DRA

External Insulation Systems

for

Cryogenic Storage Systems

Contract NAS 9-10583

FINAL REPORT: REPORT OF PROCESS VARIABLE STUDY

REPORT OF OPTICAL PROPERTIES OF KAPTON

VOLUME I

Prepared for: NASA/Manned Spacecraft Center
Propulsion and Power Division
Technical Monitor: Robert K. Allgeier
Houston, Texas

Prepared by: Alan M. Frank

COLSPAN

P.O. BOX 3467
BOULDER, COLORADO 80303

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1.0 INTRODUCTION

This is the final report of NASA contract NAS9-10583. The contents include the deliverable items as called out in Modification No. 13S Article V, Section D, items 3 and 7 and Modification No. 14S of aforesaid contract.

The results of the investigations reported herein have altered the concepts and approaches as defined at the outset of this portion of the program. Consequently, without the expenditure of additional funds not currently available the successful completion of items 4 and 6 of Section D above would not be possible and have therefore been omitted. The processes and techniques developed and results obtained have layed the groundwork for the eventual production of vastly improved thermal radiation reflectors for cryogenic insulation.

2.0 PURPOSE

The overall goals of this program is the fabrication of sputtered multi-layer optical structures, "filters" on pliable substrates that are broadband reflectors (2.5 - 20μM) and composed entirely of dialectric materials. Previous results have demonstrated the feasibility of designing such filters; however, results of initial fabrication efforts were less than satisfactory.

A review of the initial fabrication attempts indicated that a more thorough investigation of the processes involved needed to be conducted. As a result, the current program was undertaken to determine the critical process variables and understand their effect on filter performance.

Three process variables were chosen for investigation. These include: deposition rate, sputter gas pressure, and film contamination time. Simple layer samples were produced for the rate and pressure series and two layer samples for the contamination run. These represent the simplest filters for which the effects of the process variables can be observed.

It is the eventual goal that perturbations observed

for the simple filters can be used to more accurately predict the performance of multilayer stacks produced by similar techniques.

An additional goal of this program is to demonstrate sufficient control of the deposition process itself for the accurate fabrication of multilayer stacks.

Investigations were also conducted into the optical properties of the glass and Kapton substrate materials. The goal of this study is a sufficient understanding of the optical properties so that these effects can be accounted for in the design and performance of the multilayer filters.

3.0 EXPERIMENT

This experimental approach was divided into three principle operating areas, including:

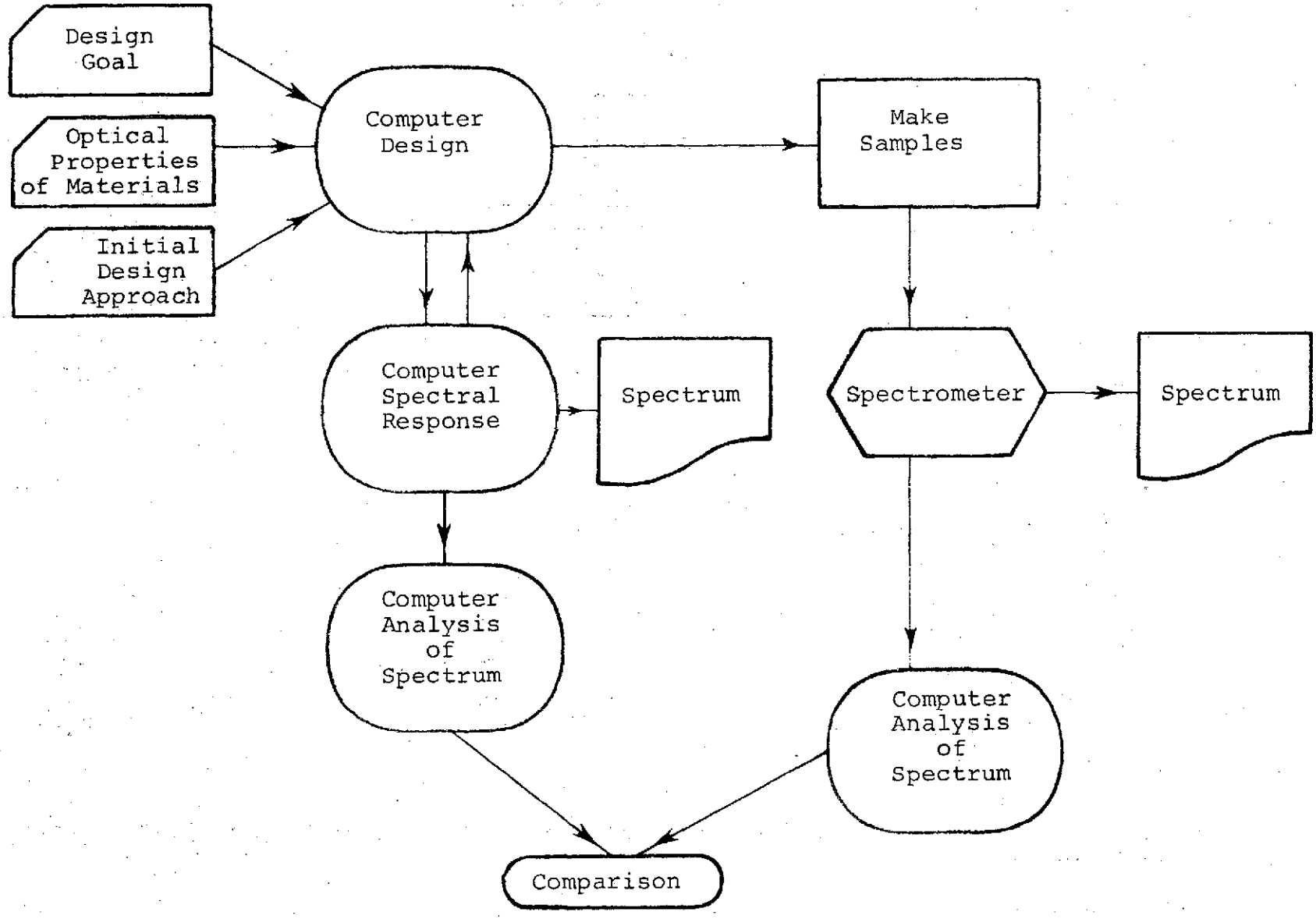
- Computer Design and Analysis
- Sample Fabrication
- Sample Testing

Both the design and fabrication areas were largely adapted from the previous experiments; however, the testing arrangements were entirely new. The operational flow of the program is described in Fig. 1.

Single layer samples have a simple sinusoidal interference function. The thicknesses of these samples were chosen to give a reasonable spread of data across the spectrum of interest. The designs were tested by computer using the program[1]. A new subroutine, which found the spectral maxima and minima, was added to the program.

Samples were fabricated by Vacuum Technology Associates, Inc.[2] using moderately high rate sputtering techniques discussed in previous reports [3]. A block diagram of the sputtering system is given in Fig. 2.

