NASA Technical Memorandum 102401

Tribological Properties of Ceramic/Ti_3Al-Nb Sliding Couples for Use as Candidate Seal Materials to 700 °C

Christopher DellaCorte, Bruce M. Steinetz, and Pamela K. Brindley
Lewis Research Center
Cleveland, Ohio

Prepared for the
International Conference on Metallurgical Coatings
sponsored by the American Vacuum Society
San Diego, California, April 2–6, 1990

(NASA-TM-102401) TRIBOLOGICAL PROPERTIES OF CERAMIC/Ti3Al-Nb SLIDING COUPLES FOR USE AS CANDIDATE SEAL MATERIALS TO 700 DEG C (NASA) 21 p
N90-12658
CSCL 07A
Unclas
G3/23 0243245

TRIBOLOGICAL PROPERTIES OF CERAMIC/Ti_3Al-Nb SLIDING COUPLES FOR USE AS CANDIDATE SEAL MATERIALS TO 700 °C

Christopher DellaCorte, Bruce M. Steinetz, and Pamela K. Brindley
National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135

ABSTRACT

Tribological properties of Ti_3Al-Nb intermetallic disks sliding against alumina-boria-silicate fabric were ascertained in air at temperatures from 25 to 700 °C. These materials are candidates for sliding seal applications for the National AeroSpace Plane. The tests were done using a pin on disk tribometer. Sliding was unidirectional at 0.27 m/sec under a nominal contact stress of 340 kPa.

Gold sputter or ion plating deposited films were used to reduce friction and wear. Rhodium and palladium films were used beneath the gold lubricating films to prevent diffusion of the substrate into the gold at high temperature.

The friction and wear of the unlubricated specimens was unacceptable. Friction coefficients were generally greater than 1.0. The ion plated gold films, when used with a rhodium diffusion barrier reduced friction by almost a factor of 2. Wear was also substantially reduced. The sputter deposited films were not adherent unless the substrate was sputter cleaned immediately prior to film deposition. Palladium did not function as a diffusion barrier.

E-5048

INTRODUCTION

This paper examines the tribological properties of ceramic/Ti3Al-Nb sliding couples in air from 25 to 700 °C. These materials are candidates for use in sliding seals for hypersonic flight vehicles. Frictional heating due to the effects of the atmosphere and also heating from engine combustion places many requirements on the seal materials and lubricants for hypersonic vehicles.

Anticipated seal temperatures may reach 1000 °C in both reducing (hydrogen) and oxidizing (air + H_2O vapor) atmospheres (Ref. 1). The materials and lubrication methods chosen, therefore, must be both thermally and chemically stable and be able to function tribologically at low temperatures for vehicle start up and also at high operating temperatures. Furthermore, to allow for active cooling and possible component distortions, the materials chosen must be thermally conductive and mechanically flexible.

One seal design which allows flexibility and thermal conductivity has been developed at NASA Lewis Research Center (Ref. 2). This seal design is intended for engine applications but could be modified for other uses such as airframe seals. Figure 1 shows, schematically, this seal design concept. The concept consists of a spring loaded ceramic rope which forms a linear seal and slides against the engine walls. The ceramic rope is woven from a high temperature alumina-boria-silicate fabric which is capable of withstanding use temperatures up to 1000 °C. The successful operation of this seal depends upon its ability to slide back and forth over the engine wall without breaking the ceramic rope or causing damage to the engine wall. Also, to reduce seal articulation power requirements, the friction between the lightly loaded seal rope (estimated at 340 kPa, 50 psi) and the engine wall must be as low as possible. Tribological data for the candidate materials are currently unavailable.

This paper presents the results of a program to determine the feasibility of using ceramic/Ti_3Al-Nb sliding couples as seal materials. Baseline friction and wear properties of the candidate materials are determined and possible lubricating methods are developed. Also, life prediction of the components is addressed. These data are required to evaluate and possibly modify the initial seal design.

MATERIALS

Pin-on-disk tests were conducted to simulate sliding seals for hypersonics vehicles. In these tests, a stainless steel pin was wrapped with a sample of high temperature ceramic rope fabric and slid against a test disk made of the intermetallic, Ti_3Al-Nb, a candidate counterface material. Lubricants were applied to either the fabric or the counterface disks by sputter or ion plating deposition techniques.

Ceramic Fabric

The fabric is woven from Alumina-Boria-Silicate fibers. The composition of the fibers, designated AF-40, is by weight, 62 percent Al_2O_3, 14 percent B_2O_3 and 24 percent SiO_2. The fabric woven from these fibers has excellent strength and flexibility to temperatures over 1000 °C (Ref. 3). The fabric is made from weave bundles of 10 μm diameter fibers woven in a crossover type satin harness pattern. The fabric resembles heavy burlap. Each weave bundle contains 390 fibers. Figure 2 is a photograph of the test fabric.

Intermetallic Disks

The counterface material tested in this study was the intermetallic, Ti_3Al-Nb. It contains 65 wt % Ti, 14 wt % Al and 21 wt % Nb. The Ti_3Al-Nb was made by hot pressing Ti_3Al-Nb powders in a vacuum. The powders are prepared by the plasma rotating electrode process (PREP). Reference 4 gives a more detailed description of this material's properties and preparation procedure.

The powders are hot pressed into a plate 5.0 mm thick, 150 mm long and 50 mm wide. 50- by 50-mm squares were cut from the plate and polished with silicon carbide sandpaper to make the test disks. A 16 mm diameter hole was cut into the center of the disk by wire electromachining methods. The disk surface was then polished to a 0.1 μm rms surface finish using aluminum oxide polishing powder. Scanning electron microscopy (SEM) and energy dispersive x-ray spectroscopy (EDS) indicate that the prepared surface was free from contaminants and large scratches. Figure 3 is a photograph of some Ti_3Al-Nb wear disks.

