REPORT DOCUMENTATION PAGE

AFRL-SR-BL-TR-00-

0535

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
		Final - 1 March 1999 to 28 February 2000

4. TITLE AND SUBTITLE
Surface Science of New Tribological Materials: Quasicrystalline Alloys

5. FUNDING NUMBERS
F49620-99-1-0127

6. AUTHOR(S)
Professor Andrews Gellman
Department of Chemical Engineering

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Carnegie-Mellon University
Pittsburgh, PA 15213

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
AFOSR/NL
801 North Randolph Street, Room 732
Arlington, VA 22203-1977

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION AVAILABILITY STATEMENT
APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Instrumentation has been purchased and an apparatus designed for the measurement of frictional forces between surfaces under ultra-high vacuum conditions. This instrument design is based on an existing apparatus that has been operating in the laboratory for several years. The apparatus is to be used for combined surface science and tribological investigations of quasicrystalline materials. Quasicrystals are alloys of complex structure exhibiting long range order but not peridocity. They have been shown to have high hardness and low friction but very little is known about the origins of thses properties. The instrument designed has the ability to allow study of the surface properties of materials in vacuum and also to allow the measurements of friction between pairs of such surfaces brought into contact under a range of sliding conditions.

14. SUBJECT TERMS
Tribologicial, Quasicrystalline

15. NUMBER OF PAGES
6

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclas	Unclas	Unclas	

AFOSR - Final Progress Report

Surface Science of New Tribological Materials: Quasicrystalline Alloys

Grant No. AFOSR-F49620-99-1-0127
Duration - Mar. 1, 1999 to Feb. 28, 2000

P.I. - Professor Andrew J. Gellman
Department of Chemical Engineering
Carnegie Mellon University
Pittsburgh, PA 15213

Summary

Instrumentation has been purchased and an apparatus designed for the measurement of frictional forces between surfaces under ultra-high vacuum conditions. This instrument design is based on an existing apparatus that has been operating in the laboratory for several years. The apparatus is to be used for combined surface science and tribological investigations of quasicrystalline materials. Quasicrystals are alloys of complex structure exhibiting long range order but not periodicity. They have been shown to have high hardness and low friction but very little is known about the origins of these properties. The instrument designed has the ability to allow study of the surface properties of materials in vacuum and also to allow the measurements of friction between pairs of such surfaces brought into contact under a range of sliding conditions.

Project Objectives

The objective of the project has been to design and build an apparatus that allows the measurement of friction between well-defined surfaces during sliding. This is based on an instrument that has been designed and used in the P.I.'s laboratory over the past ten years. The existing apparatus is one which allows the preparation of two single crystal surfaces under ultra-high vacuum conditions. These can then be brought into contact for measurements of friction induced by sliding. Such measurements allow a fundamental study of friction under the most highly defined conditions possible.

The UHV tribometer uses standard methods employed in the field of surface science for cleaning of metal single crystal surfaces. Removal of most contaminants is done using Ar^+ ion sputtering. This is then followed by annealing to high temperatures (~1000K) in order to obtain well order single crystalline surfaces. Other cleaning methods include high temperature exposure to oxygen. With these methods it is possible to create two surfaces of single crystals in ultra-high vacuum that are perfectly clean and well ordered. Their surfaces can be modified by the adsorption of lubricant molecules from the gas phase. Furthermore, it is possible to perform some analysis of the surfaces in order to spectroscopically characterize the adsorbed species. This means that the condition of the two surfaces prior to making friction measurements are characterized to the state-of-the-art allowed by modern surface science.

Surface analysis prior to bringing the two surfaces into contact for friction measurements is done using Auger Electron Spectroscopy (AES) to determine composition, Low Energy Electron Diffraction (LEED) to determine surface order. LEED is also used to determine the relative orientations of the two crystal lattices. Adsorbed species can be characterize using Thermally Programmed Reaction or Desorption Spectroscopy (TPRS / TPD) which allows the calibration of coverages on the surface and also allows study of the surface reaction and reaction kinetics of adsorbed species. In addition adsorbed molecules can be studied using vibrational spectroscopy.

Friction measurements between pairs of single crystalline surfaces are made using an ultra-high vacuum tribometer. The UHV tribometer has been designed in the P.I.'s laboratory and is the result of about ten years of development. It is the center piece of the tribology research in the lab since it allows the *in situ* measurement of friction

between ideally prepared and characterized surfaces. Once the sample surfaces have been prepared the two can be brought into contact under an applied normal load and then sheared relative to one another. The tribometer measures the normal and shear forces at the interface simultaneously and thus allows the measurement of a friction coefficient.

The existing apparatus in the P.I.'s laboratory is also equipped with instrumentation for the analysis of surface and wear scars after sliding friction measurements have been made. A Scanning Electron Microscope (SEM) can be used for the imaging of wear scars formed as a result of the sliding process. In addition a Scanning Auger Microscope can be used for analysis of the composition of the surfaces interior to the wear scars.

The UHV friction measurement techniques have been used in the P.I.'s laboratory to make a number of interesting observations over the past couple of years. One is a study of the effects of lattice orientation on the friction between pairs of Ni(100) surfaces. These measurements have revealed the existence of anisotropy in the friction between the two. A second study has looked at the effects of adsorbate coverage on friction between Ni(100) surfaces. This has revealed the effects of adsorbate layering at the interface between the two surfaces. The objectives of new apparatus are to study the frictional properties of quasicrystalline alloy surfaces.

