stress is independent of film thickness (i.e. substrate bow should be linear with film thickness) unless the films are thick enough to physically relax (typically >>200nm). Our result appeared to indicate either that the film morphology was unexpectedly and significantly changing with film thickness during a single deposition or that some extrinsic film stress mechanism was involved. The system was thoroughly examined with no resulting explanation. It was also found that a second system exhibited similar stress results.

At this time new sputter guns were purchased for the trilayer system. In our search for an extrinsic stress mechanism we also discovered that a new trilayer substrate holder, which used a ring clamp rather than four individual finger clamps, resulted in significantly different film stress. Another wafer block was designed where the wafer is pressed with a ring clamp into a recess which is partially filled with an UHV vacuum grease. The design is such that with the clamp fully compressed, the wafer is 'floating' on a 2mil thick layer of grease. Stress measurements made of Nb films using this block exhibited no dependency with film thickness. It was concluded that the clamping of the Si wafer bowed the wafer and that the subsequently deposited Nb film 'captured' some of this wafer curvature after the wafer was unclamped. Along with the new guns this resulted in improved yet still somewhat rounded electrical characteristics for junctions larger than 1.5um.

Due to requirements of future image rejecting mixers, which require resistive terminations, we were also developing a liftoff patterning technique for the trilayer/Au films. It has been reported that liftoff of trilayer films can improve the electrical characteristics of small junctions, assumably by reducing stress effects on the thin Al-oxide barrier layer. Present NRAO mixers require 2 micron line widths in the trilayer pattern which is fairly exacting. The presence of the Au layer, needed for our Au overlayer junction technology, also makes the liftoff more difficult. We developed a suitable process by adapting our older Nb trilevel junction resist technique to this process. Devices fabricated had even sharper electrical characteristics. It was also found that 1.0um junctions, using a KWL mask set, also exhibited good electrical characteristics. This result has been repeated twice; however, use of another mask set has not resulted in good electrical characteristics for small junctions. More work remains to be done to understand these results.

During this period several other laser systems for the micro machining of our quartz wafers were examined. All of them proved to be unsuitable for cutting mixer patterns in the quartz. ICP RIE systems were also investigated. One vendor, Oxford Plasma Technology, claims the capability of etching quartz 2mils thick; however, their basic system costs $600,000. Other Vendor's less expensive systems either could not cut such deep trenches or they were not willing to even try. We have also developed a lapping process where the wafer is first diced partially through, turned over, mounted and lapped to the desired thickness (e.g. 2 mils)- separating the mixers at the same time.

In the past year we have also fabricated more of the FILTO wafers which have elements designed by NRAO to indirectly measure the material properties of the Nb and SiO layers used in our processes. To date, using methods permitted in our present mask designs, we have not realized any improvement to the shorts found in these structures. It is believed that the problem is a result of the inherent poor morphology of SiO evaporated films and or submicron debris on the wafer surface.

Finally, we have continued our investigation of thin film resistors for image rejecting mixer designs. The Nb_xO_y 50 ohm/□ process we previously developed requires an improved chamber with loadlock, new pumping stack and multiple target and cleaning capability to be reproducible. Our cost estimate for constructing such a system exceeds $150K. In light of such expense we have recently started investigation of a sputtered PdAu resistor technology. This technique will not realize 50 ohm/□ films but should be capable of 12.5ohm/□ resistors.

SIS Development

(1) A major emphasis of our work will be maintaining the fabrication technology used for the fabrication of SIS elements for NRAO mixers. Included in this work will be increasing the control over process variations and material and device characteristics. It is also expected that we will interact with NRAO in the design of any new mask sets.

(2) We will continue our initial investigation of a sputtered PdAu resistor technology. This technology must be integrated into our full SIS mixer fabrication process. Measurements will be performed at 4.2K.

(3) We will continue to investigate the FILTO fabrication process in an attempt to increase the yield of the elements. In particular we will investigate the use of an anodic anodization step performed after the SiO deposition in an attempt to remove individual pinhole sites in the SiO to the base electrode. We will also investigate the use of a sputtered SiO film instead of evaporative SiO. If the sputtered SiO film can be lifted off, it should provide better coverage and fewer pinholes than evaporative SiO. We will also investigate the use of a CO2 'snow' cleaning process for removal of submicron dust and debris prior to SiO deposition. This system has been designed, but needs to be built and characterized.

