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CHARACTERIZATION OF THE STRUCTURE AND PROPERTIES OF VARIOUS METALLIC AND NONMETALLIC MATERIALS

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TECHNICAL REPORT AFML-TR-77-232
Final Report for Period 1 April 1974 – 30 April 1977

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AIR FORCE MATERIALS LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

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This technical report has been reviewed and is approved for publication.

Terry L. Bartel

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The research covered herein was performed to (1) Establish the microstructures and intrinsic properties characteristic of materials with enhanced use performance and the capability of reliably and predictably retaining this performance in aerospace systems applications, and (2) Obtain information about microstructural and property parameters associated with the achievement of improvements in structural strength and stability through the characterization of materials from AFML in-house investigations. The principal techniques	

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employed in this characterization included optical, electron and scanning electron microscopy, x-ray analysis, electron microprobe analysis and numerous physical test methods. Sample preparation, including forming, heat treatment, grinding, polishing and etching, was required and represented a substantial part of the effort. Much of the program was directed toward the study of the structure and properties of titanium and aluminum alloys.

FOREWORD

This report was prepared by Monsanto Research Corporation under United States Air Force Contract F33615-74-C-5068, "Characterization of the Structure and Properties of Various Metallic and Nonmetallic Materials". The work was administered under the direction of the Air Force Materials Laboratory, Wright-Patterson Air Force Base, Ohio, with Mr. Oscar Srp and, later in the program, Captain T. L. Bartel as Project Engineer.

Beginning in early 1976, the contractual obligations of Monsanto Research Corporation at Wright-Patterson Air Force Base began to be transferred to Systems Research Laboratories, Inc., 2800 Indian Ripple Road, Dayton, Ohio 45440, under subcontract. All staffing was provided by Systems Research Laboratories, under subcontract, by mid-year 1976 and continued in this fashion until completion.

This is the final technical report for the contract. It summarizes work carried out at the Materials Laboratory of Wright-Patterson Air Force Base during the period 1 April 1974 - 30 April 1977. The last four months of the program was an extension of the original contract period. Accordingly, this report also represents the accounting of results for the last quarter of 1976 and the first quarter 1977. For this reason, it consists primarily of the more recent accounts of work performed and reported to Monsanto Research Corporation by Systems Research Laboratories, Inc., under the technical supervision of Mr. A. G. Jackson and the administrative supervision of Mr. W. C. Tripp.

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INTRODUCTION

The rapid advance in materials technology over the past decade has been catalyzed by corresponding advances in techniques for characterizing the surface and bulk properties of materials. A knowledgeable and efficient materials exploratory development program must be built upon quantitative characterization and thorough analysis of performance evaluation results from experimental materials. The Air Force Materials Laboratory, recognizing this necessity, established a contractor-supported program for materials characterization and evaluation at their laboratories at Wright-Patterson Air Force Base. Monsanto Research Corporation, and subsequently Systems Research Laboratories, Inc., under subcontract to Monsanto Research Corporation, performed this program under Contract F33615-74-C-5068.

The organization of effort under the contract was accomplished by placing a Monsanto Research Corporation research team on a full-time basis in the Materials Laboratory at WPAFB. Dr. Arthur D. Snyder and, subsequently, Dr. Thomas A. Orofino were the Project Managers and Mr. Russell E. Pence was the Principal Investigator and on-site Group Leader. Other participants included W. J. Hillan, W. A. Houston, A. R, Kiefer, D. E. Kirk, C. E. Lowe, J. M. Raney, G. L. Teeters and J. D. Tobias.

Subcontract personnel from Systems Research Corporation later maintained with or assigned to this program and their areas of expertise were as follows: Mr. A. G. Jackson (Principal Investigator) - Scanning Electron Microscopy, Mr. R. E. Omlor - Transmission Electron Microscopy, Mr. G. L. Teeters - Metallography, Mr. M. B. Strope - electron Probe Microanalysis (EPMA), Mr. R. D. Brodecki - Photography, Mr. G. R. Cornish - Metallography, and Mr. R. C. Elder - Quantitative Metallography. The high level of performance and quality of work produced by this staff is gratefully acknowledged.

TRANSMISSION ELECTRON MICROSCOPY

Transmission electron microscopy (TEM) was utilized throughout this program to further understand the microstructure of titanium alloys, aluminum alloys, and various other materials of interest. Replica studies were made for identification of microstructure and grain boundary constituents resulting from various thermal and mechanical treatments.

In the period April 1974 - March 1975, 1588 TEM plates were made and from April 1975 - March 1976, 1234. During an especially active period from October 1976 - April 1977, 1670 TEM plates were developed and 6026 4" x 5" prints were made.

A partial list of projects on alloys and other materials studied during this contract includes:

1) The TEM was used to study Si_3N_4 specimens to compare grain size, second phase particles and porosity resulting from various processing parameters. Nickel steel specimens were observed for grain boundary precipitate by both replica and thin foil techniques.

2) Oxidation studies were made on several aluminum specimens using the high resolution attachment. These specimens were oxidized under controlled laboratory conditions and diffraction measurements made to compare the various oxides formed under these controlled conditions.

