nanofab
University of Utah

TMV Uniformity

Summary of Findings

Kevin Hensley, David Jamison

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Executive Summary

This report compares deposition uniformity for the six cathodes mounted in the dedicated configuration of the TMV Super Series sputtering system. The cathodes studied include: Au, Ir, Pt and the associated adhesion layers: Ti, Cr, TiW. In general, the four locations in front of mechanical rotation fixturing enable far superior deposition uniformity. Included is a study of the Ti adhesion layer, which does not have rotational capabilities, being rotated on the carousel to prove increased uniformity with rotation. We also attach a recommendation for upgrading the tool so that all positions are rotated. This upgrade will cost an estimated $18K, with an ETA of September 22, 2010 plus or minus 20 days depending on vendor lead times and staff priorities as well as TMV utilization.

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TMV Targets With Rotation

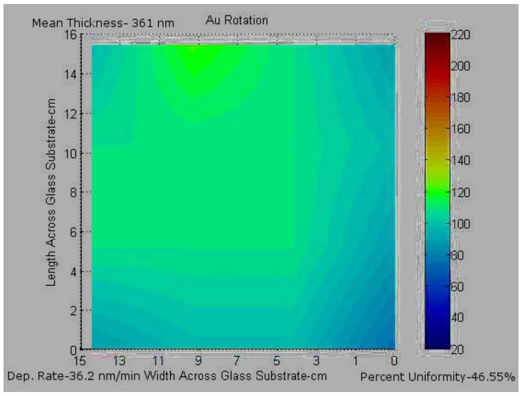

Figure 1, Au with rotation (~47% non-uniformity)

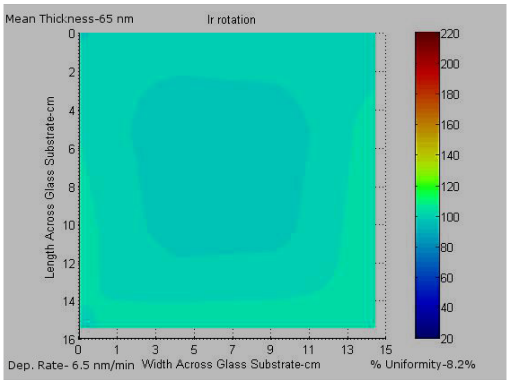

Figure 2, Ir with rotation (~8% non-uniformity)

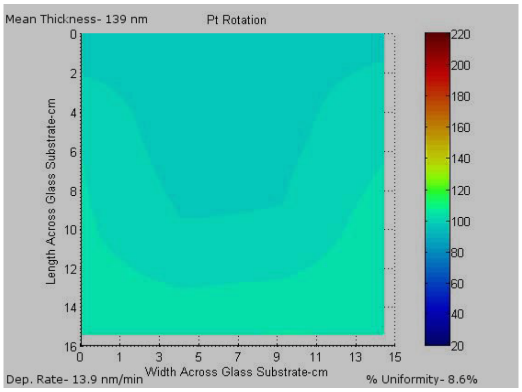

Figure 4, Pt with rotation (~9% non-uniformity)

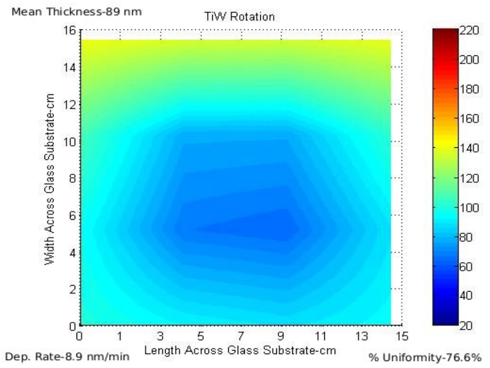

Figure 3, TiW with rotation (~77% non-uniformity)

- Substrate: Fisher Glass Microscope Slides
- *Deposition Conditions: 150 sccm Ar
- 5 mTorr dep pressure
- 100 watt (DC)
- Rotational power on at 63 rpm

*all deposition conditions the same for figures on the page

TMV Targets without Rotation

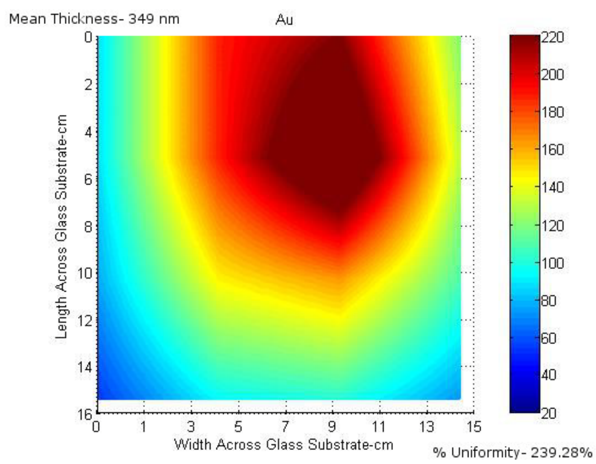

Figure 5, Au with-out rotation (~240% non-uniformity)