Sample testing was performed at the Denver Research



NASA Program Operation

Alan M. Frank

FIG. 1

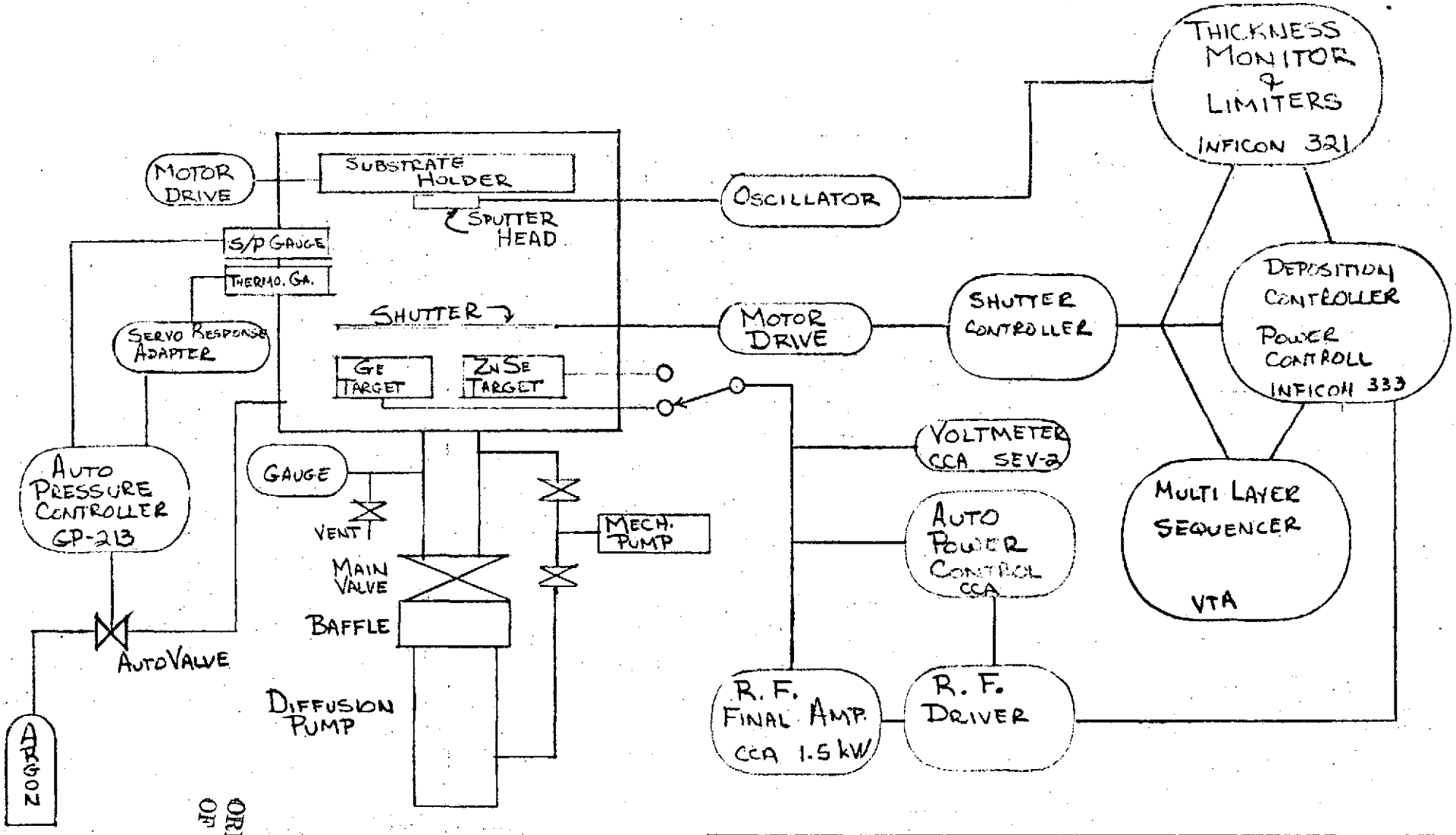


FIG. 2

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SPUTTERING SYSTEM BLOCK DIAGRAM

SCALE:	APPROVED BY: AMF	DRAWN BY
DATE: 11/1/73		REVISED
NASA NAS9-10583		
COLSPAN		DRAWING NUMBER

Institute using a Beckman IR-7 modified as a low angle of incidence spectral reflectometer.

The spectrometer is a dual beam instrument covering the spectral range 2.5 - 40. μM . A reflectometer attachment giving an angle of incidence of 2.25° was fabricated especially for this experiment. The lengthening of the optical path length caused some non-linearization of the spectrometer's response; however, this was removed from the data by running a normalization spectrum with each set of samples.

The normalized spectral maxima and minima of the samples along with the spectral data from the design program were fed into an entirely new program, "Compare". This program tabulated and matched the theoretical and experimental spectral peaks. The program computed the wavelength and reflectivity deviations of the experimental peaks with respect to matching theoretical data. The program also provides a summary average error and deviation of the errors of the matched peaks of each sample.

4.0 DATA

4.1 SPECIFICATIONS AND ASSUMPTIONS

Initial sample designs were chosen to provide a maximum amount of useful data. Particular interest was given to the short wavelength end of the spectrum since the effects of the process variables are most apparent in this region. In addition, the effects of the substrates were least apparent in this region.

Glass was chosen as the substrate for the process variable samples since the thin ($25\mu M$) Kapton substrates acted as an interference layer. In addition, it was necessary to separate the effects of the substrate from those of the deposition process. Both the glass and Kapton substrates were independently tested and an analysis is given in Sec. 4.4 below.

Initial thickness specifications of the single layer samples were chosen to give a quarter wave layer at $10\mu M$. However, deposition controller malfunctions did not allow accurate thickness preprogramming. Consequently, these samples were fabricated, their thicknesses measured then theoretical spectra generated for the known thickness. The controller was working

properly for the two layer samples and they were fabricated to prescribed thicknesses.

Because of substrate limitations no useful information was measurable above 15 μM, therefore, spectra were only run to 15 μM.

4.2 SPUTTER RATE AND PRESSURE SAMPLES

Single layer samples of Zinc Selenide (ZnSe) and Germanium (Ge) were deposited on glass at a fixed gas pressure of 10 μ MH_g and varying deposition rates. Then a second set at fixed sputter rates and varying gas pressures.

A summary of the results of these samples is given in Tables 1 and 2. These tables are a compillation of the error averages and deviations from each sample summary sheet. Figure 3 are selected ZnSe and Ge spectra, sample summary sheets and complete raw spectra are given in the appendix.

The wavelength error is the difference between the theoretical and measured wavelengths divided by the theoretical wavelength ($\Delta\lambda/\lambda$) for a given spectral peak. *

The Reflectivity error is the absolute difference

* Maxima and Minima are both called peaks.

TABLE 1

SPUTTER RATE SAMPLE SUMMARY

Sample		Rate	Wavelength Av. Error	Wavelength Deviation	Reflectivity Av. Error	Reflectivity Deviation
1A	ZnSe	180Å/min.	.0051	.0163	.0225	.0241
1B	"	180Å/min.	.0033	.0309	.0521	.1069
2A	"	480Å/min.	.0238	.0152	.0372	.0604
2B	"	480Å/min.	.0073	.0249	.0382	.0896
3A	"	920Å/min.	-.0109	.0057	.0551	.1255
3B	"	920Å/min.	.0099	.0306	.1107	.1841
4A	Ge	410Å/min.	.0002	.0291	.1374	.1983
4B	"	410Å/min.	-.0290	.0211	.1250	.1722
5A*	"	820	-.0262	.0253	.1356	.2435
5B*	"	820	-.0153	.0527	.1022	.1907
6-2	"	830	.0205	.0063	.0768	.1148
7-2	"	970	-.0317	.0270	.0506	.0731

Sputtering pressure 10 μM Hg except as indicated by * where pressure was 9 μM Hg.

TABLE 2

SPUTTER PRESSURE SAMPLE SUMMARY

Sample		Pressure	Wavelength Av. Error	Wavelength Deviation	Reflectivity Av. Error	Reflectivity Deviation
8-2	Ge	5 μ M Hg	.0909	.0046	.0531	.1163
10-2	Ge	10 μ M Hg	.0339	.0197	.1110	.1354
9-2	Ge	15 μ M Hg	.0453	.0260	.1186	.1562
11-2	ZnSe	5 μ M Hg	-.0110	.0322	.6693	.1387
12-2	"	10 μ M Hg	-.0176	.0293	.0446	.0970
13-3	"	15 μ M	-.0467	.0287	.0502	.0964

Ge Samples were deposited at rates of approximately 520Å/min.

ZnSe Samples were deposited at rates of approximately 400Å/min.

TABLE 3

A. Design of Two Layer Samples

LAYER	THICKNESS	RE(INDEX)	IM(INDEX)
1 Glass	0.000000	1.500000	0.000000
2 ZnSe	1.540700	2.434000	0.000000
3 Ge	0.932400	4.021990	0.000000
4 Air	0.000000	1.000000	0.000000

B. Theoretical Maximum & Minimum Spectral Reflectivity of Two Layer Samples

Wavelength	Reflectivity Maxima	Minima
2.01000	5.73123-001	
2.14000		3.69563-001
2.29000	5.73394-001	
2.50000		4.00833-002
2.75000	5.73199-001	
3.00000		3.69303-001
3.30000	5.73429-001	
3.75000		4.00828-002
4.34000	5.73021-001	
5.00000		3.69181-001
5.88000	5.71753-001	
7.46000		4.01094-002
10.20000	5.67132-001	
14.70000		3.80985-001
16.00000	4.01576-001	

of normalized maximum or minimum reflectivities between theoretical and measured peaks. The errors are computed only for those measured peaks which could be identified as corresponding to theoretical peaks (i.e. "matched peaks".) The average error is the average of the errors of all matches peaks for a given sample. The standard deviation represents the variation of the errors about the average.

The Results of these tests show that, with the possible exception of Germanium at low sputter rates, the wavelength errors are consistant for all deposition parameters measured. These errors appear to result only from thickness measurement error. The larger errors for the Germanium samples result from the larger index of refraction and are consistant with the above results.

The Reflectivity data shows significantly large errors.

Parametric trends are apparent in the ZnSe sputter rate and Ge pressure runs. The last two Ge sputter rate samples, however, indicate that the cause of the large errors is probably due to interactions with the residual gases within the chamber. Very small traces of metallic or other vapors would be trapped

in the deposited layer by the sputtering process causing significant errors in reflectivity. This theory is consistant with the parametric results and could be proven with the use of a residual gas analyzer.