3) An attempt to understand the pre-failure behavior of metals was made on a nickel base super alloy. The gage length of tensile specimens was polished and etched prior to placement in the test machine. These polished specimens were pulled and the test momentarily held at various load levels for replication of the surface. The replicas were catalogued for later observation. Examination of the replicas showed deformation of the base metal and a more dramatic effect of preliminary cracking which occurred in the carbide particles present in the microstructure.

4) Studies were made on fatigued 7075 Al alloys, with special interest directed towards dislocation debris interacting with hardening precipitates. A special technique, described in Methods was developed See Figs. 3 and 4).

5) Studies were made on diffusion bonded and, in some cases, heat-treated Ti-6-2-4-2 and Ti-6-2-4-6 with interest at and away from the bond interface on the structures and substructures which developed (See Figs. 3 and 4) as a result of the bonding process and testing protocols. This program was designed to study turbine blade applications of titanium alloys.

6) Powdered Al alloys were investigated mainly for oxide identification and location in the structure (See Figs. 5 and 6).

7) AF2-1DA tensile specimens pulled at 1400°F for slip studies for engine-life prediction (See Fig. 7).

8) Characterization of fracture surface of titanium alloys using various replication techniques.

Methods

The 7075 Al alloys were prepared using standard electropolishing techniques and photographs were taken. It was decided to electropolish macrosamples and compare standard sample-preparation techniques to the following new technique.

A 2S Al electrode was formed to fit into a beaker. Samples were cut to a 20-mil thickness and 1-in.-square area and were inserted into a 75% methanol and 25% nitric acid solution. Voltage was applied and the sample thinned to the desired thickness. The sample was then electropolished to complete the sample preparation using the Fischione electropolisher (See Fig. 8). TEM micrographs produced from foils prepared using this method show greater clarity of detail, as can be seen by comparing Figs. 1 and 2 with Fig. 9.

AF2-1DA foils were prepared for TEM studies (See Fig. 10). The sample was ground to 3-5 mil thickness. Discs punched from the strip using a standard TEM disc punch were then thinned with a twin-jet electropolisher made by Fischione. Either of two solutions has proved to be effective: 1) 87% methanol, 13% sulfuric acid, and 2) 94% acetic acid, 6% perchloric acid. The sulfuric acid-methanol solution is used at a dc current level of 85-100 mA while the acetic-perchloric solution is used at about 55 mA. The solutions produce substantially equivalent results. Solution (1) requires an operating temperature of -30°C whereas solution (2) can be used at room temperature.

Because of the large number of specimens generated for TEM studies, efforts were initiated to develop a foil polishing technique for Ti and Al alloys using the Minimet polisher. The goal of this program was the development of a rapid specimen preparation technique. Unfortunately, recent TEM problems, primarily humidity and temperature control, have prevented complete evaluation of this technique. Preliminary results were promising with regard to repeatability, uniformity, and speed of preparation of foils.

SCANNING ELECTRON MICROSCOPY

Scanning electron microscopy (SEM) is very applicable to materials characterization because of its large depth of field, high magnification capability, and chemical analysis capability (qualitative and quantitative). The large depth of field (several microns at 5000X) provides resolution of rough topography not attainable with optical techniques. High magnification, up to 50,000X, allows detailed examination of microstructures. Chemical-analysis capability using energy-dispersive x-ray spectrometry yields information on inclusions, grains, grain boundaries, solubility, and diffusion effects.

Specimens for SEM analysis were submitted by a number of branches within AFWAL. The Metals and Ceramics Division was represented by the Processing and High Temperature Materials Branch, the Metals Behavior Branch, Non-Destructive Evaluation Branch, and Structural Metals Branch. Most of the specimens were received from AFML and consisted of tensile fractures, etched and mounted specimens, and several unusual specimens related to wear particles and to adhesive metal surfaces.

A large number of fracture specimens of AF-112 were analyzed for initiation sites and for composition of inclusions found on the fracture surface. Then, additional specimens were analyzed for extrusions resulting from the type of mechanical test applied.

Specimens from aircraft for wear studies were received in the form of Ferrograms (Ref. 1). These specially prepared slides of metallic particles from lubricating oil and hydraulic fluids were analyzed for elemental composition of specific particles and Fig. 11 shows the particles as they appear in the scanning electron microscope. EDS x-ray analysis also was conducted, where the line appears in the figure. The results are shown in Figs. 12 and 13. This technique is useful for determining the location of the source of the particles by identifying the type of alloy which constitutes the particles through its chemical composition. In the example cited, Ti, Mg and Cr also were identified as constituents.

The above are typical examples of efforts conducted in accomplishing the tasks on this program. A complete log of work performed has been submitted separately and is on file in the Structural Metals Branch of AFML.

---

[1] E. R. Bowen and V. C. Wescott, Wear Particle Atlas, Final Report on Contract No. N00156-74-C-1682 (U.S. Naval Air Engineering Center, Lakehurst, New Jersey, July 1976).

ELECTRON PROBE MICROANALYSIS

The Etec Autoprobe for electron probe microanalysis was put into operation in AFML early in this contract period, replacing the older Philips unit. The Autoprobe includes scanning microscope capabilities, thus making possible secondary, back-scattered, and sample current observations, along with x-ray mapping and the ability to make spot or step-scan analysis with strip chart or teletype data collection.