LUBRICATION TREATMENTS

Fabric

For lubrication, sputtered gold was applied to the fabric surface. Prior to gold deposition, the fabric was sputter cleaned. The deposition parameters are given in Table I.

Disks

Some wear disks were coated with gold either by sputtering or ion plating. Ion plating differs from sputtering in that a voltage potential is applied between the source and the specimen during deposition producing a more graded interface. Consequently, ion plating produces more adherent coatings than sputtering (Ref. 5). The motivation for using ion plating was that the better coating adherence would result in better lubrication than the sputtered coatings. Figure 4 shows, schematically, the ion plating process.

Diffusion Barrier Treatments

To function as lubricant coatings, the deposited films must not chemically react or change composition during use. Although no chemical reactions between gold and the candidate materials are expected, some diffusion, enhanced by the high test temperatures, may occur reducing the lubricating properties of the gold films. Therefore several diffusion barriers are also evaluated by performing furnace heat treatment tests at up to 700 °C, then examining the specimens for evidence of gross solid state diffusion.

Palladium is one diffusion barrier which was tested. Prior to sputter depositing a 100 nm thick gold film, a 50 nm palladium diffusion barrier was sputter deposited (see Table I). The literature (Ref. 6) indicates that at elevated temperatures, palladium will react with the titanium in the substrate disk to form a titanium palladium intermetallic, Ti_3Pd, reaction layer approximately 40 nm thick. This layer may then act as a diffusion barrier to prevent any intermixing of the gold lubricating film and the test disk constituents.

Rhodium was also tested as a potential diffusion barrier. It may function well because its high melting temperature, approximately 2000 °C, leads to low homologous temperatures during use. Thus, a rhodium layer may inhibit thermally activated or enhanced diffusion.

Test samples were prepared by sputter depositing 150 nm of rhodium onto heat treatment coupons and wear disks. A 150 nm gold lubricant film was then sputter deposited over the rhodium.

EXPERIMENTS/APPARATUS

A pin-on-disk apparatus was used in this study to evaluate the candidate seal materials and the lubrication methods proposed. In these experiments, a metal pin was covered with the fabric to be tested and loaded against the Ti_3Al-Nb disk by means of deadweights. The fabric was fastened to the pin with a wire loop clamp which rested in a machined groove in the outside diameter of the pin (Fig. 5). The pin had a 25.4 mm radius and a 3.2 mm diameter flat spot on its tip.

The sliding velocity for these tests was 0.27 m/sec. The applied load to the pin was 270 g which gives a nominal contact pressure between the fabric and the disk of about 340 kPa (50 psi). The atmosphere during these tests was air with a relative humidity of 35 percent at 25 °C. The maximum temperature for the tests was 700 °C. This temperature is considered the maximum use temperature for Ti_3Al-Nb, above which it oxidizes severely.

Prior to each test, the unlubricated polished disks were cleaned with ethyl alcohol, lightly scrubbed with levigated alumina, rinsed with deionized water and dried. The lubricated disks were not treated after lubricant deposition. After the specimens were loaded, the test chamber was purged with the test gas for 10 min before testing was begun.

The total test duration was 1 hr. The specimens were slid for the first 20 min at room temperature then slid during 10 min heating period to 700 °C. They were then slid for 10 min at 700 °C and then slid for the final 20 min during cooling to 25 °C. Selected specimens were tested twice to ascertain tribological behavior after repeated test temperature cycles.

RESULTS

Table II summarizes the friction and wear data. Although the friction coefficient for the unlubricated specimens was 0.30±0.03 during the initial room temperature sliding it increased further into the test. The uncertainties represent typical data scatter during the tests. Generally, at least two repeat tests were performed for each material combination. At higher temperatures, the friction was higher. Figure 6 is a plot of the friction coefficient versus test temperature for a set of these specimens. At 700 °C, the friction coefficient was 1.5±0.2. Upon cooling, the friction coefficient decreased only slightly to 1.3±0.2. Repeated test temperature cycling produced friction coefficients between 1.3 and 1.5±0.2. Severe fiber breakage (more than 100 fibers broken in a single weave bundle) occurred during these tests.

The results for the gold coated fabric sliding on the unlubricated disk are presented in Fig. 7. Again, the friction coefficient was low at 0.37±0.03 initially at room temperature. However, upon heating, the friction increased to 1.3±0.2 at 700 °C. When cooled to room temperature again, the friction decreased slightly to 1.0±0.2 (Fig. 7). Therefore no significant benefit was obtained by applying the sputtered gold to the fabric when slid against the intermetallic. Severe fiber breakage occurred during these tests.

When the gold sputter coated disk was slid against the bare fabric, the friction coefficient was initially low at room temperature 0.20±0.03. Like previous tests, at 700 °C, the friction coefficient was high, 1.4±0.2 (Fig. 8). Upon cooling, the friction increased slightly to 1.8±0.1 between 200 and 400 °C but then decreased to 0.9±0.1 at 25 °C. Moderate, but unacceptable, fiber breakage (between 40 and 100 fibers broken in a single weave bundle) occurred. It was observed that the gold on the wear track of the disk was wiped off by the fabric after only a few minutes of sliding which indicated poor adhesion of the sputtered film to the disk.

