Final Report for ER54440, "Measurements and Modeling of Low Energy 910 to 1000 eV) Sputtering and Reflection.

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This report is a compilation of the three annual progress reports. All detail can be found in the refereed publications enumerated within.

DOE Patent Clearance Granted

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Progress Report for FY 97

This has been a busy year for the Measurements and Modeling project. I have two new graduate students working on the project, Jean-Paul Allain and Darren Alman. They have rebuilt and re-aligned the system and now know where every wire and power supply goes. In the modelling end, they are now competent to run our current codes and have even made some corrections to the codes to allow them to run under Fortran-90.

New data has been obtained for the sputtering of Al and Ti and initial experiments have been conducted for the sputtering of Li. Temperature control of the substrate has been added and a new alignment system devised and tested. We also had to modify the sample loading to use reactive materials like Li.

In the modelling, we have added a new module for the sputtering of liquid metals and generalized changes of the surface binding energy as a function of depth. This has led to some interesting predictions that we hope to confirm experimentally. Extensive results for the angular distribution of sputtered materials has been made for several collaborations with other experiments.

We have presented results related to this contract at the following conferences:

American Vacuum Society, San Jose, CA, October 1997:

"The Effects of Ta Crystallites at the Ta/Al / Al-Cu Interface of Hyper-Texture Aluminum," presented by J.P. Allain.

"Measurements and Modeling of Low-energy Sputtering as a function of Target Temperature and Grain Size," by D.N. Ruzic

Plasma-Surface Interactions, San Diego, CA, May 1998:

"Measurements and Modeling of Lithium Sputtering," presented by J.P. Allain and D. Alman.

One paper has been published so far this fiscal year, though it mainly covers earlier work:

P.C. Smith and D.N. Ruzic, "Low-energy(10-700 eV) angularly-resolved sputtering measurements for D+ on Be," Nuclear Fusion, Vol 35. No. 5 (1998) 8pp.

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Several other publications relating to the MS thesis work of J.P. Allain and D. Alman are in progress.

Our future plans continue along the lines of the proposal. We will measure more temperature and crystallographic effects of Ti and Cu targets while introducing an apparatus to directly measure reflection and to more accurately measure the angular distribution of sputtered material.

Progress Report for FY 98

This has been another busy year for the Measurements and Modeling project. I have one new graduate students working on the project, Rajiv Ranjan, in addition to Jean-Paul Allain and Darren Alman. In addition, we have added the capability to sputter real magnetron targets and produce metalization for sub-micron interconnects. Graduate student, Monica Allain is working on this aspect of the project. The combination of laboratory measurements of sputtering with actual industrial-scale applications of sputtering makes the data more useful and focused on the real needs in the community. When coupled to our simulations, a very useful synergy has emerged.

New data has been obtained for the sputtering of Li by D, He, and Li and initial experiments have been conducted for the sputtering of liquid Li. More work was also done on Ti and Al.

In the modeling, we have improved the input and output routines while adding the capability to speed statistical analysis of the results. We have also converted the codes to run on our own workstations. Previously, the super computers at NERSC were required.

We have presented results related to this contract at the following conferences:

American Vacuum Society, Baltimore MD, November 1998:

"Characterization of Magnetron-Sputtered partially ionized Deposition as a Function of Metal and Gas-Species" presented by Monica Allain.

"Combined Monte-Carlo and Fluid Sputter Transport Model in an Ionized PVD System with Experimental Plasma Characterization" presented by D.R. Juliano

"Measurements and Modeling of Ti and Ta Sputtering as a Function of Target Microstructure and Temperature" by J.P. Allain

"The Application of Helicon Antennas as a Secondary Plasma Source for Ionized PVD" presented by D.B. Hayden

International conference on Metallurgical Coatings and Thin Films, San Diego, CA, April 1999:

"Comparison of Inductively Coupled vs Helicon Driven Plasmas for Ionized PVD Applications"

presented by Monica Allain and D. N. Ruzic

Two papers that contain some work related to this contract have been published so far this fiscal year:

1. Brooks, J.N., D. Alman, G. Federici, D.N. Ruzic, and D.G. Whyte, "Erosion redeposition analysis: status of modeling and code validation for semi-detached edge plasmas," J. Nuclear Materials, 266-269, 58-66 (1999).
2. Ruzic, D. N., M.C. Allain, and R.V. Budny, "The Effect of Lithium Wall Conditioning in TFTR on Plasma-Surface Interactions," J. Nucl. Mater., 266-269, 1303-1308 (1999).

Several other publications relating to this work are in progress.

Our future plans continue along the lines of the proposal. We will measure sputtering data for Ti and TiN and other diffusion barriers for interconnect applications. The liquid metal work will also continue.

Progress Report for FY 99

In this final year of the three-year grant, a number of publications were finished. These concluded our non-fusion sputtering measurements, and our sputtering experiments utilizing a commercial-size magnetron. Once again we attended and presented at the AVS meeting and the ICMCTF meetings.

The publications are:

Hayden, D.B., D.R. Juliano, M.N. Neumann, M.M. Allain, D.N. Ruzic, "Helicon Plasma Source for Ionized PVD," Surf. Coating Tech., 120-121, 401-404 (1999)

Smith, P.C. and D.N. Ruzic, "Low-energy Ar⁺ Ion Induced Angularly-Resolved Al(100) and Al(110) Sputtering Measurements," J. Vac. Sci. and Tech. A 17, 3161-3166, (1999)

Alman, D.A. and D.N. Ruzic, "A model of hydrocarbon reactions in low temperature hydrogen plasmas," Physics of Plasmas, 7 (2000) 1421-1432.

Allain, M.M C. D.B. Hayden, D.R. Juliano, D.N. Ruzic, "Characterization of magnetron-sputtered partially ionized deposition as a function of metal and gas species". J. Vac. Sci. Technol. A 13 (2000) 797-801.

Juliano, D.R., D.N. Ruzic, M.M.C. Allain, D.B. Hayden, "Influences on ionization fraction in an inductively coupled ionized physical vapor desposition device plasma", accepted in J. Appl. Phys. (2000).

Norman, J.E., Ning LI, D.N. Ruzic, "Iionized Plasma Vapor Deposition of TiN Films", submitted to J. Vac. Sci. Technol. A, September 2000.