Work done with the instrument in the 1975-1976 period included:

1) Examination of diffusion couples of Ti-Ti/Mo by step-scanning across the couple to be used in determining the diffusion rate of Mo.

2) Examination of oxide particles in Ti fracture defects.

3) Inclusion studies of Fe and Cu in 7075 aluminum alloys.

4) Identification of foreign material on electrode posts of failed microswitches.

5) Identification of brazing alloys used in titanium joints.

6) Examination of Ti powders for thermal battery applications.

During the period October 1976 - April 1977, 275 specimens were examined in the electron microprobe, despite the fact that equipment problems caused six weeks of down time during that period. About 1,300 photographs were taken to record microprobe images and x-ray data.

The following are short summaries of some of the areas of work:

1) A series of welds was made in βIII Ti alloys. The microprobe was used to characterize these welds as to cell size, elemental segregation, and porosity. Correlation of these data with welding conditions aids in the determination of optimum welding conditions.

2) Forty Ti alloy specimens were examined for Y_2O_3 distribution. Because of the large difference in average atomic number between Ti and Y_2O_3, the back-scattered electron-imaging technique was ideally suited for this effort (See Fig. 14).

3) For studies of structure and homogenity in IN-100 and other Ni-base alloys, a good etching method was required to reveal microstructure. The microprobe SEM capability was used for evaluation of the etch quality of many specimens through relative comparisons of the topographical feature of each (See Fig. 15).

4) The microprobe was used for several specimens of combusted Ti alloys to examine the oxide layer for elements present. The elements found were Ti, Al, Sn, Zr, V, and Cr. This program of examination by microprobe was quite extensive and required special specimen mounts to be set up to collect the Ti during combustion (See Figs. 16 and 17).

5) Figure 18 is just one of a series of SEM photographs used for characterization of copper powders to determine surface features, general topography, etching, shape, and size.

Many more specimens were examined by the microprobe technique. A tally of requests made through the period of this contract is given in Table 1.

When used for thermal applications, the interest in characterization of powders is to determine those properties related to burning rate and calorie output. For other applications, such as extrusion, characterization is used to determine those properties affecting the reduction parameters of the extrudate.

METALLOGRAPHY AND PHOTOGRAPHY LABORATORIES

The tasks in the metallography laboratory throughout the course of this contract were primarily concerned with preparation and evaluation of various Ti and Al alloys. Preparation included cutting, grinding, polishing and use of specific etches to reveal microstructures. The types of samples submitted included compact tension, charpy, tensile and various types of small samples cut from alloys for metallographic evaluation. Alloys submitted included AF-115, AF2-1DA, Ti-6-2-4-2, Ti-6-4, Ti-8-1-1, Ti-5.5-2-2-5, 7075-T73 Al, Al (MA87) powder, IN-100, Ni-base superalloys, and 7075 Al powder.

Other tasks performed consisted of heat treating Ti and Al alloys in vacuum and air furnaces, routine maintenance of equipment, and inventory control of equipment and instrumentation assigned to the Characterization Facility.

An example of the type of data produced as shown in Fig. 19 which is a micrograph of an AF-1D2A specimen which has been etched to reveal the grain structure. Figure 20 is an optical micrograph of a Ti-Al diffusion bond in which the region of the bond (center of the figure) can be easily identified. For this type of specimen optical microscopy has proven to be invaluable in reaching an understanding of the microstructure.

One of the special techniques developed during this report period included a method for polishing the test area of large specimens for subsequent examination by laser to study crack tip opening displacement. Numerous attempts at hand-polishing and hand-held devices led to attempts at the modification of a standard polishing wheel wherein an adapter was designed and fabricated to fit the motor drive shaft thus allowing the polishing wheel to operate above the existing table top. This method has produced satisfactory results in both quality of finish and an increase in size of polish area.

During the evaluation of a β-III (beta stabilized) titanium alloy, a dark layer formed on the surface of metallographic specimens when etched by the standard procedure impairing the study of the microstructure. Attempts were made to resolve the structure by both TEM replica studies and SEM examination with little success. A new etching technique was developed as follows: after final polish, the specimen is swabbed with 10% HCl/H_2O and then etched with a solution of 10 ml H_2O_2 and 3 drops of HF for 5 sec. to 60 sec. This method produced very satisfactory results.

An indication of activity in the metallographic area is given by the number of micrographs processed. In the 1974-1975 period, for example, total items processed (prints, plates, and transparencies) averaged about 1050 per month. The corresponding figure for 1975-1976 was 900 per month. Table 2 gives a detailed breakdown of work for the 1976-1977 period.

QUANTITATIVE METALLOGRAPHY

The quantitative metallographic work conducted prior to 1976 was the responsibility of another contractor (University of Cincinnati). Subsequent work, under the present contract, is summarized below. The basic instrument is an optical scanner and counter capable of resolving rather complex patterns, arrays, or photographs of collections of particles in terms of size, shape, number, and distribution.