It should also be noted that samples produced simultaneously (e.g., samples 1A and 1B, etc) often had significantly different reflectivities. This observation lends credence to the above theory as well as suggesting a localized source as well as geometric shielding effects.

4.3 TWO LAYER SAMPLES

The two layer samples were prepared in an effort to determine the effect of varying the soak time between layers. In addition, the two layer samples provided a definitive test of the performance of the deposition controller.

The samples were designed to give maximum information in the 2.5 - 10 μM region. The design of these samples is the classic quarter wave stack. (glass $(LH)^1$ air, where L=ZnSe (n=2.43) and H= Ge (n=4.02)).[4] The design parameters and computed spectral response are given in Table 3. The samples

were made at moderate sputtering rates, with a gas pressure of 10 μM Hg and with interlayer soak times of 12 sec (minimum interlayer time), 10 min. and 45 min.

An important difference between single and multilayer samples is that the maximum and minimum reflectivities of the single layer samples are nearly independent of the thickness of the layer. Consequently, the effects of thickness and quality are neatly separated in the results of wavelength and reflectivity respectively.

On the other hand, in multilayers the reflectivities are strongly a function of layer thicknesses as well as quality.

Three runs of two samples each were fabricated and one sample of each run was tested on the spectrometer and run through the computer. The resulting spectral waveforms (Fig. 3) were sufficiently different from the computed spectrum that the comparison program was not able to properly match the spectral peaks.

The two layers were deposited without breaking vacuum, therefore, thickness measurements of the individual layers were not practical. Consequently, only a measurement

Figure 3 - Sample Spectra

These spectra include a normalization curve which is the spectrometer response to 100 percent reflectivity. The spectra were measured in four overlaping orders with a factor of 4 scale change between upper and lower order pairs.

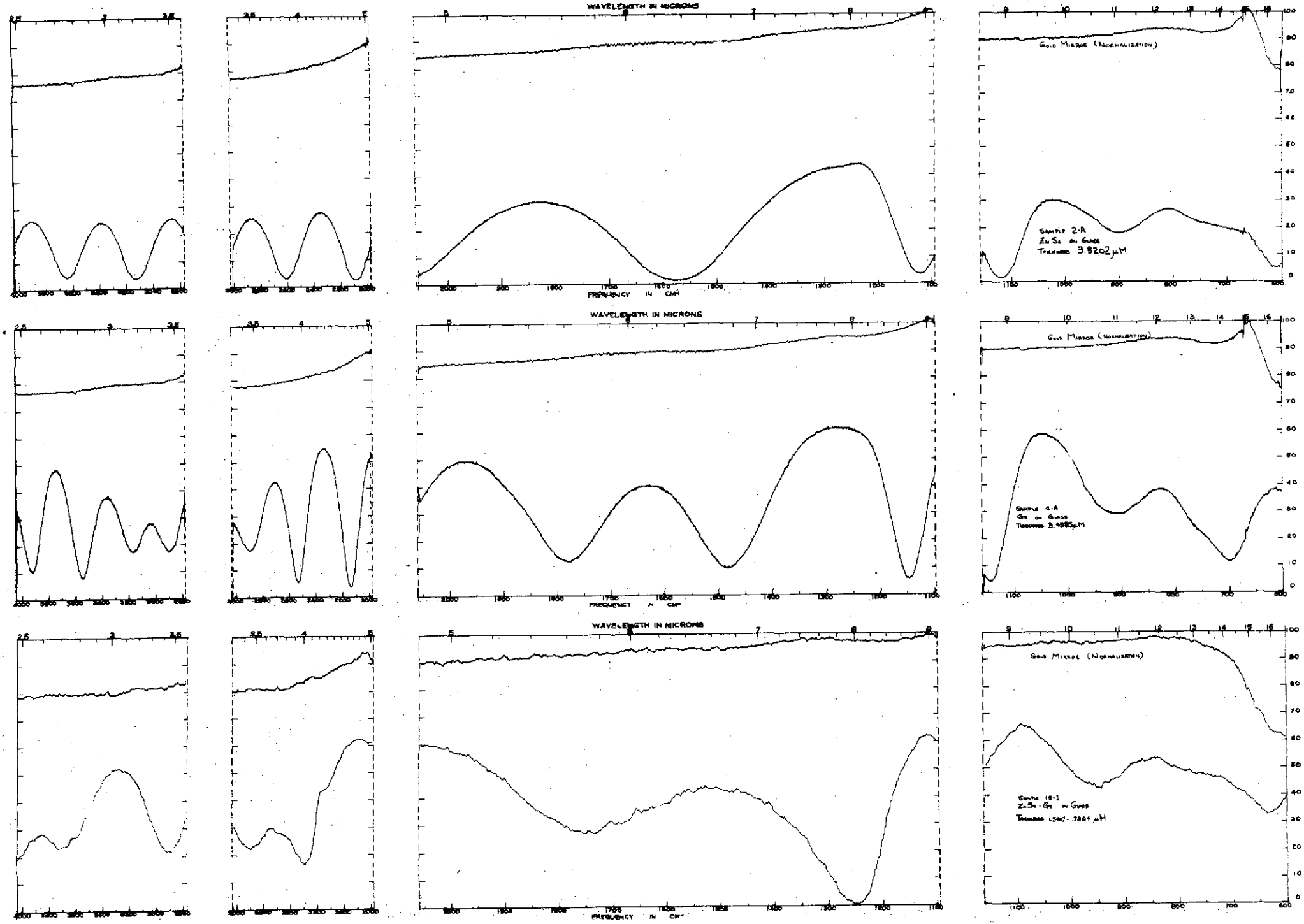

Figure 3 - Sample Spectra

of total mass deposited was made. These measurements represent the total thickness and are given in Table 4. Single layer errors are estimated by assuming a statistical ensemble including compensating errors, consequently the single layer average errors would be larger than the two layer average by $\sqrt{2}$.

These errors are too large for good multilayer filter fabrication particularly because of the very high indicies of the deposited materials. A partial cause of these errors is the interaction of the controller head with the very intense radio frequency field inside the chamber. Good quality filter fabrication in this spectral region will require control in the 10^{-6} gm/cm^2 range, that is to a thickness of better than 100 Å.

In a roll coating system, active control of the deposition rate will be required, then measurement of layer thickness would occur downstream from the deposition area. An interferometer could provide the required accuracy.

It should be noted that samples made simultaneously have different thicknesses. This is a geometric effect of the circular symetry of the sputtering system used for

TABLE 4

TWO LAYER SAMPLE SUMMARY

Sample	Soak Time	Weight Added (gm)	Weight Error (Absolute) (gm)	(%)
14-1	44 min.	.02235	2.4×10^{-4}	1.1
14-2	44 min	.02281	2.1×10^{-4}	0.9
15-1	12 sec.	.02301	4.1×10^{-4}	1.8
15-2	12 sec.	.02370	1.1×10^{-3}	4.9
16-1	10 min.	.02275	1.5×10^{-4}	0.7
16-2	10 min.	.02255	0.5×10^{-4}	0.2
	Design Weight	.02260 gm		
	Average Errors		3.6×10^{-4} gm	1.6%
	Average Thickness Error		390 Å	
	Average Controller Error		1.8×10^{-5} gm/cm^2	
	Estimated Average Errors for Single Layer			
	Average Error		5.0×10^{-4} gm	2.3%
	Average Thickness Error		540 Å	
	Average Controller Error		2.5×10^{-5} gm/cm^2	

these samples. This problem would be eliminated with the line geometry of a roll coater.

4.4 SUBSTRATE TESTS

The optical properties of the substrate of a dialectric interference filter are as important to the performance of the filter as those of any individual layer. In fact, in the design and modeling of a multilayer filter the substrate is treated as the first layer.

The DuPont, Polyimide film "Kapton' had been chosen by virtue of its cryogenic properties to be the substrate material for the all dialectric reflector concept. The infrared optical properties of Kapton were not heretofore sufficiently well known to mkae any judgments as to its suitability as an optical substrate. Polished glass microscope slides were chosen as the substrate for the process variable samples for its mechanical and optical properties as well as availability and cost.

Samples of Kapton and the glass substrates were tested for spectral reflectivity exactly as the filter samples previously described. The samples were also tested for spectral absorbtivity, although over much of the spectrum the glass samples were too thick for

any useful data.

The resulting spectra are shown in Fig. 4 and are discussed here qualitatively. The reflectivity peak of the glass at 9.4 μM explains the anomolus behavior of the filter samples in that spectral region.