The friction for the disk, ion plated with the gold film, was low at room temperature, 0.20±0.05. Upon heating, the friction coefficient remained low, 0.20, and the wear track remained gold in color until the specimens were heated to 400 °C. At this temperature the friction began to increase sharply and the disk surface became dark brown in color. After 4 min of sliding above 400 °C, the fabric failed completely, allowing the stainless steel pin to slide against the intermetallic disk. The tests were terminated at this point. Visual observation of the disk surface showed that the ion plated gold film was no longer visible even outside the wear track.

The intermetallic specimen coated with the palladium and the gold films failed the furnace heat treatment test. Although good adhesion of the films was obtained, the specimens suffered severe diffusion when heated above 400 °C. After they were heated to 700 °C, an x-ray photoelectron spectroscopy (XPS) depth profile was performed which indicated that the surface was primarily aluminum (2p peak) with small amounts of titanium ($2p^{3/2}$ peak). These were probably in the form of oxides since oxygen was also detected (Fig. 9). Neither of these oxides is a good lubricant. Therefore no tribotest specimens with palladium/gold films were tested.

The heat treatment coupons coated with rhodium and gold did not fail the static heat treatment test. At 400 °C, the gold surface remained visibly yellow. After 2 hr at 700 °C the surface had become violet in color but remained smooth and shiny. A post heat treatment XPS depth profile, shown in Fig. 10, indicates that the outermost surface layer was a thin film of rhodium ($3d^{5/2}$ peak), presumably the oxide. Under this layer was a much thicker layer of gold and titanium, aluminum and oxygen. Under this layer was a rhodium rich layer. Figure 11 shows a sketch of the layered structure following the heat treatment.

Because the near surface region contained significant gold and had a smooth surface it could provide lubrication to the fabric. Therefore, tribotest disk specimens were prepared tested.

The friction coefficient for the rhodium/gold film was initially low, 0.20±0.05. The friction remained low until the test temperature reached 500 °C. Then the friction increased. At 700 °C, the friction coefficient was 1.0±0.1. Upon cooling to room temperature, it decreased to 0.6±0.1. The general shape of the friction graph is similar to Fig. 8. After testing, the disk surface was smooth and shiny in appearance and had a violet color similar to the heat treatment sample. The fabric damage during these tests was mild (less than 40 fibers in any single bundle were broken) and is considered acceptable.

DISCUSSION

It was hoped that the bare fabric sliding against the Ti_3Al-Nb intermetallic would show good tribological properties. This result, however, was not obtained. In fact, the lubrication treatments tested here, such as sputter deposited gold films, which markedly improved the properties of fabric/

superalloy sliding couples studied previously (Ref. 7) were not at all successful for the intermetallic disks.

The reason for this behavior, or at least a partial justification for it, can be understood by noting that the major constituent of the intermetallic is titanium. Titanium has traditionally been very difficult to lubricate, even when sliding under mild conditions such as room temperature in oils and greases (Ref. 8).

The naturally occurring passivating film on titanium is a form of rutile, TiO_2, which can prevent good bonding between lubricant films and the underlying metal. If an intermediate lubricant film is to function well, it must bond to both rubbing surfaces and be easily shearable to allow for low friction and wear. If this bonding does not occur, as is the case here, the film will not function and the surfaces will not be lubricated. This may be one reason why the intermetallic is difficult to lubricate in these tests.

Another reason is that the surface of the intermetallic becomes rough when it oxidizes, which may increase the friction and wear. The surface finish of the polished disks was 0.1 μm rms and the oxide film which develops during testing or static heating had a surface finish of 0.4 μm rms. Therefore, during sliding, rough oxide "asperities" may be grabbing at and breaking the individual fibers which may lead to high friction and fabric damage.

Gold was sputtered onto the fabric surface as a solid film lubricant. Since the gold does not adhere to the oxide layer on the Ti_3Al-Nb surface it did not transfer from the fabric to this surface and, hence, did not lubricate well. EDS analysis of the wear specimens after sliding indicated that no gold had transferred to the disk surface. Visual examination showed that most of the gold which had been sputtered onto the fabric had been worn off during sliding. Clearly, sputtering gold onto the fabric is not a good lubrication method.

To encourage the development of a good lubricating film, gold was next sputtered onto the polished intermetallic disk surface. By doing this, a larger volume of gold is present over the entire disk sliding area instead of only over the small pin area as was the case previously. It was hoped that by having a larger gold wear volume available, longer wear lives would be achieved. This lubrication method, however, was also unsuccessful. After only a few minutes of sliding, the pin fabric had wiped the gold off of the disk surface. This indicated that there was again a very poor bond between the gold and the substrate.

To achieve better bonding, a more energetic form of coating, ion plating, was tried. The test results were interesting but not tribologically successful. At room temperature, the friction coefficient was very low. The gold film remained in the wear track on the disk and the friction remained low until the specimens were heated to 400 °C. As previously stated, at 400 °C, the shiny gold film on the track turned brown and dull and the friction increased an order of magnitude.

EDS x-ray analysis of the ion plated specimen after testing, shown in Fig. 12, indicated that the surface had a very high concentration level of titanium and aluminum and a low concentration level of gold. When the surface was scraped with a razor blade and then re-analyzed, the gold level increased as shown in Fig. 13. This indicated that a surface film , probably rich in titanium dioxide, was present which covered the gold lubricating film. Since no chemical reaction between gold and the intermetallic was found in the literature, it was concluded that the gold and the intermetallic were interacting through gross diffusion at elevated temperatures. It is believed that the sputter deposited gold films did not exhibit obvious diffusion effects because the metal substrate was not sputter etched prior to gold deposition.

Therefore an oxide film separated the gold from the intermetallic substrate. Although the oxide film present at the surface prevents good coating adherence, it also acts as a diffusion barrier.