Area measurements on some forged rings using data obtained from the Quantimet/Epidiascope illustrate applications using this instrument. About 75 rings were measured and compared with those from a number of control (known-area) rings. The faces of the sample rings were very irregular and could not be easily measured by any other immediately available method. The areas of the rings and the holes were determined and compiled according to their size distributions to provide information on the amount of deformation which occurred during forging.

Using the Quantimet/microscope, several Ti samples were examined for percent primary-α present microstructurally. Several micrographs representing other heat treatments were also analyzed for percent primary-α. Results from this study were used to illustrate microstructural differences in supposedly similar samples and to show the effects of different heat treatments upon the otherwise identical samples.

The diameters of several tensile specimens were measured on the Quantimet/Epidiascope and the results compared with those from measurements made using more conventional instruments (e.g., calipers and a tool-maker's microscope). This study indicated that only approximations of diameters can be made from samples with curved surfaces because of large errors which exist in measurement.

Quantitative analyses for Fe and Si precipitates in two Al alloys were also recently completed. The samples were supposedly identical except that one had undergone hot rolling. Using photomicrographs, measurements and calculations were performed to ascertain the following:

1) Volume percent of Fe + Si in the sample
2) Average particle size
3) Particle size distribution

Results indicate that hot rolling causes numerous small particles which appear to contribute to cract propagation in contrast to a few large particles.

A particle analysis of Y_2O_3 in Ti also was completed on over 300 micrographs. The particles were counted and sized using the Particle Size Analyzer TGZ 3 to provide a particle size analysis and distribution of Y_2O_3 in the Ti matrix. Results were tabulated for over 30 groups of pictures.

Effect of Rolling on Ti

The rolling effect on the microsctructure of a number of Ti samples was carefully investigated. A total of 127 samples were measured for thickness and 21 of these were selected for examination. Both longitudinal and transverse samples were mounted, polished, and etched to reveal the microstructure. In addition, selected sections were cut for heat treatment and examined in the same manner. The purpose of this work was to determine sample integrity before and after heat treatment.

Diffusion-Bonded Ti

A Ti-64 alloy which was diffusion bonded and super-plastically formed to a specific shape was examined by metallographic techniques. Four different sections - representing all of the different possible bonding and super-plastically formed areas - were cut, mounted, polished, and examined. The sections were examined microscopically for bond integrity at highly stressed points and low stress areas. The material was also examined for structural inhomogeneities at the sheet interfaces and in the individual sheets themselves. Results from the metallographical study showed little microstructure variance across the sheet interfaces and no distinct bond interface. Little loss of bond integrity appeared except where sectioning of the parent structure had caused excessive stress on the specimen. Two sections that represented the different super-plastically formed areas were prepared for examination to show their changing dimensions. Graphical analysis of the formed areas indicates that the super-plastic forming operation was not uniform.

ENERGY-STRUCTURE INTERACTIONS

In order to meet future Air Force requirements for advanced flight materials, significant advances in nondestructive evaluation of materials must be made. The research in energy-structure interactions done under this contract had as its immediate objective the development of the strong scientific and technological base required for evolution of a new generation of improved methods based on the interaction of quantum acoustic waves or phonons with the molecular structure of a material. The long-range objective is to develop quantum detectors that can be operated in the field with as much as a 10^9 increase in sensitivity over state-of-the-art piezoelectric detectors.

The basic phenomenon under investigation is called ESR, Electron Spin Resonance. Of particular interest is the optical detection of electron spin resonance in zero field in molecules in the excited metastable triplet state. The phenomenon is probably most simply explained through a general discussion of the basic experiment: A sample of some organic molecular crystal such as paradichlorobenzene is "fixed" to an ultrasonic transducer (piezoelectric GHz range). The transducer is driven by a microwave sweep oscillator in the 0.1 to 10 GHz range. The transducer and crystal sample are placed in a cyrogenic Dewar so that the crystal sample is centrally located in a region of the Dewar that has optical (quartz) windows. A high pressure mercury arc lamp, appropriately filtered, is used to excite the crystal sample into the metastable triplet state. A sufficiently low temperature must be maintained and the optical characteristics of the sample region should also be maximized. Therefore, liquid helium is run into this region of the Dewar and pumped on to maintain the helium below the λ point (no bubbles and index of refraction approximately that of quartz windows). When the molecules of the crystal are properly excited, a sustained phosphorescence (in this case a blue glow) is observed on a macro scale.

A spectrometer, with its optical axis situated at a right angle to the arc lamp, is then used to record the spectra of the sample. If the microwave sweep oscillator is swept through a frequency range, the energy of the phonons produced in the transducer and transmitted to the sample will also vary. When phonons with sufficient energy quanta interact with the excited molecules of the crystal sample, some of the electrons in the lower level of the triplet state will jump to a higher level. This will be observed as a change in the optical spectra of the excited sample.

A number of combinations of variables in this interaction can be continuously varied, and also various noise reduction techniques can be used. Transient or pulsed response can also be investigated. Whatever technique is used, the basic resonance phenomenon is still ESR.