The Kapton samples show a very complex spectrum resulting from the organic nature of the material. All organic polymers would have similar spectral features. The regular high frequency features in absorbtion spectra are the interference between the front and back surfaces. At the shorter wavelengths (3 μM) this interference structure is consistent with an index of refraction of 1.7; however, at longer wavelengths ($> 10 \mu M$) the index is significantly higher. The reflectivity curve is characteristic of the classical "Anomolous dispersion" of absorbing materials[5]. It is clear from these tests that some effort would have to be undertaken to analyze the optical properties so as to sufficiently characterize the material for use in the all dialectric filter. Even with the proper characterization of the optical properties an extremely complex filter would be

Figure 4 - Substrate Samples

The substrate reflectivity data uses the X10 expansion of the spectrometer. The normalization measures 100%; however, because of the linear expansion it also represents 10% in the expanded scale. A glass absorption sample is not given because the thickness of the samples prevented a meaning full measurement.

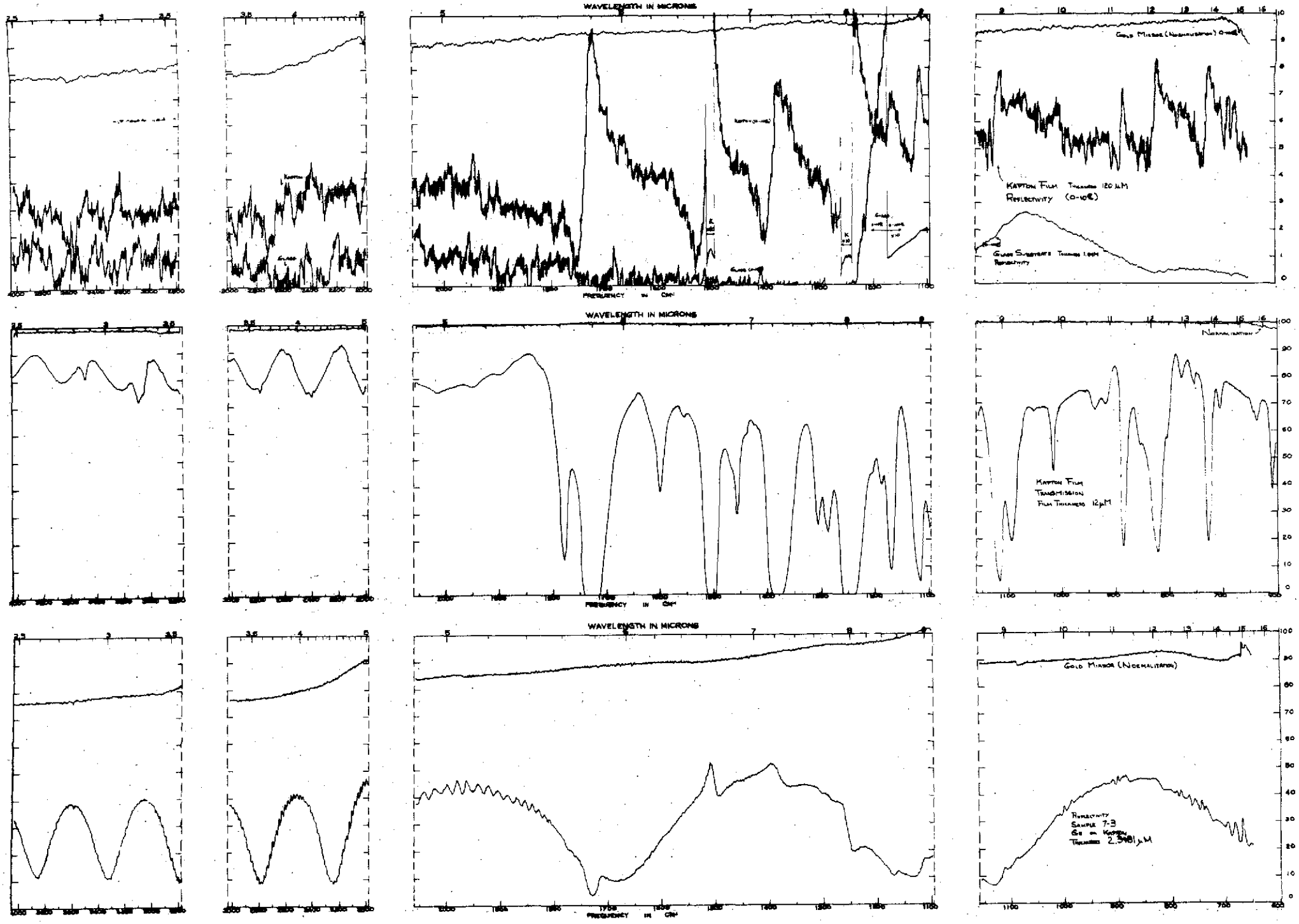

Figure 4 - Substrate Samples

required if the concept is possible at all with such polymer films.

Single layer samples of both Ge and ZnSe were deposited on Kapton substrates. These samples (Fig. 4) clearly show the effects of the substrate on the filter performance particularly above 5 μM. In addition, the period of the back - front interface structure significantly shorter at 15 μM than at 3 μM indicating a higher index of refraction.

These substrate tests have shown that fabrication of an all dialectric broadband reflector, if at all possible, would require an extremely complex, difficult and expensive filter design. On the other hand a metallized substrate with a dialectric interference coating could economically provide the enhanced reflectivities.

5.0 CONCLUSIONS

This study of the deposition process and substrates has succeeded in demonstrating the ability to use moderately high rate sputtering for the fabrication of interference filters in the infra red. This study has also defined the areas requiring further study -- these being:

- Residual gas analysis of the sputtering environment and establishment of pump down and cleanup requirements.

- Further refinements of the control of the deposition rate and layer thickness.

- Use of metallized polymer substrates for interference enhanced thermal reflectors.

With the techniques and procedures developed over the course of this program, the refinements mentioned above, and the development of the roll coater as designed and reported earlier[6] , the concept of a durable, rapdily producible, optically superior thermal reflector is now possible.

REFERENCES

1. Available commercially from: Optimization Associates, Inc.
   P. O. Box 4752
   Rochester, New York

2. VTA, Incorporated
   2125 Pearl Street
   Boulder, Colorado 80302

3. A. M. Frank, Modification and Test of Fabrication Equipment, HAS 9-10583, 1 Nov. 1973.

4. Mil - HDBK - 141 Optical Design.

5. Jenkins and White, Fundamentals of Optics 3rd Ed. McGraw-Hill New York 1957.

6. A. M. Frank, Design of Roll Coating Sub System, NAS9-10583, 5, Dec. 1973.

APPENDIX A

Optical Properties of Materials as Used in Process Sample Designs.

Wavelength	Index Real	Imag.
*MATERIAL GLASS		
10.000000	1.500000	
0.000000	0.000000	-0.000000
*MATERIAL AIR		
10.000000	1.000000	
0.000000	0.000000	-0.000000
*MATERIAL ZnSe		
4.000000	2.434000	
5.000000	2.431000	-0.000000
6.000000	2.427000	-0.000000
7.000000	2.423000	-0.000000
8.000000	2.418000	-0.000000
9.000000	2.414000	-0.000000
10.000000	2.408000	-0.000000
12.000000	2.398000	-0.000000
14.000000	2.388000	-0.000000
16.000000	2.378000	-0.000000
0.000000	0.000000	-0.000000
*MATERIAL GE		
4.000000	4.021990	
5.000000	4.016090	-0.000000
6.100000	4.009990	-0.000000
7.000000	4.006650	-0.000000
8.050000	4.004580	-0.000000
9.100000	4.003330	-0.000000
10.000000	4.003200	-0.000000
12.000000	4.002320	-0.000000
14.000000	4.001300	-0.000000
16.000000	4.000300	-0.000000
0.000000	0.000000	-0.000000

Linear interpolation is used to estimate intermediate values. Single values are taken as constants over the entire spectral range.