Poate et al. (Ref. 6) studied the interdiffusion of gold and titanium films at elevated temperatures. They found that in air, the diffusion of titanium through gold was very rapid above 400 °C. The titanium diffuses through the grain boundaries of the gold and oxidizes when it contacts the air. This oxidation process uses up free titanium at the gold/air interface creating a chemical sink for free titanium which helps to enhance the diffusion process. They estimate that the oxide layer grows to be about 40 nm thick before the process is slowed.

The observations of Poate et al. (Ref. 6) agree with the results of the tribotests. At room temperature, the friction is low because the fabric is sliding on a gold film. At 400 °C, the titanium diffuses through the gold and the surface film becomes a rough, thin oxide which does not provide lubrication. Therefore, the friction increases and the fabric fails. Clearly, a diffusion barrier as well as a lubricant film is needed.

Only the ion plated gold film experienced this diffusion problem. Since the sputtering of gold onto the disk surface was done without presputter cleaning, the sputtered gold film was actually applied over an oxide layer which prevented titanium diffusion yet also prevented good adhesion.

One attempt to achieve both diffusion inhibition and lubrication was to use a palladium diffusion barrier under the sputtered or ion plated gold film. This procedure failed. Like the ion plated gold films, the specimens suffered severe diffusion when heated above 400 °C in a furnace. After a heat treatment to 700 °C, an x-ray photoelectron spectroscopy (XPS) depth profile was done which indicated that the surface was primarily aluminum oxide with some titanium oxide (Fig. 9). Neither of these oxides is a good lubricant. Thus, a better diffusion barrier was needed.

One reason why the Pd film failed may be that gold and palladium can form solid solutions, especially at elevated temperatures. Thus, when the specimens were heated, the gold and palladium intermixed allowing gold and the substrate to interact. Clearly a successful diffusion barrier will be one that does not form solid solutions with either gold or the Ti_3Al-Nb substrate.

Rhodium was chosen as a diffusion barrier because its high melting temperature (~2000 °C) leads to low homologous temperatures during use which may hinder diffusional processes. Also, gold and rhodium form no solid solutions with one another even up to 1000 °C.

There was no discernible interdiffusion of the rhodium/gold films during the heat treatment tests until the temperature reached 700 °C. At 700 °C, a violet film covered the surface. The surface, however, remained smooth. After the treatment, an XPS depth profile was performed. Figure 10 shows the results. The surface layer was a thin film of rhodium (presumably the oxide) under which was a thicker gold layer with significant amounts of titanium and aluminum and oxygen. Under this layer was a rhodium rich layer with aluminum, titanium and oxygen (Fig. 11). Although the lubricating film suffered some diffusion, because the surface region still contained significant gold and had a smooth surface finish it did provide some lubrication to the fabric.

Though the friction for the rhodium/gold film increased following the heating cycle, the fabric sustained no significant fiber breakage, probably because the smooth surface had no rough asperities to "grab" at individual fibers. This result is very encouraging because it suggests a long useful life for the seal materials. The high friction is not encouraging but can be accounted for in the final seal design (i.e., pressure balancing the seal to reduce the applied load and thus reduce the actuation forces).

It is clear from these tests that the mechanical properties, such as the friction coefficient and fiber fracture, of the candidate seal materials are important. When the test temperature is high, however, the chemistry and diffusion properties of the candidate materials must also be considered.

The final recommendation to the seal designers is as follows. If Ti_3Al-Nb is chosen as a counterface material it must be protected from oxidation by a diffusion barrier layer such as rhodium over which is applied a gold lubricating film. Also, after the exact seal loads, temperatures and environment is known (i.e., after a test engine has been fired), the optimization of lubricant coating techniques and thicknesses must be done to ensure the best possible tribological results.

CONCLUSIONS

1. The friction coefficient and the fabric wear for the unlubricated Ti_3Al-Nb intermetallic disks are unacceptably high.

2. Sputtered gold films do not adhere well to the intermetallic unless the surface is sputter etched prior to gold deposition.

3. The ion plated gold films on the intermetallic disks provided effective lubrication only at room temperature. At elevated temperatures, diffusion of the substrate constituents through the gold severely reduced its lubrication effectiveness.

4. The gold films on the Ti_3Al-Nb intermetallic disks are able to provide lubrication only when a rhodium diffusion barrier is applied prior to gold deposition. The rhodium prevents gross substrate oxidation and help to maintain smooth sliding surfaces to prevent fiber breakage.

5. Successful diffusion barriers will not only prevent substrate oxidation but also prevent intermixing of the lubricant and the substrate and the lubricant and the barrier.

REFERENCES

1. R.I. Jaffe, R.A. Perkins, and G.M. Pound, in High Temperature Oxidation Resistant Coatings (National Academy of Sciences, NACE, Washington, D.C., 1970), pp. 141-158.
2. B.M. Steinetz, C. DellaCorte, and P. Sirocky, "On the Development of Hypersonic Engine Seals," NASA TP-2854, Aug. 1988.
3. P.M. Swako, and H.K. Tran, SAMPE Quart., **17**, 7-13, (1985).
4. P.K. Brindley, in High-Temperature Ordered Intermetallic Alloys II; Proceedings of the Second Symposium, Boston, MA, Dec. 2-4, 1986 (Materials Research Society, Pittsburgh, PA, 1987), pp. 419-424.
5. T. Spalvins, "Plasma Deposition and Surface Modifications for Wear Resistance," NASA TM-82972, 1982.
6. J.M. Poate, K.N. Tu, and J.W. Mayer, Thin Films-Interdiffusion and Reactions (Thermochemical Society, Princeton, New Jersey, 1978), pp. 341-355.
7. C. DellaCorte, "Tribological Properties of Alumina-Boria-Silicate Fabric from 25 to 850 °C," NASA TM-100806, 1988.
8. E.R. Braithwaite, Solid Lubricants and Surfaces (The MacMillan Co., New York, 1964), p. 229.