Experiments using optically detected acoustic paramagnetic resonance (ODAR) in organic crystal systems were completed. Because of physical constraints the organic system probably will have only limited practical application to the development of a quantum acoustic detector. An inorganic system such as ruby should have greater potential for success, owing to its greater durability and better acoustic properties.

An experimental system which is designed to evaluate the use of ODAR in organic systems has been developed. It differs from previous ODAR systems in that an external magnetic field must be used to lift the system degeneracy. A sample rod with a superconducting magnet incorporated was designed and fabricated, and preliminary experiments undertaken.

A CW acoustic spectroscopy system using an HP-8660C Frequency Synthesizer was successfully interfaced to a Northern Scientific signal analyzer, allowing collection of data for comparison with the computer model developed earlier. Excellent agreement has been obtained for water-tank data at normal incidence. Non-normal incidence studies are currently being examined with particular emphasis being placed upon mode-converted shear-wave attenuation in neat-cast resin.

Hardware development included initial design of a low-input-impedance, low-noise amplifier for an electromagnetic acoustic transducer (EMAT) and preliminary studies of psuedo-random binary noise and correlation techniques for use in an alternative approach to pulse-echo ultrasonic techniques.

CONCLUSIONS

The systematic characterization of the structure and properties of advanced materials is a continuing effort. Many of the tasks summarized in this report have not been completed due to the nature of the research and additional effort will be required before valid conclusions can be drawn.

It can be stated, however, that characterization is an essential part of all experiments on materials as evidenced by the wide variety of specimens examined in this effort -- fracture, tensile, compression, heat-treated, corroded, etched, and polished specimens. Examination and analyses require expertise in the application of the sophisticated techniques of electron optics and optical microscopy, as well as in experimentation using these techniques.

As the demands of the Air Force for higher-performance materials increase, the requirements for materials characterization on a very sophisticated level increase as well. For these efforts, competent personnel and sophisticated instrumentation will be required to find answers to questions related to materials performance.

APPENDIX

(Figures and Tables)

Figure 1. 7075 Al Alloy Fatigue. Dark Band is Dislocation Debris. 57,000x

Figure 2. 7075 Al Alloy. Dark Band is Dislocation Debris. 30,000x

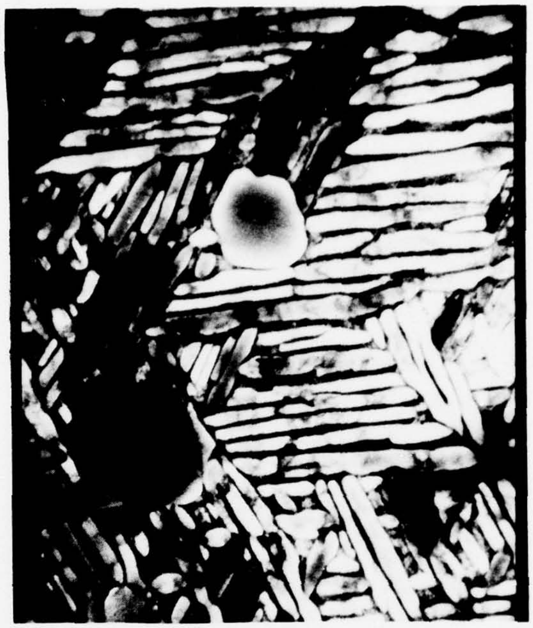


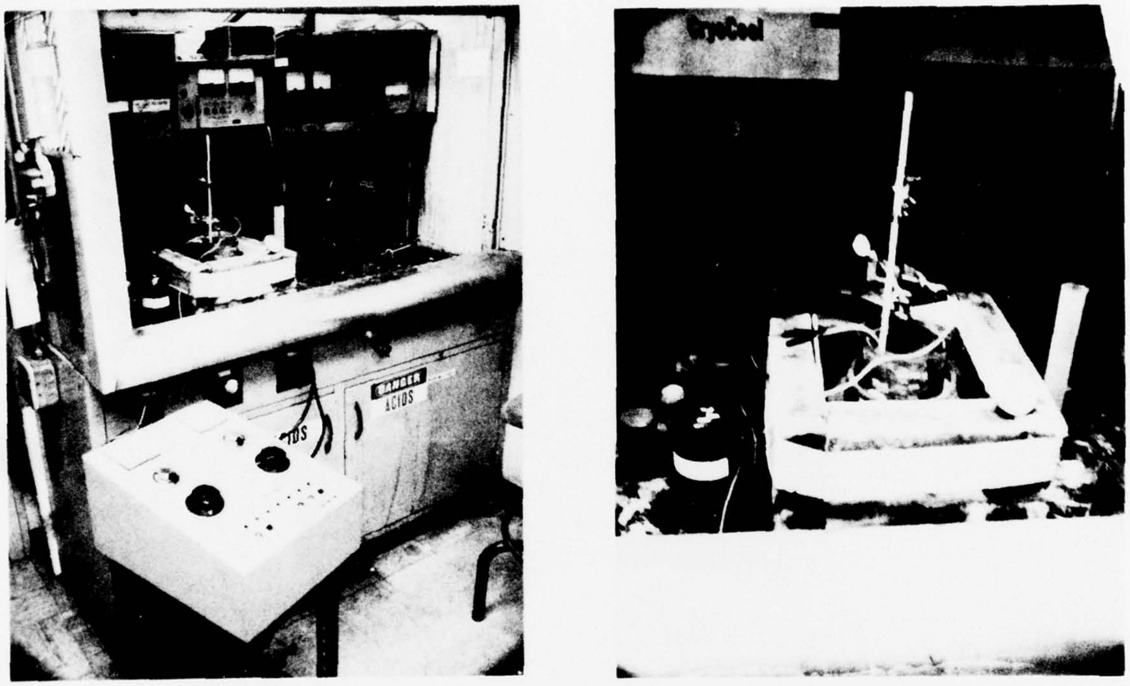
Figure 3. α- and β-Structure of Ti-6-2-4-2. 2,500x