APPENDIX B

Listing of Program "Compare"

```
      PROGRAM COMPARE
C     ALAN FRANK     22 MARCH 1974
C     COMPARES SPECTRAL REFLECTIVITY PEAKS
      COMMON/PARE/SAMP,MTL,SUBS,THIK,RATE,PRESS,TSPEC(3,50),SPEC(3,50)
     1,IT,IS,DW(50),DI(50)
C     TSPEC,  SPEC(1,J)=WAVELENGTH,(2,J)=REFLECTIVITY,(3,J)=FLAG
C     FLAG CODE   +=MAXIMA,  -=MINIMA,  VALUE=INDEX OF CORESP PEAK,  100=NO CORE
    1 READ(60,100)SAMP,MTL,SUBS,THIK,RATE,PRESS
      IF(EOF,60)99,2
    2 CONTINUE
      WRITE(61,101)SAMP,MTL,SUBS,THIK,RATE,PRESS
      CALL SETSPC (TSPEC,IT)
      CALL SETSPC (SPEC,IS)
C     DET. CORESPONDING PEAKS
      JJ=1
      DO 10 I=1,IT
      II=I
      IF(I.EQ.IT)II=I-1
      MATCH=JJ
      MFLAG=0
      DO 8 J=JJ,IS
      DT=ABS(TSPEC(1,II)-TSPEC(1,II+1))
      DS=ABS(TSPEC(1,I)-SPEC(1,J))
      IF(DS.GT.DT.OR .TSPEC(3,I).NE.SPEC(3,J))GO TO 8
      IF(TSPEC(1,I).GT.SPEC(1,J+1))GO TO 8
      MFLAG=1
      DM=ABS(TSPEC(1,I)-SPEC(1,MATCH))
      IF(DS.LT.DM)MATCH=J
    8 CONTINUE
      IF(MFLAG.EQ.0)GO TO 10
      TSPEC(3,I)=SPEC(3,MATCH)*FLOAT(MATCH)/100.
      SPEC(3,MATCH)=TSPEC(3,I)*FLOAT(I)/100.
      JJ=MATCH+1
      IF(JJ.EQ.IS)GO TO 11
   10 CONTINUE
C     COMPUTE WAVELENGTH AND REFLECTIVITY ERRORS
   11 DO 20 I=1,IT
      DW(I)=0.
      DI(I)=0.
      SP=ABS(TSPEC(3,I))
      IF(SP.GT.50.)GO TO 20
      ISP=IFIX(SP+.1)
      DW(I)=(TSPEC(1,I)-SPEC(1,ISP))/TSPEC(1,I)
      DI(I)=TSPEC(2,I)-SPEC(2,ISP)
   20 CONTINUE
C     OUTPUT
      I=1
      J=1
   21 IF(I.GT.IT)GO TO 40
      TSP=ABS(TSPEC(3,I))
      ITSP=IFIX(TSP+.1)
      IF(TSPEC(1,I).GT.SPEC(1,J).AND.ITSP.NE.J)GO TO 40
      IF(ITSP.GT.50)GO TO 30
      IF(ITSP.GT.J)GO TO 40
      IF(TSPEC(3,I).LT.0.)GO TO 25
```

```
C       MATCHED PEAKS
        WRITE(61,102)TSPEC(1,I),SPEC(1,ITSP),DW(I),TSPEC(2,I),SPEC(2,ITSP)
       1,DI(I)
        I=I+1
        J=J+1
        GO TO 21
   25   WRITE(61,103)TSPEC(1,I),SPEC(1,ITSP),DW(I),TSPEC(2,I),SPEC(2,ITSP)
       1,DI(I)
        I=I+1
        J=J+1
        GO TO 21
C       UNMATCHED THEORETICAL
   30   IF(TSPEC(3,I).LT.0.)GO TO 35
        WRITE(61,104)TSPEC(1,I),TSPEC(2,I)
        I=I+1
        GO TO 21
   35   WRITE(61,105)TSPEC(1,I),TSPEC(2,I)
        I=I+1
        GO TO 21
C       UNMATCHED MEASURED
   40   IF(J.GT.IS)GO TO 50
        IF(SPEC(3,J).LT.0.)GO TO 45
        WRITE(61,106)SPEC(1,J),SPEC(2,J)
        J=J+1
        GO TO 21
   45   WRITE(61,107)SPEC(1,J),SPEC(2,J)
        J=J+1
        GO TO 21
C       COMPUTE AVERAGE AND STANDARD DEVIATION OF ERRORS
   50   AN=0.
        ADW=0.
        ADI=0.
        SDW=0.
        SDI=0.
        DO 55 I=1,IT
        SP=ABS(TSPEC(3,I))
        IF(SP.GT.50.)GO TO 55
        AN=AN+1.
        ADW=ADW+DW(I)
        ADI=ADI+ABS(DI(I))
   55   CONTINUE
        ADW=ADW/AN
        ADI=ADI/AN
        DO 59 I=1,IT
        SP=ABS(TSPEC(3,I))
        IF(SP.GT.50.)GO TO 59
        SDI=SDI+(DI(I)-ADI)**2
        SDW=SDW+(DW(I)-ADW)**2
   59   CONTINUE
        SDW=SQRT(SDW/AN)
        SDI=SQRT(SDI/AN)
        WRITE(61,108)ADW,SDW,ADI,SDI
        GO TO 1
   99   STOP
  100   FORMAT(3(A8,2X),3F10.5)
```

```
101 FORMAT(*1 SAMPLE *,A8,* PERFORMANCE SUMMARY*,//,* MATERIAL*,12X,
   1A8,/* SUBSTRATE*,11X,A8,/* THICKNESS*,11X,F10.4,* MICRONS*,/
   2* DEPOSITION RATE*,5X,F10.0,* ANGSTROMS / MINUTE*,/
   3* SPUTTER GAS PRESSURE*,F10.0,* MICRONS MERCURY*,//,
   4* WAVELENGTH (MICRONS)*,10X,*ERROR*,10X,*REFLECTIVITY (NORMALIZED)
   5*,4X,*ERROR*,/,
   6* THEORETICAL     MEASURED*,7X,*DW / W*,9X,*THEORETICAL     MEASURED
   7*,7X,*DR*,/,46X,3(*MAX     MIN*,5X),/)
102 FORMAT(1X,2(F10.4,5X),F10.4,2X,3(F9.4,6X))
103 FORMAT(1X,3(F10.4,5X),1X,3(F9.4,6X))
104 FORMAT(1X,F10.4,5X,2(5X,*XXXXX*,5X),F6.4,4X,2(5X,*XXXXX*,5X))
105 FORMAT(1X,F10.4,5X,2(5X,*XXXXX*,5X),4X,F6.4,4X,2(5X,*XXXXX*,5X))
106 FORMAT(6X,*XXXXX*,5X,F10.4,10X,2(*XXXXX*,5X),5X,F6.4,9X,*XXXXX*)
107 FORMAT(6X,*XXXXX*,5X,F10.4,10X,*XXXXX*,9X,*XXXXX*,10X,F6.4,9X,*XXX
   1XX*)
108 FORMAT(1H0,*WAVELENGTH ERRORS*,                                  /,1X,
   1    *AVERAGE    *,F10.4,10X,*DEVIATION *,F10.4,15X ,/,1H0,
   2 *REFLECTIVITY ERRORS*,/,1X,
   3    *AVERAGE    *,F10.4,10X,*DEVIATION *,F10.4)
     END
```

```
      SUBROUTINE SETSPC (SPC,II)
      DIMENSION SPC(3,50)
      DATA (FLAG=100.)
      DO 10 J=1,50
      READ(60,100)WVL,AMAX,AMIN
      IF(WVL.EQ.0.)GO TO 20
      SPC(1,J)=WVL
      IF(AMAX.EQ.0.)GO TO 8
      SPC(2,J)=AMAX
      SPC(3,J)=FLAG
      GO TO 10
    8 SPC(2,J)=AMIN
      SPC(3,J)=-FLAG
   10 CONTINUE
      WRITE(61,200)
      II=50
      RETURN
   20 II=J-1
      RETURN
  100 FORMAT(3F10.5)
  200 FORMAT(*0  PEAK LIMIT EXCEDED*)
      END
```

APPENDIX C - Sample Data

Sample numbers contain two characters - the first is the deposition run, the second is the location in the sample holder. Two substrate holders were used. The first containing two positions (A, B) and the second containing four positions (1-4) with positions 3 and 4 set up for Kapton substrates.

Not all substrate positions were used for every deposition run. In several cases samples were not run through the entire testing procedure, e.g. samples on Kapton were not run through the comparison program, etc.

C. 1 Performance Summary Sheets

The following performance summary sheets are the output from program "Compare" as given in Appendix B. The information at the top of each sheet serves to describe the sample and summarizes the fabrication parameters.

The tabulated data is the comparison between the theoretical and measured spectral peaks. The first two columns are the wavelengths of the theoretical and measured peaks, respectively. When theoretical and measured peaks are "matched", i.e., identified by the program as corresponding, their wavelengths are listed on the same line.

Those peaks which are not matched are listed; however, the symbol XXXXX appears in place of the corresponding data. When the peaks are matched, a fractional wavelength deviation from the theoretical value is computed and listed in the third column.

The last three columns are the reflectivity data arranged as the wavelength data. However, in this data, the maxima and minima are offset by a half column. Since the reflectivity is already normalized, the error is the simple deviation from the theoretical value.

The summaries at the bottom of each page give the averages and standard deviations of the errors of the matched peaks. It should be noted that the reflectivity summary is of the absolute value of the errrors whereas the sign information is retained in the wavelength data.