TABLE I. - SPUTTER DEPOSITION PARAMETERS

Coating material	Thickness, nm	Sputtering time, min	Power, kW	Argon flowrate, cc/min	Chamber pressure, mtorr
Rh	150	12.5	0.20	≈10	10
Pd	50	5.0	.20	≈10	10
Au	150	10.0	.05	≈10	50

TABLE II. - SUMMARY OF Ti_3Al-Nb SLIDING AGAINST CERAMIC FABRIC

[Note: Extent of fiber breakage: Severe; more than 100 broken fibers in one bundle. Moderate; more than 40 but less than 100 broken fibers in one bundle. Mild; less than 30 to 40 broken fibers in one bundle.]

Fabric coating or lubricant treatment	Disk coating or lubricant treatment	Final friction coefficient		Fiber breakage	Comments
		25 °C	700 °C		
None	None	1.3±0.2	1.3±0.2	Severe	No material transfer
150 nm Au film (sputtered)	None	1.0±0.2	1.3±0.1	Severe	No Au transfer to disk
None	150 nm Au film (sputtered)	1.8±0.1	1.4±0.2	Moderate	Poor Au adhesion to disk
None	150 nm Au film (ion plated)	0.20±0.05 (initial value)	Test terminated at 450 °C	Severe	Fabric failed. Tested only to 450 °C
None	150 nm Rh film over 150 nm Au film (sputtered)	0.6±0.1	1.0±0.1	Mild	Smooth final surface

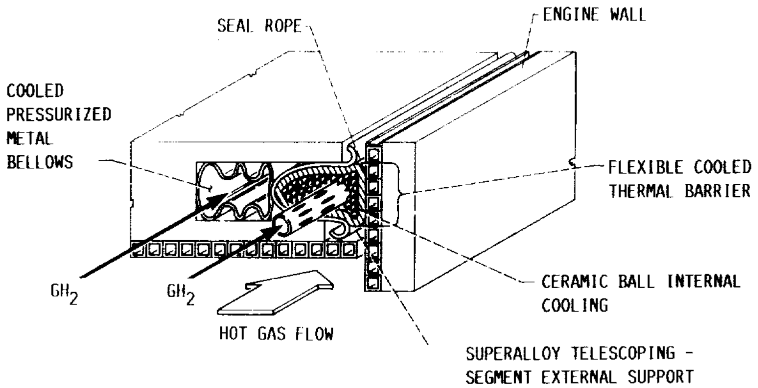

FIGURE 1. - CROSS SECTION OF PROPOSED ENGINE SEAL.

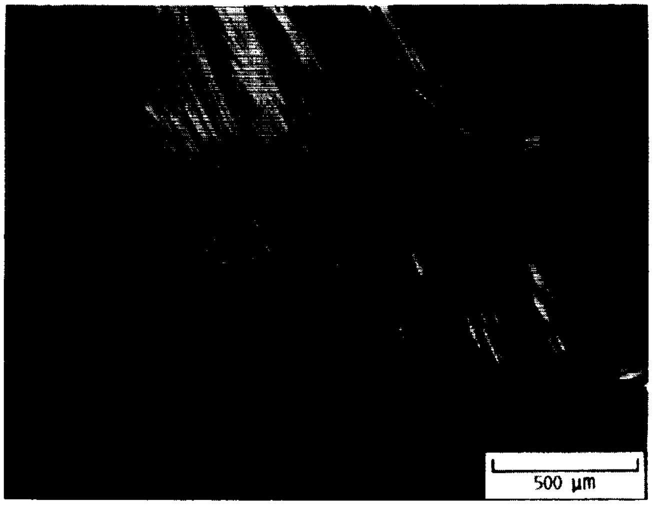

FIGURE 2. - VIRGIN FABRIC BUNDLES.

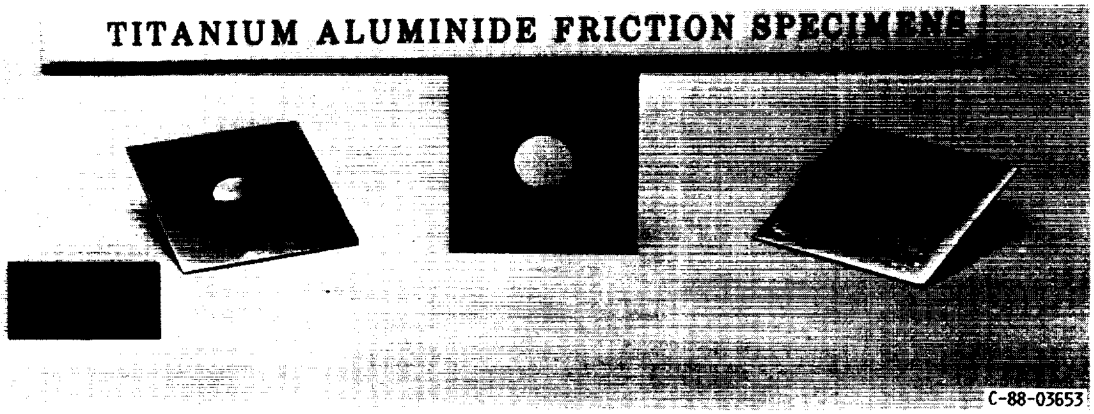

FIGURE 3. - Ti_3Al-Nb INTERMETALLIC TEST DISKS.