Figure 4. Same as Fig. 3, But With Magnification of Acicular Grain. 32,750x

Figure 5. Powdered Al Alloy. Grain Boundary and Cobalt Precipitates Shown. 23,500x

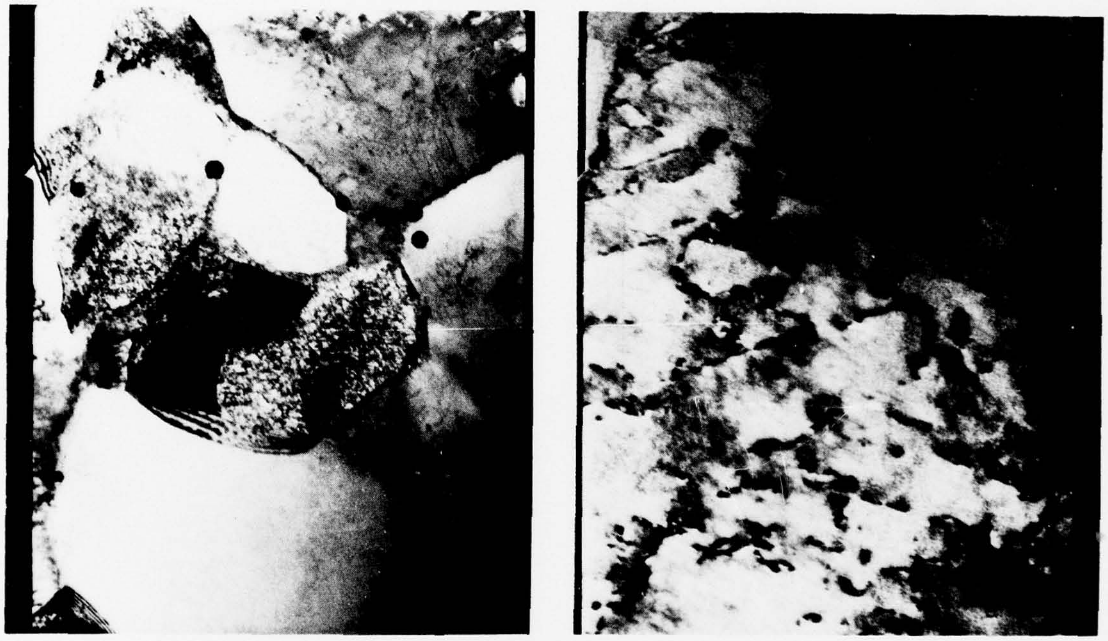
Figure 6. Longitudinal Specimen Showing Oxide Stringers. 12,000x

Figure 7. Replica of Superalloy AF2-1DA Showing Slip Plane. 12,000x



(a) (b)

Figure 8. Experimental Setup for Thinning of Foils



(a) 5,000x

(b) 30,000x

Figure 9. Foil Prepared Using Method Described in Text. Features are Sharper and More Pronounced.

Figure 10. AF2-1DA. Microstructure of γ. 35,500x

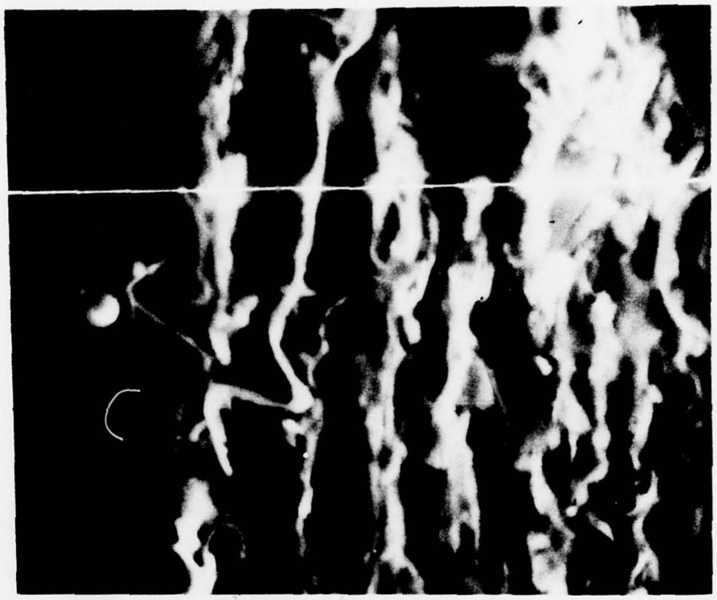


Figure 11. SEM Micrograph of Ferrogram Showing Wear Particles. Line is Reference Line for X-ray EDS Analysis. 1,600x