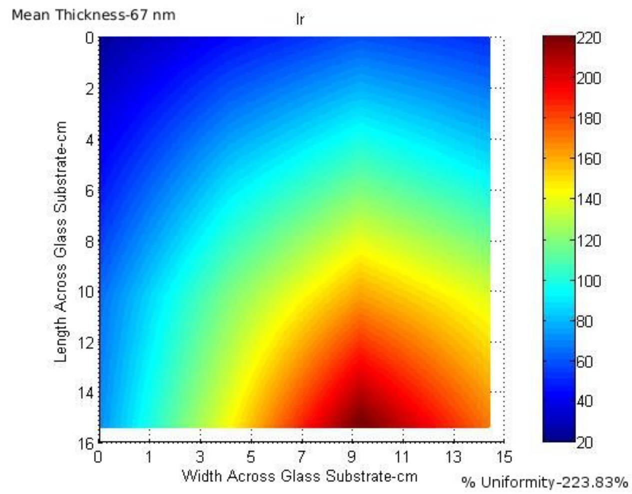

Figure 6, Ir with-out rotation (~224% non-uniformity)

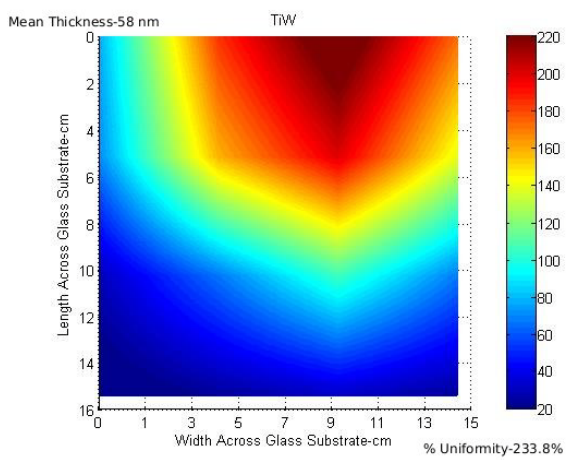

Figure 7, TiW with-out rotation (~234% non-uniformity)

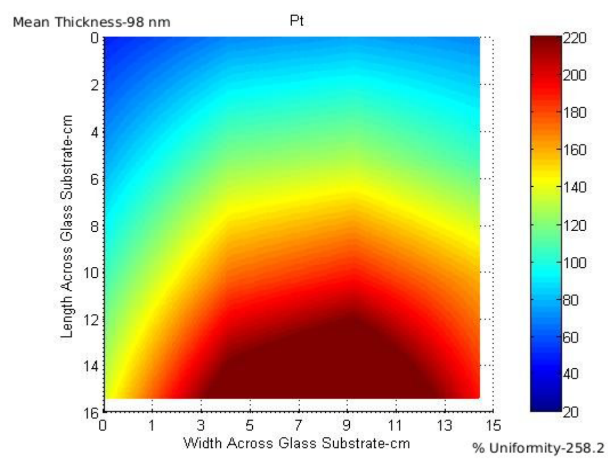

Figure 8, Pt with-out rotation (~258% non-uniformity)

- Substrate: Fisher Glass Microscope Slides
- *Deposition Conditions: 150 sccm Ar
- 5 mTorr dep. pressure
- 100 watt (DC)
- Rotational power off

*all deposition conditions the same for figures on this page

TMV Targets without Rotation

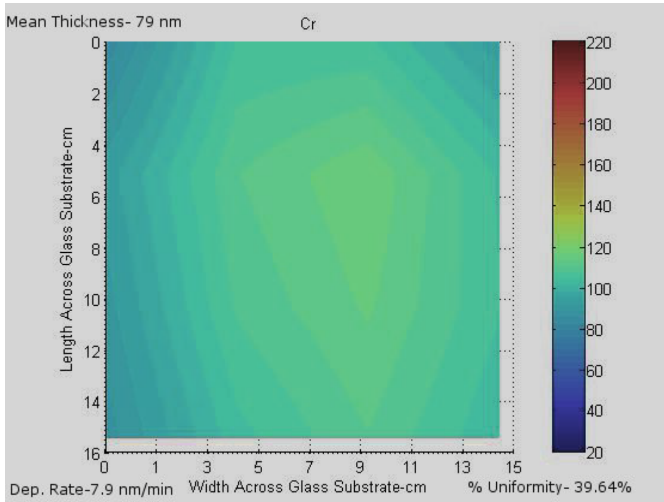

Figure 9, Cr rotation NA (~40% uniformity)