SAMPLE 1A PERFORMANCE SUMMARY

MATERIAL	ZN SE
SUBSTRATE	GLASS
THICKNESS	3.8314 MICRONS
DEPOSITION RATE	180 ANGSTROMS / MINUTE
SPUTTER GAS PRESSURE	10 MICRONS MERCURY

WAVELENGTH (MICRONS)		ERROR	REFLECTIVITY (NORMALIZED)				ERROR	
THEORETICAL	MEASURED	DW / W	THEORETICAL		MEASURED		DR	
			MAX	MIN	MAX	MIN	MAX	MIN
2.0700	XXXXX	XXXXX	0.0405		XXXXX		XXXXX	
2.1900	XXXXX	XXXXX	0.3550		XXXXX		XXXXX	
2.3300	XXXXX	XXXXX	0.0401		XXXXX		XXXXX	
2.4900	2.4890	0.0004	0.3552		0.3500		0.0052	
2.6600	2.6770	-0.0064	0.0406		0.0850		-0.0444	
2.8700	2.8740	-0.0014	0.3554		0.3150		0.0404	
3.1100	3.1250	-0.0048	0.0401		0.0450		-0.0049	
3.3900	3.3960	-0.0018	0.3555		0.3200		0.0355	
3.7300	3.7450	-0.0040	0.0401		0.0400		0.0001	
4.1400	4.1410	-0.0002	0.3553		0.3380		0.0173	
4.6600	4.6730	-0.0028	0.0401		0.0120		0.0281	
5.3200	5.3330	-0.0024	0.3541		0.3420		0.0121	
6.2000	6.1800	0.0032	0.0401		0.0050		0.0351	
7.4200	7.1700	0.0337	0.3513		0.3360		0.0153	
9.2500	8.8110	0.0475	0.0401		0.0080		0.0321	
XXXXX	9.6810	XXXXX	XXXXX		0.3700		XXXXX	
XXXXX	11.1000	XXXXX	XXXXX		0.1780		XXXXX	
12.2000	XXXXX	XXXXX	0.3436		XXXXX		XXXXX	
XXXXX	12.3000	XXXXX	XXXXX		0.2580		XXXXX	

WAVELENGTH ERRORS

AVERAGE	0.0051	DEVIATION	0.0163

REFLECTIVITY ERRORS

AVERAGE	0.0225	DEVIATION	0.0241

SAMPLE 1B PERFORMANCE SUMMARY

MATERIAL	ZN SE
SUBSTRATE	GLASS
THICKNESS	3.1413 MICRONS
DEPOSITION RATE	180 ANGSTROMS / MINUTE
SPUTTER GAS PRESSURE	10 MICRONS MERCURY

WAVELENGTH (MICRONS) THEORETICAL	WAVELENGTH (MICRONS) MEASURED	ERROR DW / W	REFLECTIVITY (NORMALIZED) THEORETICAL MAX	REFLECTIVITY (NORMALIZED) THEORETICAL MIN	REFLECTIVITY (NORMALIZED) MEASURED MAX	REFLECTIVITY (NORMALIZED) MEASURED MIN	ERROR DR MAX	ERROR DR MIN
2.0400	XXXXX	XXXXX	0.3554		XXXXX		XXXXX	
2.1800	XXXXX	XXXXX		0.0409		XXXXX		XXXXX
2.3500	XXXXX	XXXXX	0.3554		XXXXX		XXXXX	
2.5500	2.5770	-0.0106		0.0402		0.1150		-0.0748
2.7800	2.7850	-0.0018	0.3555		0.3130		0.0425	
3.0600	3.0820	-0.0072		0.0401		0.0620		-0.0219
3.4000	3.4360	-0.0106	0.3554		0.3150		0.0404	
3.8200	3.8310	-0.0029		0.0401		0.0560		-0.0159
4.3700	4.3960	-0.0059	0.3551		0.3280		0.0271	
5.0800	5.1280	-0.0094		0.0402		0.0230		0.0172
6.1000	6.1700	-0.0115	0.3531		0.3600		-0.0069	
7.6000	7.6200	-0.0026		0.0401		0.0010		0.0391
10.0500	9.0900	0.0955	0.3471		0.5820		-0.2349	
XXXXX	10.6400	XXXXX		XXXXX		0.1080		XXXXX
XXXXX	11.6300	XXXXX	XXXXX		0.1700		XXXXX	

WAVELENGTH ERRORS AVERAGE	0.0033	DEVIATION	0.0309
REFLECTIVITY ERRORS AVERAGE	0.0521	DEVIATION	0.1069

SAMPLE 2A PERFORMANCE SUMMARY

MATERIAL	ZN SE
SUBSTRATE	GLASS
THICKNESS	3.8202 MICRONS
DEPOSITION RATE	480 ANGSTROMS / MINUTE
SPUTTER GAS PRESSURE	10 MICRONS MERCURY

WAVELENGTH (MICRONS)		ERROR	REFLECTIVITY (NORMALIZED)			
THEORETICAL	MEASURED	DW / W	THEORETICAL		MEASURED		ERROR OR	
			MAX	MIN	MAX	MIN	MAX	MIN
2.0700	XXXXX	XXXXX	0.0415		XXXXX		XXXXX	
2.1900	XXXXX	XXXXX	0.3553		XXXXX		XXXXX	
2.3200	XXXXX	XXXXX	0.0411		XXXXX		XXXXX	
2.4800	XXXXX	XXXXX	0.3554		XXXXX		XXXXX	
2.6600	2.6010	0.0222	0.0405		0.1340		-0.0935	
2.8600	2.7820	0.0273	0.3555		0.3120		0.0435	
3.1000	3.0300	0.0226	0.0401		0.0870		-0.0469	
3.3800	3.3060	0.0219	0.3555		0.3150		0.0405	
3.7200	3.6230	0.0261	0.0401		0.0720		-0.0319	
4.1300	4.0240	0.0257	0.3553		0.3370		0.0183	
4.6400	4.5250	0.0248	0.0402		0.0410		-0.0008	
5.3000	5.1900	0.0208	0.3541		0.3400		0.0141	
6.1800	6.0200	0.0259	0.0401		0.0230		0.0171	
7.4000	7.3300	0.0027	0.3513		0.4130		-0.0617	
9.2000	8.6000	0.0652	0.0401		0.0350		0.0051	
XXXXX	9.4900	XXXXX	XXXXX		0.4320		XXXXX	
XXXXX	10.9600	XXXXX	XXXXX		0.1900		XXXXX	
12.2000	12.2000	0.0000	0.3437		0.2710		0.0727	

WAVELENGTH ERRORS

AVERAGE	0.0238	DEVIATION	0.0152

REFLECTIVITY ERRORS

AVERAGE	0.0372	DEVIATION	0.0604

SAMPLE 28 PERFORMANCE SUMMARY

MATERIAL	ZN SE
SUBSTRATE	GLASS
THICKNESS	4.3127 MICRONS
DEPOSITION RATE	480 ANGSTROMS / MINUTE
SPUTTER GAS PRESSURE	10 MICRONS MERCURY

WAVELENGTH (MICRONS) THEORETICAL	MEASURED	ERROR DW / W	REFLECTIVITY (NORMALIZED) THEORETICAL MAX	MIN	MEASURED MAX	MIN	ERROR DR MAX	MIN
2.0000	XXXXX	XXXXX	0.3554		XXXXX		XXXXX	
2.1000	XXXXX	XXXXX		0.0402		XXXXX		XXXXX
2.2100	XXXXX	XXXXX	0.3555		XXXXX		XXXXX	
2.3300	XXXXX	XXXXX		0.0405		XXXXX		XXXXX
2.4700	XXXXX	XXXXX	0.3555		XXXXX		XXXXX	
2.6200	2.6320	-0.0046		0.0408		0.0970		-0.0562
2.8000	2.7840	0.0057	0.3554		0.3400		0.0154	
3.0000	3.0030	-0.0010		0.0401		0.0600		-0.0199
3.2300	3.2310	-0.0003	0.3555		0.3350		0.0205	
3.5000	3.5090	-0.0026		0.0401		0.0460		-0.0059
3.8200	3.8200	0.0000	0.3554		0.3420		0.0134	
4.2000	4.1800	0.0048		0.0401		0.0400		0.0001
4.6600	4.6600	0.0000	0.3548		0.3530		0.0018	
5.2400	5.2400	0.0000		0.0401		0.0170		0.0231
5.9800	5.9800	0.0000	0.3533		0.3650		-0.0117	
6.9600	6.9500	0.0014		0.0401		0.0010		0.0391
8.3400	8.3500	-0.0012	0.3500		0.6000		-0.2501	
10.4000	9.4300	0.0933		0.0402		0.0010		0.0392
XXXXX	10.4600	XXXXX	XXXXX		0.2050		XXXXX	
XXXXX	11.2300	XXXXX		XXXXX		0.1500		XXXXX