(4) We will try to understand and resolve apparent geometrical effects on the quality of small junctions.

(5) We will keep abreast of technology and cost for the separation of irregularly shaped chips from our quartz wafers.

(6) We will also interact with Drs. S-K. Pan and A.R. Kerr of the Central Development Laboratory on all matters.

Resume : Arthur W. Lichtenberger

Education: Ph.D. (Electrical Engineering) University of Virginia, 1987,
Dissertation: SIS Nb Trilayer and NbCN Edge Junctions for Mixer Applications.
M.S.E.E. University of Virginia, 1985
Thesis: Optimization of Submicron SIS Nb Edge Junctions.
B.S. (Physics) Amherst College, 1980.
Thesis: Superfluid Transitions in Thin Helium Films

Experience: Department of Electrical Engineering, University of Virginia, Charlottesville, Virginia.
Research Associate Professor, 10/93 - present
Research Assistant Professor, 8/87 - 10/93
Graduate Research Assistant, 1/82-8/87.
Graduate Teaching Assistant, 9/81-1/82.
Department of Radio Astronomy, University of Massachusetts, Amherst, Massachusetts.
Technician Department of Radio Astronomy, 9/80-7/81.
Department of Physics, Amherst College, Amherst, Massachusetts.
Research Amherst College, 9/79-9/80.

Relevant Publications:

W.W. Clark IV, J. M. Beatrice, and A. W. Lichtenberger, "Effects of Geometry and Hardware on the Stress of Nb Thin Films", submitted to IEEE Transactions on Applied Superconductivity.

W.L Bishop, and A.W. Lichtenberger, "Accurate Control of Whole Wafer Quartz Thinning and Dicing Processes for Waveguide Receivers", submitted to IEEE Transactions on Applied Superconductivity.

C. Walker, and A.W. Lichtenberger, "A New Laser Micromachining System for the Fabrication of THz Waveguide and Quasi-Optical Components", Proceedings of the Eleventh International Symposium on Space Technology, 2000.

A.R. Kerr, S.-K. Pan and A.W. Lichtenberger, "A Nb/Al-oxide/Nb Low Noise Integrated Balanced Mixer", Proceedings of the Eleventh International Symposium on Space Technology, 2000.

R.B. Bass and A.W. Lichtenberger, "Focussed Ion Beam Fabrication of Sub Micron Nb/Al-oxide/Nb Junctions, IEEE Transactions on Applied Superconductivity, June 1999.

R.S. Amos, C.E. Tong, S.-K. Pan, and A.W. Lichtenberger, "Nb/Al-oxide/Nb Edge Junctions for Distributed Mixers", IEEE Transactions on Applied Superconductivity, June 1999.

H.H. Huang, J.Z. Zhang, R.E. Miller and A.W. Lichtenberger, "Unexpected Geometrical Effects in the Fabrication of Nb/Al-oxide/Nb Junctions", IEEE Trans. on Appl. Superconductivity, June 1999.

C.I. Wilson, L.S. Salinas, and A.W. Lichtenberger "Nb-oxide Thin Film Resistors", IEEE Transactions on Applied Superconductivity, June 1999.

Budget Detail
7/1/00 - 6/30/01

A.	Personnel & Benefits			
	1. A. W. Lichtenberger, PI			
	25% effort CY @ $86,000 CY			21,500
	Allowance for salary increase			627
	Fringe Benefits - 24.5%			5,421
	2. J. Zhang, Laboratory Specialist			
	80% effort CY @ $32,333 CY			25,866
	Allowance for salary increase			754
	Fringe Benefits - 31.5%			8,385
	SUBTOTAL PERSONNEL & BENEFITS			**$62,553**
B.	Materials and Supplies			
	Quartz substrates, ultra flats Si wafers, targets, chemicals, liquid He			18,000
C.	Equipment			
	Balzers TMP 500 Turbo Pump and Power Supply			16,800
D.	Technical Services			
	1. Laboratory Cleanroom	6,000		
	2. Machine shop work	2,000		
				8,000
E.	Other Contractual Services			
	1. Copy, communications, etc.	540		
	2. Publications	907		
				1,447
	TOTAL DIRECT COSTS			**$106,800**
F.	Indirect Costs - 48% Modified Total Direct Costs			43,200
	TOTAL			**$150,000**