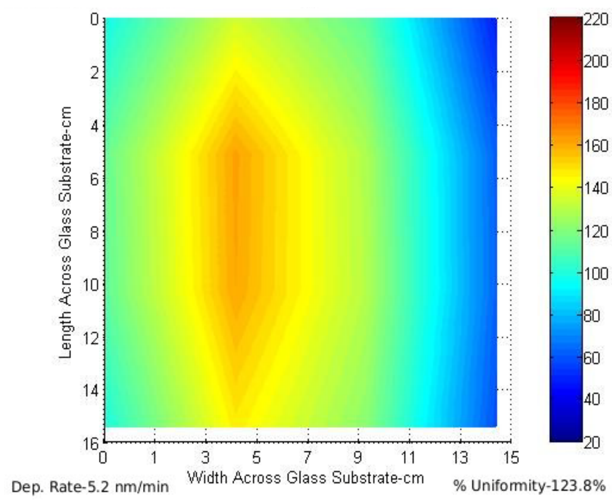

Figure 10, Ti rotation NA (~124% non-uniformity)

- Substrate: Fisher Glass Microscope Slides
- *Deposition Conditions: 150 sccm Ar
- 5 mTorr dep. Pressure
- 100 watt (DC)
- Rotational power: NA

*all deposition conditions the same for figures on the page

TMV Targets without Rotation With Carousel rotation

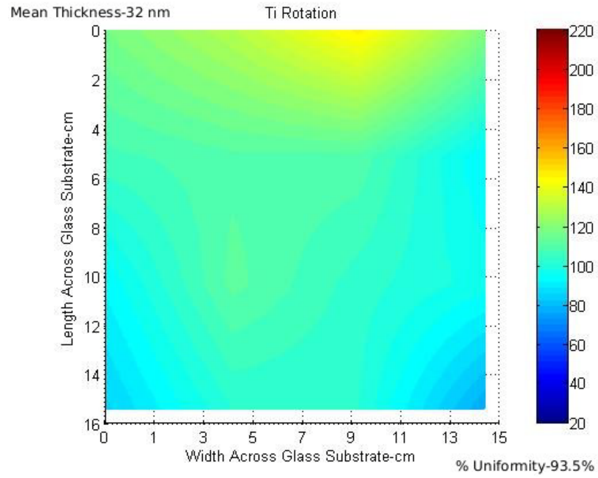

Figure 11, Ti rotating carousel (~94% non-uniformity)

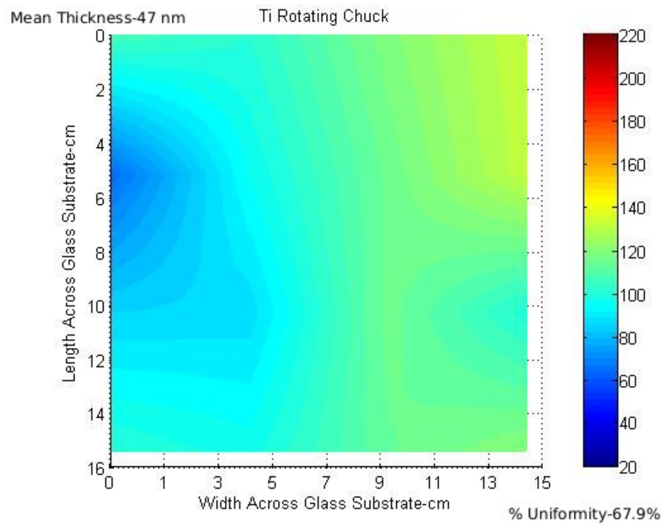

Figure 12, Ti rotating chuck on rotating carousel (~68% non-uniformity)

- Deposition conditions same as previous pages except for rotation.

Rotation on figure 11 was done by putting a grid of glass slides on a non-rotating chuck and then continuously rotating the sample carousel. The sample carousel has eight sample positions. As a result, when the carousel is rotated the deposition rate is divided by eight. This increases the deposition time by eight as well. Titanium has a deposition rate of only 5.27 nm/min so if it gets divided by eight, the dep. rate drops to .65 nm/min which is unrealistically slow.

Rotation on Figure 12 was done by putting the glass slide grid on a rotating chuck with the carousel being continuously rotated. This circular rotation increased the percent uniformity by 25.6% so the addition of circular rotation does increase uniformity.