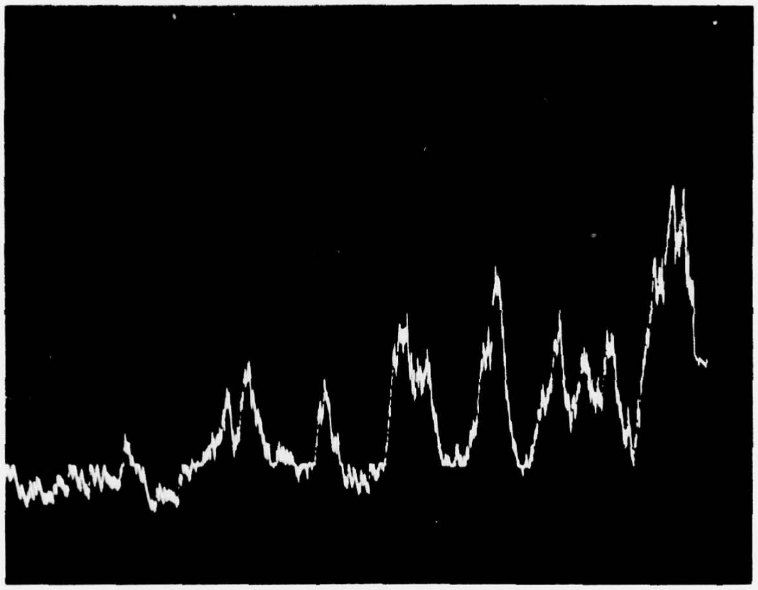


Figure 12. Ni Line Scan Showing Relative Quantity of Ni. Compare this Figure with Fig. 11 to Obtain Information on Location of Ni along Reference Line.