Technical Progress and Accomplishments

The new apparatus that is being constructed using the funds from this grant is based on the design of the existing instrument in the P.I.'s laboratory. Figure 1 shows a schematic of the apparatus as it will look once completed. It uses the equipment from an existing UHV chamber that is currently in use for study of lubricant surface chemistry. To this apparatus we will be adding the instrumentation bought with the funds of this grant. The additional instrumentation will be:

- a LEED optics to be used for low energy electron diffraction and for Auger Electron Spectroscopy,
- a turbopump for differential pumping,
- a differentially pumped ion sputter gun for sample surface cleaning,

- a new manipulator to allow sample motion for friction measurements.
- and a UHV tribometer designed and constructed in the P.I.'s lab

During the grant period the new chamber has been designed and all of the pieces of instrumentation above have been purchased. At this point in time the components have all arrived and have been tested individually. They have not been assembled as a complete unit yet because it has been necessary to allow the graduate student using the existing chamber to complete his thesis research before dismantling. This is being completed over the next few months and at that point the recently purchased instrumentation will be assembled.

In the meantime work on the scientific component of the proposal has progressed using the existing UHV tribometer. Measurements are currently underway of the frictional properties of quasicrystalline approximants. In addition measurements are being made of the oxidation kinetics of quasicrystals and quasicrystalline approximants. Once the new apparatus is completely assembled this work will be transferred to it.

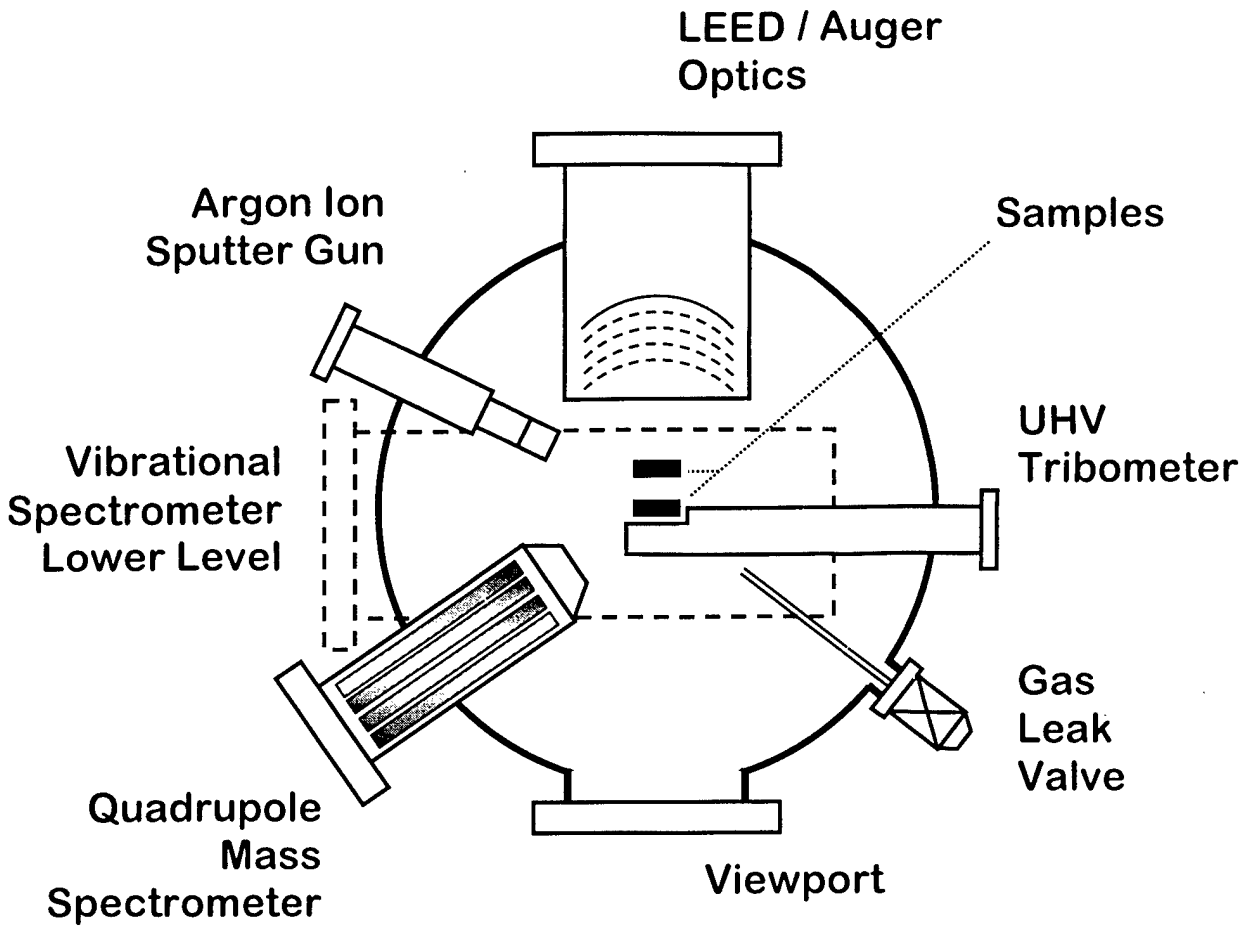

Figure 1. Schematic representation of UHV tribometry chamber designed for the equipment purchased under this grant. The schematic shows a cross section through a cylindrical UHV chamber. The top level houses the UHV tribometer and the instrumentation for surface preparation and analysis. The lower level of the chamber houses a surface vibrational spectrometer.

Equipment Purchases:

1. Omicron Reverse View LEED Optics	$38,140.00
2. Omicon ISE 10 Differentially Pumped Ion Gun	17,430.60
3. Balzers 250 l/s turbopumps	11,863.00
4. Huntington PM-800 UHV manipulator	8,877.75
5. MDC Vacuum Bell Jar	22,443.65
6. Components for UHV Tribometer	$98,755.00
Total	