Appendix: Data Collection Method

The substrate that was deposited on was a grid of glass microscope slides, two slides across and 4 slides down. Each slide provided 2 measurements on the 4-point probe for the film sheet resistance. After the sheet resistance was measured, two thickness measurements were made on the Tencor P-10 profilometer. Using the Sheet resistance multiplied by one of the actual thickness measurements converted to cm gives the bulk resistivity of the film. Once bulk resistivity has been calculated, it is divided by the sheet resistance for each measurement to convert to thickness. The second measurement that was taken on the Tencor is to check for accuracy. The majority of the converted thickness readings were no more than 10 nm different from the actual measurements taken. Each glass slide was scribed with a location and an orientation so the grid of measurements could be constructed accurately. The percent uniformity is calculated by subtracting the smallest value from the largest and diving by the mean value, then multiplying your result by 100.

Formulas:

Calculating Bulk resistivity: Thickness (cm)*Sheet Resistance (ohms-per-square) =Bulk resistivity (micro- ohm-cm)

Calculating Thickness: Bulk resistivity (micro-ohm-cm)/Sheet resistance (ohms-per-square) =Thickness (cm)

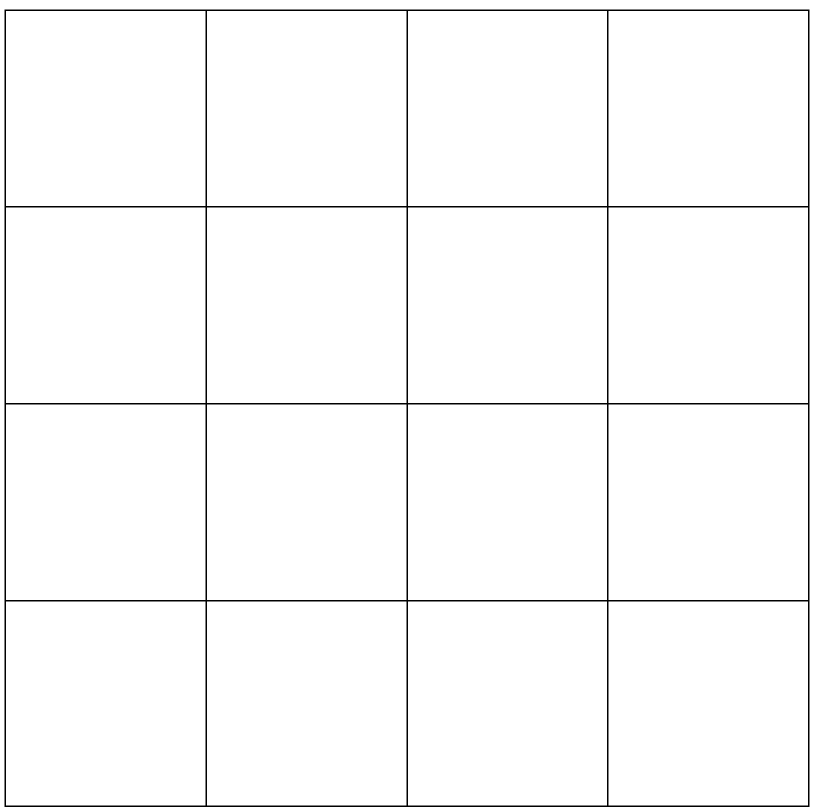

Figure 13, Example of Glass slide grid separated into measurement zones

Cost Estimate For Uniformity Upgrade

Wafer Rotation Design Proposal to Improve Uniformity

Introduction:

After considerable research and consideration the following design is proposed to effectively rotate four distinct deposition samples in all four sputtering locations in the TM Vacuum Super Series. This proposal will require physical modifications to the process chamber, require the fabrication of a mounting apparatus, and utilize parts from various vendors. Moreover, the proposed design will increase the reliability of the rotational mechanism by eliminated failure points and simplifying the maintenance and operation procedures.

Physical modifications:

In order to accommodate the proposed design, the substrate heating capabilities currently installed in the process chamber will have to be un-installed. The substrate heating assembly has been underutilized and no future utilization is foreseen. This modification can be reversed if future needs favor heat over sample rotation.

All other physical modifications will be limited to bolt-on assemblies and will not require permanent alterations to the chamber, transfer system, carousel, or control software.

Additionally, the current rotational apparatus will be completely removed to accommodate the proposed mechanism.