WAVELENGTH ERRORS

AVERAGE	0.0073	DEVIATION	0.0249

REFLECTIVITY ERRORS

AVERAGE	0.0382	DEVIATION	0.0896

SAMPLE 3A PERFORMANCE SUMMARY

MATERIAL	ZN SE
SUBSTRATE	GLASS
THICKNESS	2.5699 MICRONS
DEPOSITION RATE	920 ANGSTROMS / MINUTE
SPUTTER GAS PRESSURE	10 MICRONS MERCURY

WAVELENGTH (MICRONS)		ERROR	REFLECTIVITY (NORMALIZED)		ERROR	
THEORETICAL	MEASURED	ΔW / W	THEORETICAL		MEASURED		DR	
			MAX	MIN	MAX	MIN	MAX	MIN
2.0800	XXXXX	XXXXX	0.0410		XXXXX		XXXXX	
2.2700	XXXXX	XXXXX	0.3552		XXXXX		XXXXX	
2.5000	2.5250	-0.0100	0.0401		0.1100		-0.0699	
2.7800	2.7780	0.0007	0.3555		0.3280		0.0275	
3.1300	3.1850	-0.0176	0.0401		0.0630		-0.0229	
3.5700	3.5970	-0.0076	0.3554		0.3250		0.0304	
4.1700	4.2020	-0.0077	0.0401		0.0450		-0.0049	
5.0000	5.0630	-0.0126	0.3450		0.3350		0.0100	
6.2400	6.3490	-0.0175	0.0401		0.0200		0.0201	
8.2800	8.4030	-0.0149	0.3500		0.6050		-0.2550	
XXXXX	9.9010	XXXXX	XXXXX		0.0010		XXXXX	
XXXXX	10.9400	XXXXX	XXXXX		0.1100		XXXXX	
XXXXX	12.1200	XXXXX	XXXXX		0.0450		XXXXX	

WAVELENGTH ERRORS

AVERAGE -0.0109 DEVIATION 0.0057

REFLECTIVITY ERRORS

AVERAGE 0.0551 DEVIATION 0.1255

SAMPLE 3B PERFORMANCE SUMMARY

MATERIAL	ZN SE
SUBSTRATE	GLASS
THICKNESS	2.9572 MICRONS
DEPOSITION RATE	920 ANGSTROMS / MINUTE
SPUTTER GAS PRESSURE	10 MICRONS MERCURY

WAVELENGTH (MICRONS)		ERROR	REFLECTIVITY (NORMALIZED)		ERROR	
THEORETICAL	MEASURED	DW / W	THEORETICAL		MEASURED	DR	
			MAX	MIN	MAX	MIN	MAX	MIN
2.0600	XXXXX	XXXXX	0.0408		XXXXX		XXXXX	
2.2100	XXXXX	XXXXX	0.3551		XXXXX		XXXXX	
2.4000	XXXXX	XXXXX	0.0401		XXXXX		XXXXX	
2.6200	2.6500	-0.0115	0.3554		0.2600		0.0954	
2.8800	3.0000	-0.0417	0.0401		0.1800		-0.1399	
3.2000	3.2700	-0.0219	0.3555		0.2300		0.1254	
3.6000	3.5200	0.0222	0.0401		0.1700		-0.1299	
4.1100	4.0400	0.0170	0.3553		0.2580		0.0973	
4.7900	4.6700	0.0251	0.0401		0.1250		-0.0849	
5.7400	5.6800	0.0105	0.3536		0.3020		0.0516	
7.1600	7.0300	0.0182	0.0401		0.0750		-0.0349	
9.5000	8.8200	0.0716	0.3481		0.5850		-0.2369	
XXXXX	10.2100	XXXXX	XXXXX		0.0800		XXXXX	
XXXXX	11.3600	XXXXX	XXXXX		0.1420		XXXXX	

WAVELENGTH ERRORS

AVERAGE	0.0099	DEVIATION	0.0306

REFLECTIVITY ERRORS

AVERAGE	0.1107	DEVIATION	0.1841

SAMPLE 4A PERFORMANCE SUMMARY

MATERIAL	GE
SUBSTRATE	GLASS
THICKNESS	3.4385 MICRONS
DEPOSITION RATE	410 ANGSTROMS / MINUTE
SPUTTER GAS PRESSURE	10 MICRONS MERCURY

WAVELENGTH (MICRONS) THEORETICAL	MEASURED	ERROR DW / W	REFLECTIVITY (NORMALIZED) THEORETICAL MAX	MIN	MEASURED MAX	MIN	ERROR DR MAX	MIN
2.0500	XXXXX	XXXXX	0.6895		XXXXX		XXXXX	
2.1300	XXXXX	XXXXX		0.0446		XXXXX		XXXXX
2.2100	XXXXX	XXXXX	0.6892		XXXXX		XXXXX	
2.3000	XXXXX	XXXXX		0.0525		XXXXX		XXXXX
2.4100	XXXXX	XXXXX	0.6885		XXXXX		XXXXX	
2.5100	2.5280	-0.0072		0.0472		0.1850		-0.1378
2.6300	2.6420	-0.0046	0.6891		0.6280		0.0611	
2.7700	2.7890	-0.0069		0.0446		0.1600		-0.1154
2.9100	2.9370	-0.0093	0.6896		0.4320		0.2576	
3.0700	3.1350	-0.0212		0.0417		0.2700		-0.2283
3.2500	3.2680	-0.0055	0.6894		0.3650		0.3244	
3.4600	3.4130	0.0136		0.0409		0.2500		-0.2091
3.6900	3.6100	0.0217	0.6896		0.5420		0.1476	
3.9500	3.8830	0.0170		0.0402		0.1430		-0.1028
4.2500	4.1930	0.0134	0.6894		0.6600		0.0294	
4.6100	4.6300	-0.0043		0.0408		0.0550		-0.0143
5.0200	5.0300	-0.0020	0.6889		0.5650		0.1239	
5.5200	5.5700	-0.0091		0.0401		0.1480		-0.1079
6.1200	6.0800	0.0065	0.6880		0.4420		0.2460	
6.8800	6.7000	0.0262		0.0406		0.1080		-0.0674
7.8600	7.7200	0.0178	0.6874		0.6730		0.0144	
9.2000	8.7000	0.0543		0.0411		0.0350		0.0061
XXXXX	9.5200	XXXXX	XXXXX		0.6250		XXXXX	
XXXXX	10.9900	XXXXX		XXXXX		0.3250		XXXXX
11.0000	12.0600	-0.0964	0.6871		0.4080		0.2791	
13.7500	XXXXX	XXXXX		0.0401	XXXXX		XXXXX	
XXXXX	14.3000	XXXXX	XXXXX		0.0880		XXXXX	

WAVELENGTH ERRORS
AVERAGE 0.0002 DEVIATION 0.0291

REFLECTIVITY ERRORS
AVERAGE 0.1374 DEVIATION 0.1983

SAMPLE 4B PERFORMANCE SUMMARY

MATERIAL	GE
SUBSTRATE	GLASS
THICKNESS	3.4949 MICRONS
DEPOSITION RATE	410 ANGSTROMS / MINUTE
SPUTTER GAS PRESSURE	10 MICRONS MERCURY

WAVELENGTH (MICRONS) THEORETICAL	WAVELENGTH (MICRONS) MEASURED	ERROR DW / W	REFLECTIVITY (NORMALIZED) THEORETICAL MAX	REFLECTIVITY (NORMALIZED) THEORETICAL MIN	REFLECTIVITY (NORMALIZED) MEASURED MAX	REFLECTIVITY (NORMALIZED) MEASURED MIN	ERROR DR MAX	ERROR DR MIN
2.0100	XXXXX	XXXXX	0.0440		XXXXX		XXXXX	
2.0800	XXXXX	XXXXX		0.6892		XXXXX		XXXXX
2.1600	XXXXX	XXXXX	0.0443		XXXXX		XXXXX	
2.2500	XXXXX	XXXXX		0.6896		XXXXX		XXXXX
2.3400	XXXXX	XXXXX	0.0437		XXXXX		XXXXX	
2.4400	2.5450	-0.0430		0.6887		0.4300		0.2587
2.5600	2.6320	-0.0281	0.0471		0.2140		-0.1669	
2.6800	2.7400	-0.0224		0.6894		0.5850		0.1044
2.8100	2.9150	-0.0374	0.0404		0.1500		-0.1096	
2.9600	3.0860	-0.0426		0.6896		0.5150		0.1746
3.1200	3.2570	-0.0439	0.0421		0.2300		-0.1879	
3.3100	3.4130	-0.0311		0.6895		0.4400		0.2495
3.5100	3.5780	-0.0194	0.0417		0.1680		-0.1263	
3.7500	3.8170	-0.0179		0.6896		0.6650		0.0246
4.0200	4.1490	-0.0321	0.0411		0.1300		-0.0889	
4.3200	4.4600	-0.0324		0.6894		0.5600		0.1294
4.6800	4.8200	-0.0299	0.0401		0.1850		-0.1449	
5.1000	5.1900	-0.0176		0.6888		0.5070		0.1818
5.6000	5.6700	-0.0125	0.0415		0.0100		0.0315	
6.2200	6.3900	-0.0273		0.6880		0.7100		-0.0220
7.0000	7.2900	-0.0414	0.0401		0.0010		0.0391	
8.0000	8.2300	-0.0287		0.6874		0.6930		-0.0056
9.3500	9.0100	0.0364	0.0411		0.0100		0.0311	
XXXXX	9.8500	XXXXX	XXXXX		0.5500		XXXXX	
XXXXX	10.8500	XXXXX	XXXXX		0.3050		XXXXX	
11.2000	12.1000	-0.0804		0.6871		0.3880		0.2991
14.0000	XXXXX	XXXXX	0.0402		XXXXX		XXXXX	
XXXXX	14.4000	XXXXX	XXXXX		0.0680		XXXXX	