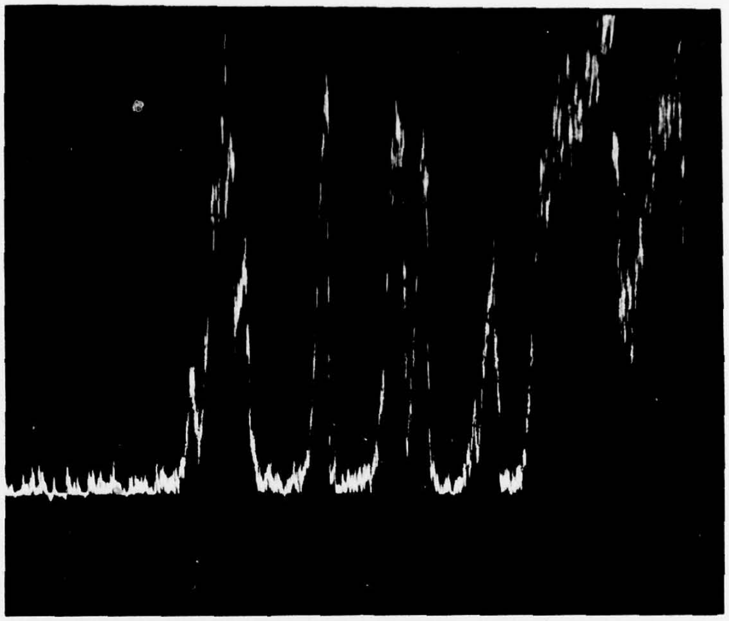


Figure 13. Fe Line Scan Showing Relative Quantity of Fe

Figure 14. Y_2O_3 Particles in Cast Ti Alloy. 500x

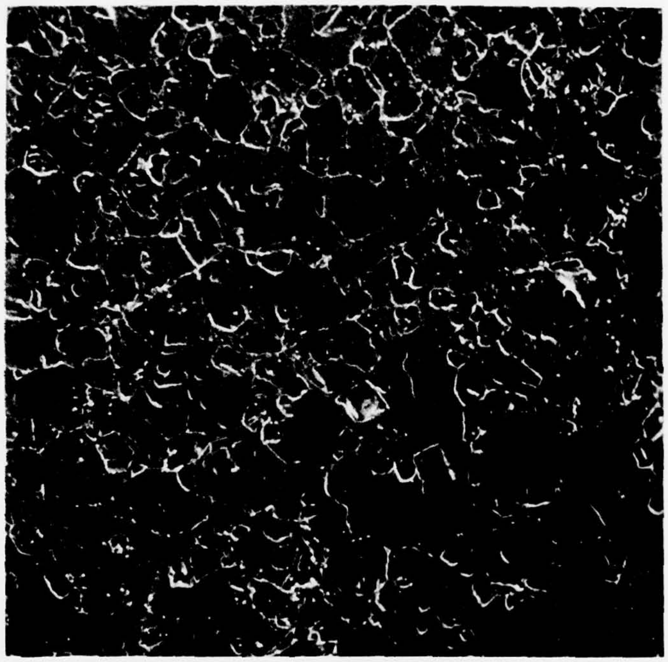


Figure 15. Grain Boundaries in IN-100. 2,000x

Figure 16. Combustion Surface of Ti Alloy. 500x

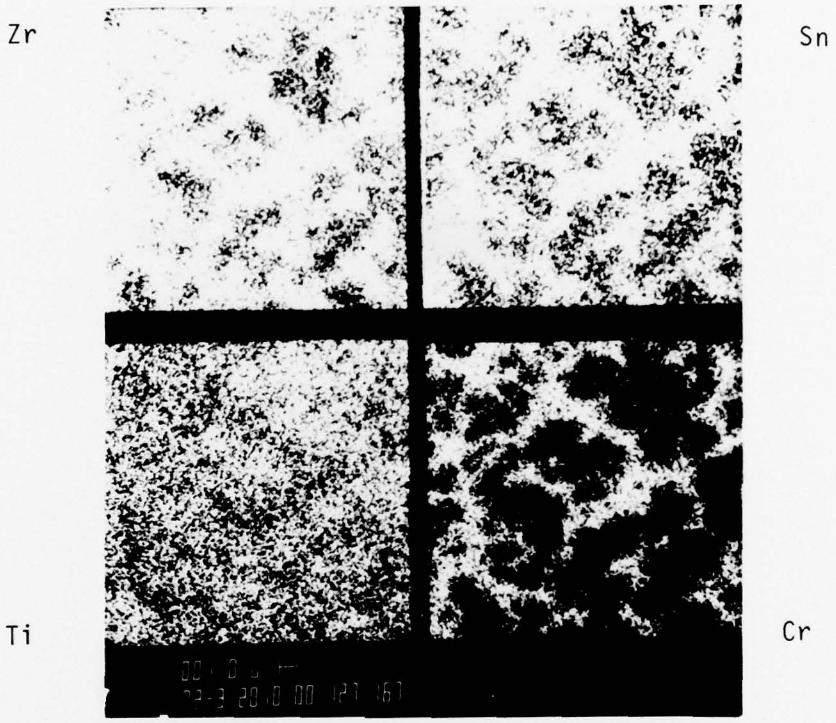


Figure 17. Four-Quadrant X-Ray Area Scan for Four Elements. 2,000x

Figure 18. Copper Powder. 100x

Figure 19. Optical Micrograph of AF2-1DA. 63x

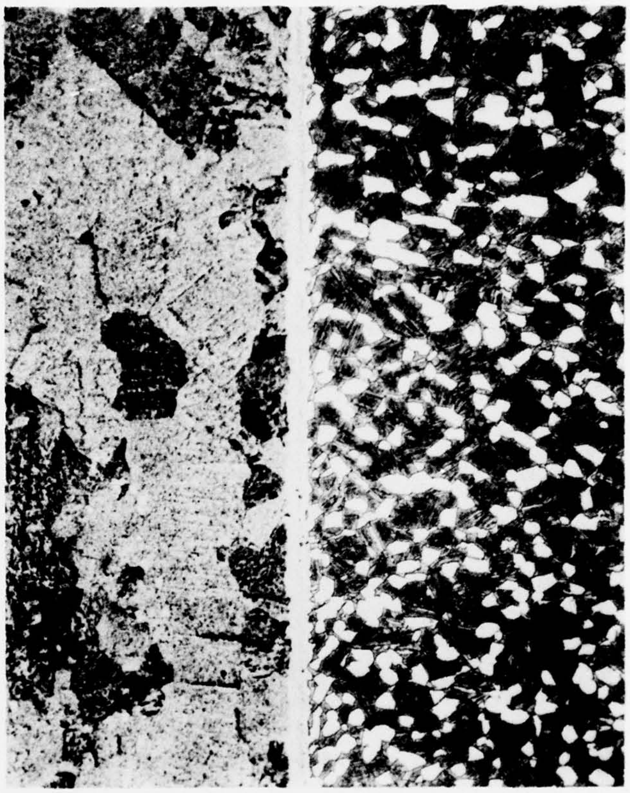


Figure 20. Optical Micrograph of Al-Ti Diffusion Bond. 100x

TABLE 1

NUMBER OF REQUESTS PROCESSED BY ELECTRON PROBE MICROANALYSIS

Period of Time	No. of Requests
1973	27
1974	23
1975	41
1976 (January and February)	16
1976 (March through December)	174
1977 (January through April)	31 (including 5 weeks down time)

TABLE 2

DETAIL OF REQUESTS PROCESSED IN PHOTOLAB (1976-1977)

Date	Plates	Prints 4x5	8x10	Slides	Negs	Misc	Total Prints
March 1976	157	451	85	37	20	39	632
April	103	547	178	129	31	68	953
May	129	806	21	56	14	25	922
June	77	623	171	8	52	34	888
July	56	489	70	6	50	48	663
August	22	253	322	86	13	27	701
September	148	898	183	93	40	78	1,292
October	135	742	52	47	35	82	958
November	119	947	118	42	45	31	1,183
December	695	2,324	4	1	1	0	2,330
January 1977	287	1,305	80	6	4	267	1,662
February	359	1,703	1	23	6	93	1,826
March	140	821	208	21	30	50	1,322
Total Plates	2,427				Total Prints		15,332

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