Motive:

Current status:

The current rotational apparatus has proven unreliable, underpowered, and difficult to repair, maintain, and calibrate. When originally designed and installed, the apparatus was for sample rotation limited to two sputter location that accommodate four sputter materials. Only two chucks are currently capable of rotation due to excess wear caused by alignment complexity in the drive mechanism.

Uniformity:

This proposal accommodates rotation in all four sputter locations which is proven necessary for uniformity according to our data collection. The consistency of deposition uniformity will also be improved by reduced downtime, reduced chamber venting, and improved rotational smoothness. Moreover, the proposed design will allow operators to adjust rotational speed reliably from 1rpm to 150rpm.

Reliability:

This proposal is designed to reduce the sum of moving parts to a minimum thus greatly reducing points of failure. Each of the four sputter location and each of the four rotating chucks will use redundant parts allowing ease of repair and diagnosis of failures.

The proposed apparatus can accommodate up to three degrees of misalignment of the carousel's location. Additionally, the drive mechanism eliminates any physical contact between the drive system and the sample holders which greatly reduces wear in the case of a jammed or failed chuck.

Strategy:

Fabrication and testing of the new apparatus will be accomplished without interruption to the current operation of the TMV. Once all materials and assemblies have been received, fabricated, and tested the installation will begin. All work that requires the chamber to be vented and the machine to be taken off-line will be prioritized. The installation of the mechanisms inside the chamber will be expedited to eliminate downtime and chamber contamination.

Description of Rotational Mechanism:

The mechanism will consist of four UHV compatible stepper motors each mounted at one sputter location in a horizontal configuration. The motor shafts will terminate in a magnetic disk coupling. The motor mounting assemblies will be fabricated from vacuum compatible stainless steel and provide for three axes of positioning adjustment. These motor mounts will be fastened to a stainless steel base plate that will locate the entire assembly in the chamber.

The drive motors will be controlled by a stepper motor controller located near the operator's control panel. UHV electrical feedthroughs will provide power and drive signals to the motors. The motors will be individually driven by the controller via a switchable/ selectable relay box.

The mating sides of the magnetic disk couplers will be mounted to the chucks' rotation shafts. Considerable research has gone into ensuring the magnetic flux of these couplers will not interfere with the deposition process. However, if necessary a ferrous stainless steel shield can be incorporated to eliminate any magnetic interference.

Budget:

At the time of this writing some elements of the budget are not finalized and careful estimates have been inserted. The total cost of parts and materials for the initial installation is $17,856.00. Annual maintenance and repair budget is estimated at $600.

BOM:

Please refer to the attached bill of materials for detailed information on parts, vendors, and assemblies. Some elements of the mechanism will be custom built in house and have been noted as such on the BOM.

Time Line:

This proposal is estimated to require 75 man hours to complete. This estimate incorporates ordering, fabrication, assembly, calibration, and testing. Additional time will be required to characterize the uniformity and deposition rates once the mechanism is installed. The bulk of the work will be performed by members of the Nanofab's technical staff and will be directed by Kevin Hensley.

Completion Date:

The calendar time line for this proposal is subject to personnel priorities and vendors' lead times. With current staff availability and lead times in consideration a completion date is estimated for September 22nd, 2010. This estimate may float as much as 20 days plus or minus depending on TMV utilization, staffing priorities, and unforeseen design alterations. Uniformity and deposition rate characterization will follow the calendar completion date.

Bill of Materials and Costs (not including labor):

Part Description	**Vendor**	**Lead Time / Labor hours**	**Qty**	**List Price $**	**Total $**
UHV Stepper Motor #665912	MDC Vacuum	8 weeks	4	$3,582.00	$14,328.00
Stepper Motor Controller #692007	MDC Vacuum	6 weeks	1	$1,650.00	$1,650.00
Magnetic disk coupling # S50DCM-17H04	SDP Inc.	2 weeks	4	$39.00	$156.00
Multi pin electrical Feedthrough #IFTAG205103	Kurt J. Lesker	4 weeks	1	$466.00	$466.00
20 pin instrument connector #FTAAMPH20MS	Kurt J. Lesker	4 weeks	1	$56.00	$56.00
Stainless Steel Stock	Multiple	2 weeks	n/a	$500.00	$500.00
Custom Machining	In house	16 hours	n/a	$150.00	$150.00
Stainless Steel Fasteners (vented)	Multiple	1 week	n/a	$150.00	$150.00
Interconnect Wiring Supplies	Multiple	1 week	n/a	$150.00	$150.00
In-Vacuum Insulated Wire #680500	MDC Vacuum	2 weeks	1	$50.00	$50.00
Shipping (estimate)					$200.00
TOTAL					$17,856.00

Figure 14, Bill of Materials and costs (labor not included)