BUDGET NOTES

* Personnel - Faculty appointments are generally effective calendar year (CY) beginning July 1 or Academic Year (AY) beginning September 1. A. W. Lichtenberger, PI - 25% effort CY @ $86,000 CY; plus increases. J. Zhang, Lab Specialist - 80% effort CY @ $32,333 CY; plus increases.

* Salary Increases - A 5% salary increase is applied to a majority of SEAS proposals, effective 11/25/00, and is accumulated annually from this date. Faculty increases are based on contributions in academic and research areas and are approved by the State of Virginia Budget Office. Staff increases are based on State of Virginia proficiency guidelines. New salaries are given as soon as they are available.

* Fringe Benefits - The University of Virginia's fringe benefits rates, as they apply to sponsored programs are proposed as follows: 24.5% for faculty and professional staff, 31.5% for classified staff, 18.5% for part-time faculty and staff and 7% for wage employees and summer effort by faculty with AY appointments. Fringe benefits apply to graduate and undergraduate research assistants if not enrolled full time (generally 12 hrs. for undergraduates and 9 hrs. for graduates).

* Materials and Supplies - Laboratory supplies for specific use in the research project (Quartz substrates, ultra flats Si wafers, targets, machine shop work, chemicals, liquid He). Does not include office or other general purpose supplies.

* Equipment - Blazers TMP 500 Turbo Pump and Power Supply - $16,800.

* Laboratory Fees for Cleanroom Facility - The Semiconductor Device Laboratory's Cleanroom facility is provided for sponsored research programs and its operational costs must be obtained from individual research grants and contracts requiring use of this facility. Fees are based on usage of the facility in the following manner: $500 per month for those needing direct access to the cleanroom; $200 per month for those needing access only to areas outside the cleanroom.

* Central Support Services (Machine Shop) - Rates are established for each fiscal year by the managing unit and approved by the University Office of the Comptroller. Rates are applied equally to all University users.

* Publications - Publications and page charges in related technical journals.

* Other Costs - Estimated project related costs for photocopying, long distance phone and FAX, reports preparation, etc. are based on prior SEAS research experience. The University of Virginia system, through copy cards, etc., is able to document such costs as related to the project.

* Indirect Costs - The University of Virginia's negotiated MTDC Indirect Cost rates with DHHS per agreement of 6/23/99 are: 7/1/98 - 6/30/2002, and until further amended, 48% "on campus" and 23.6% "off-campus". (Note: The MTDC base consists of total direct costs less individual equipment items in excess of $2,000, alterations and renovations, patient care costs, stipends, tuition remission and rental costs of off-campus facilities.) Includes overhead on the first $25,000 of subcontracts.

Current and Pending Support

THIS PROPOSAL

Development of SIS Fixed Tuned Mixer Elements with Integrated Tuning Elements.
7/1/99-6/30/00
National Radio Astronomy Observatory
PI: Arthur Lichtenberger
$150,000

Investigation of Superconductive Mixers for Astronomical Receivers,
8/1/00-9/30/02
National Science Foundation
$386,095
PI: Arthur W. Lichtenberger
Status: I just heard on the NSF Fastlane that the work has been funded

Micromachining of TeraHertz Waveguide and Quasi-Optical Components for Suborbital and Space-Born Detectors.
6/01/00-5/31/02, NASA.
PIs: Christopher Walker (U. of Arizona), Arthur Lichtenberger (UVa), Gordon Chin (NASA Goddard).
$350,043. UVa's portion is $145K

Development of SIS Fixed Tuned Mixer Elements with Integrated Tuning Elements
7/1/98-6/30/99
National Radio Astronomy Observatory
PI: Arthur Lichtenberger
$150,000

DISTRIBUTION LIST

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