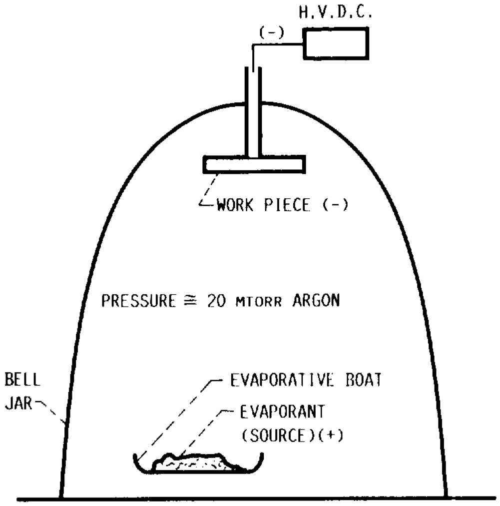

FIGURE 4. - ION PLATING.

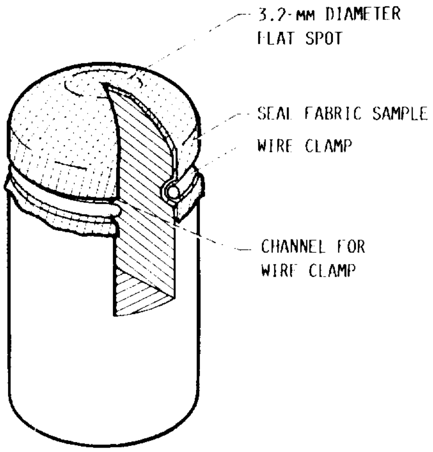

FIGURE 5. - PIN TEST SPECIMEN.

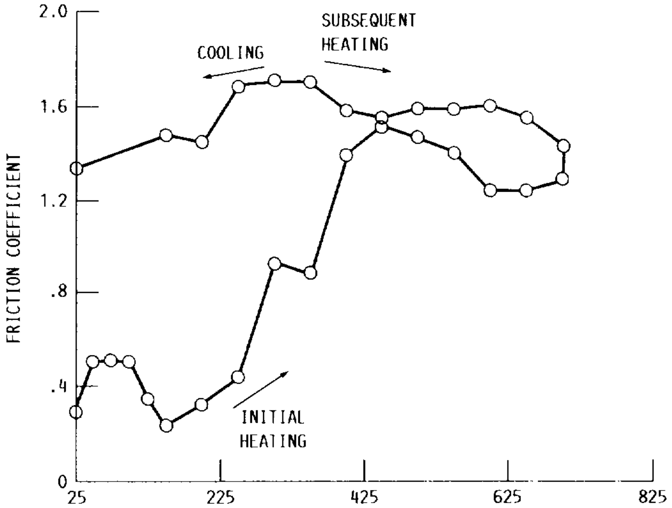

FIGURE 6. - FRICTION COEFFICIENT FOR FABRIC SLIDING AGAINST Ti_3Al-Nb INTERMETALLIC DISK. AIR ATMOSPHERE, 0.27 kg LOAD, 0.27 m/s SLIDING VELOCITY.

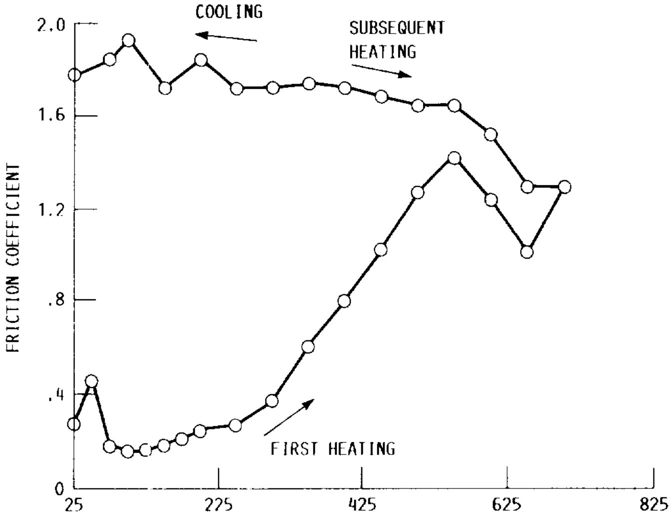

FIGURE 7. - FRICTION COEFFICIENT FOR THE FABRIC COATED WITH 150 nm GOLD WHEN SLIDING AGAINST THE Ti_3Al-Nb INTERMALLIC DISK. AIR ATMOSPHERE, 0.27 kg LOAD, 0.27 m/s SLIDING VELOCITY.

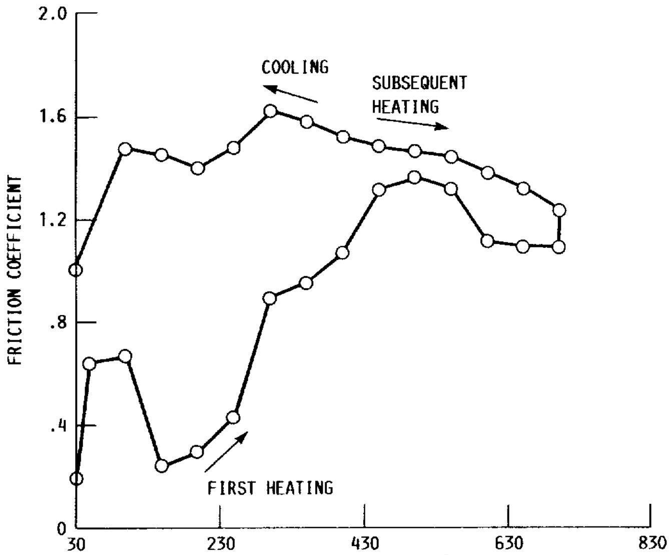

FIGURE 8. - FRICTION COEFFICIENT FOR FABRIC SLIDING AGAINST A GOLD COATED Ti_3Al-Nb DISK. AIR ATMOSPHERE, 0.27 kg LOAD, 0.27 m/s SLIDING VELOCITY.

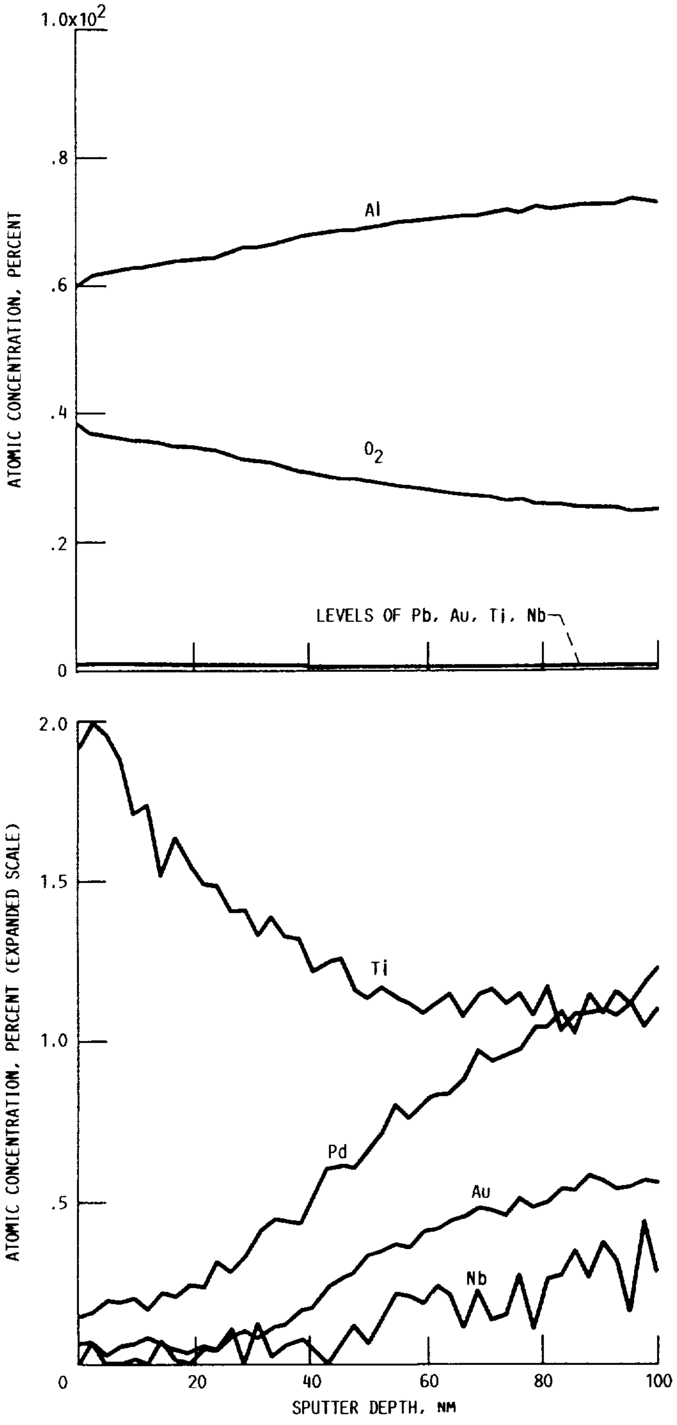

FIGURE 9. - XPS DEPTH PROFILE RESULTS OF HEAT TREATED INTERMETALLIC WHICH WAS COATED WITH 50 NM PALADIUM AND 100 NM OF GOLD.

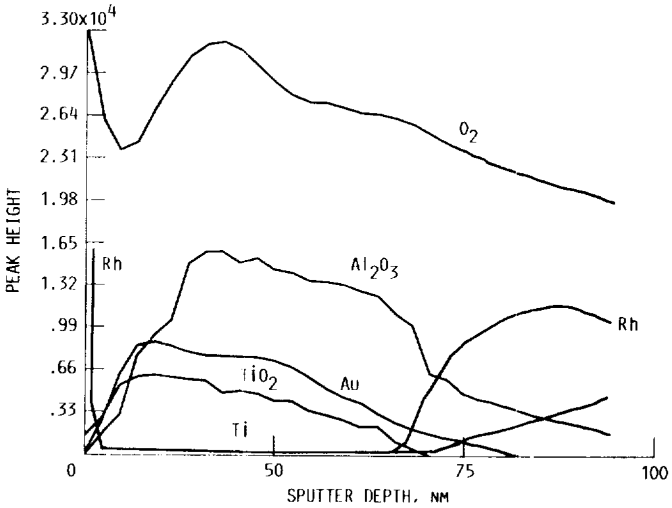

FIGURE 10. - XPS DEPTH PROFILE OF HEAT TREATED INTERMETALLIC SPECIMEN COATED WITH 50 NM RHODIUM AND 100 NM OF GOLD.

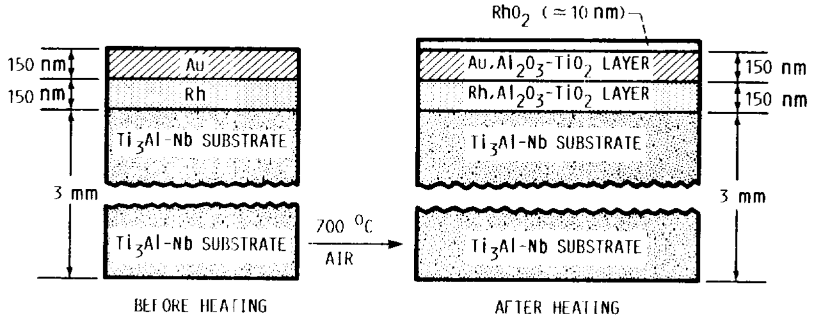

FIGURE 11. - MODEL OF INTERMETALLIC FILM LAYER COMPOSITION BEFORE AND AFTER HEAT TREATMENT IN AIR AT 700 °C.

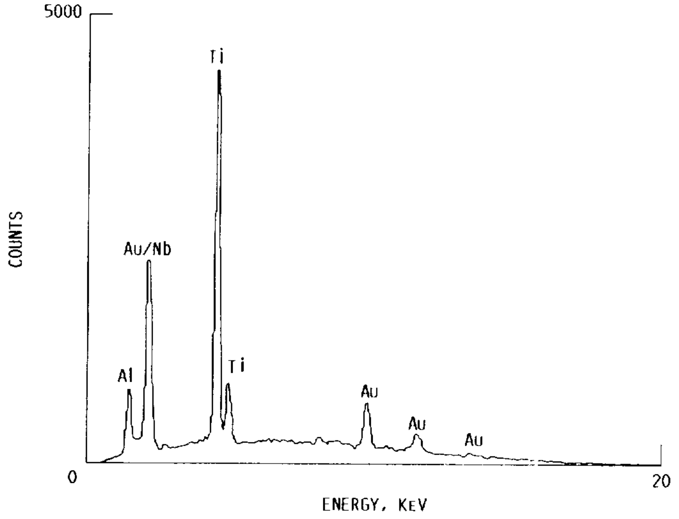

FIGURE 12. - EDS X-RAY SPECTRUM OF Ti_3Al-Nb DISK ION PLATED WITH GOLD AND SLID AGAINST FABRIC AT 700 °C. NO POST TEST SURFACE PREPARATION MADE PRIOR TO ANALYSIS.

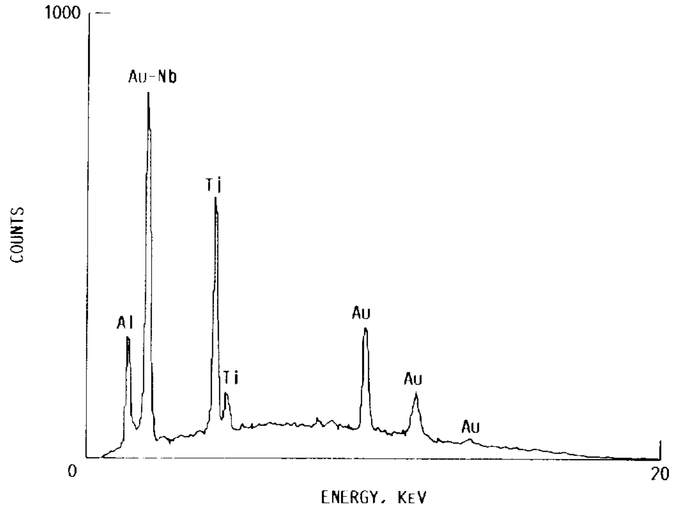

FIGURE 13. - EDS X-RAY SPECTRUM OF Ti_3Al-Nb DISK ION PLATED WITH GOLD AFTER SLIDING AGAINST FABRIC AT 700 °C. SURFACE SCRAPED PRIOR TO ANALYSIS.

NASA
National Aeronautics and
Space Administration

Report Documentation Page

1. Report No. NASA TM-102401	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle

Tribological Properties of Ceramic/Ti_3Al-Nb Sliding Couples for Use as Candidate Seal Materials to 700 °C

5. Report Date

6. Performing Organization Code

7. Author(s)

Christopher DellaCorte, Bruce M. Steinetz, and Pamela K. Brindley

8. Performing Organization Report No.

E-5048

10. Work Unit No.

505-63-1A

9. Performing Organization Name and Address

National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135-3191

11. Contract or Grant No.

13. Type of Report and Period Covered

Technical Memorandum

12. Sponsoring Agency Name and Address

National Aeronautics and Space Administration
Washington, D.C. 20546-0001

14. Sponsoring Agency Code

15. Supplementary Notes

Prepared for the International Conference on Metallurgical Coatings sponsored by the American Vacuum Society, San Diego, California, April 2-6, 1990.

16. Abstract

Tribological properties of Ti_3Al-Nb intermetallic disks sliding against alumina-boria-silicate fabric were ascertained in air at temperatures from 25 to 700 °C. These materials are candidates for sliding seal applications for the National AeroSpace Plane. The tests were done using a pin on disk tribometer. Sliding was unidirectional at 0.27 m/sec under a nominal contact stress of 340 kPa. Gold sputter or ion plating deposited films were used to reduce friction and wear. Rhodium and palladium films were used beneath the gold lubricating films to prevent diffusion of the substrate into the gold at high temperature. The friction and wear of the unlubricated specimens was unacceptable. Friction coefficients were generally greater than 1.0. The ion plated gold films, when used with a rhodium diffusion barrier reduced friction by almost a factor of 2. Wear was also substantially reduced. The sputter deposited films were not adherent unless the substrate was sputter cleaned immediately prior to film deposition. Palladium did not function as a diffusion barrier.

17. Key Words (Suggested by Author(s)) Tribology; High temperature; Friction; Wear; Ceramics; Titanium aluminide; Lubrication	18. Distribution Statement Unclassified – Unlimited Subject Category 23

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No of pages 20	22. Price* A03

NASA FORM 1626 OCT 86

*For sale by the National Technical Information Service, Springfield, Virginia 22161