WAVELENGTH ERRORS

AVERAGE	-0.0290	DEVIATION	0.0211

REFLECTIVITY ERRORS

AVERAGE	0.1250	DEVIATION	0.1722

SAMPLE 5A PERFORMANCE SUMMARY

MATERIAL	GE
SUBSTRATE	GLASS
THICKNESS	3.1898 MICRONS
DEPOSITION RATE	820 ANGSTROMS / MINUTE
SPUTTER GAS PRESSURE	9 MICRONS MERCURY

WAVELENGTH (MICRONS) THEORETICAL	MEASURED	ERROR DW / W	REFLECTIVITY (NORMALIZED) THEORETICAL MAX	MIN	MEASURED MAX	MIN	ERROR DR MAX	MIN
2.0500	XXXXX	XXXXX	0.6891		XXXXX		XXXXX	
2.1400	XXXXX	XXXXX		0.0423		XXXXX		XXXXX
2.2300	XXXXX	XXXXX	0.6896		XXXXX		XXXXX	
2.3300	XXXXX	XXXXX		0.0428		XXXXX		XXXXX
2.4400	2.5480	-0.0443	0.6891		0.5500		0.1391	
2.5700	2.6780	-0.0420		0.0455		0.3600		-0.3145
2.7000	2.8010	-0.0374	0.6896		0.5300		0.1596	
2.8500	2.9590	-0.0382		0.0402		0.3200		-0.2798
3.0200	3.1150	-0.0315	0.6896		0.5700		0.1196	
3.2100	3.3330	-0.0383		0.0411		0.2900		-0.2489
3.4200	3.5210	-0.0295	0.6896		0.5800		0.1096	
3.6700	3.7810	-0.0302		0.0416		0.2850		-0.2434
3.9500	4.0240	-0.0187	0.6896		0.6000		0.0896	
4.2700	4.4050	-0.0316		0.0409		0.2250		-0.1841
4.6600	4.8080	-0.0318	0.6891		0.6500		0.0391	
5.1200	5.2910	-0.0334		0.0403		0.1700		-0.1297
5.6800	5.8650	-0.0326	0.6883		0.6500		0.0383	
6.4000	6.6010	-0.0314		0.0404		0.1250		-0.0846
7.3000	7.5360	-0.0323	0.6876		0.7250		-0.0374	
8.5200	8.6360	-0.0136		0.0401		0.1250		-0.0848
10.2000	9.4790	0.0707	0.6872		0.6900		-0.0028	
XXXXX	11.1100	XXXXX	XXXXX		0.5000		XXXXX	
XXXXX	12.6600	XXXXX		XXXXX		0.1200		XXXXX

WAVELENGTH ERRORS

AVERAGE	-0.0262	DEVIATION	0.0253

REFLECTIVITY ERRORS

AVERAGE	0.1356	DEVIATION	0.2435

SAMPLE 5B PERFORMANCE SUMMARY

MATERIAL GE
SUBSTRATE GLASS
THICKNESS 3.0200 MICRONS
DEPOSITION RATE 820 ANGSTROMS / MINUTE
SPUTTER GAS PRESSURE 9 MICRONS MERCURY

WAVELENGTH (MICRONS) THEORETICAL	MEASURED	ERROR DW / W	REFLECTIVITY (NORMALIZED) THEORETICAL MAX	THEORETICAL MIN	MEASURED MAX	MEASURED MIN	ERROR DR MAX	ERROR DR MIN
2.0200	XXXXX	XXXXX	0.0529		XXXXX		XXXXX	
2.1100	XXXXX	XXXXX	0.6893		XXXXX		XXXXX	
2.2100	XXXXX	XXXXX	0.0414		XXXXX		XXXXX	
2.3100	XXXXX	XXXXX	0.6891		XXXXX		XXXXX	
2.4300	XXXXX	XXXXX	0.0403		XXXXX		XXXXX	
2.5600	2.5060	0.0211	0.6894		0.6100		0.0794	
2.7000	2.6250	0.0278	0.0403		0.3100		-0.2697	
2.8600	2.7400	0.0420	0.6895		0.5600		0.1295	
3.0400	2.8990	0.0464	0.0418		0.2900		-0.2482	
3.2400	3.0670	0.0534	0.6896		0.5900		0.0996	
3.4700	3.2680	0.0582	0.0401		0.2300		-0.1899	
XXXXX	3.4480	XXXXX	XXXXX		0.6200		XXXXX	
XXXXX	3.6900	XXXXX	XXXXX		0.2500		XXXXX	
3.7400	3.9760	-0.0631	0.6896		0.6300		0.0596	
4.0500	4.2920	-0.0598	0.0402		0.1900		-0.1498	
4.4100	4.7170	-0.0696	0.6893		0.6700		0.0193	
4.8500	5.1700	-0.0660	0.0402		0.1250		-0.0848	
5.3800	5.7300	-0.0651	0.6885		0.6600		0.0285	
6.0600	6.4400	-0.0627	0.0403		0.0800		-0.0397	
6.9200	7.4300	-0.0737	0.6877		0.7300		-0.0423	
8.0600	8.4600	-0.0496	0.0401		0.0800		-0.0399	
9.6500	9.3500	0.0311	0.6872		0.7400		-0.0528	
XXXXX	11.1100	XXXXX	XXXXX		0.4500		XXXXX	
12.1000	XXXXX	XXXXX	0.0402		XXXXX		XXXXX	
XXXXX	12.4700	XXXXX	XXXXX		0.1000		XXXXX	

WAVELENGTH ERRORS
AVERAGE -0.0153 DEVIATION 0.0527

REFLECTIVITY ERRORS
AVERAGE 0.1022 DEVIATION 0.1907

SAMPLE 6-2 PERFORMANCE SUMMARY

MATERIAL	GE
SUBSTRATE	GLASS
THICKNESS	2.8042 MICRONS
DEPOSITION RATE	830 ANGSTROMS / MINUTE
SPUTTER GAS PRESSURE	10 MICRONS MERCURY

WAVELENGTH (MICRONS)		ERROR	REFLECTIVITY (NORMALIZED)				ERROR	
THEORETICAL	MEASURED	DW / W	THEORETICAL		MEASURED		DR	
			MAX	MIN	MAX	MIN	MAX	MIN
2.0500	XXXXX	XXXXX	0.0402		XXXXX		XXXXX	
2.1500	XXXXX	XXXXX	0.6895		XXXXX		XXXXX	
2.2600	XXXXX	XXXXX	0.0476		XXXXX		XXXXX	
2.3700	XXXXX	XXXXX	0.6890		XXXXX		XXXXX	
2.5100	2.5840	-0.0295	0.0437		0.1700		-0.1263	
2.6500	2.7250	-0.0283	0.6894		0.5800		0.1093	
2.8200	2.8900	-0.0248	0.0401		0.1500		-0.1099	
3.0100	3.0900	-0.0266	0.6895		0.5800		0.1095	
3.2200	3.3000	-0.0248	0.0406		0.1200		-0.0794	
3.4700	3.5500	-0.0231	0.6896		0.5900		0.0996	
3.7600	3.8300	-0.0186	0.0401		0.1100		-0.0699	
4.1000	4.1600	-0.0146	0.6895		0.6000		0.0895	
4.5100	4.5700	-0.0133	0.0402		0.0900		-0.0498	
XXXXX	5.0600	XXXXX	XXXXX		0.6200		XXXXX	
5.6200	5.7000	-0.0142	0.0404		0.0700		-0.0296	
6.4200	6.5400	-0.0187	0.6879		0.6500		0.0379	
7.4800	7.5500	-0.0094	0.0403		0.0300		0.0103	
XXXXX	8.7700	XXXXX	XXXXX		0.7900		XXXXX	
XXXXX	10.2600	XXXXX	XXXXX		0.1500		XXXXX	

WAVELENGTH ERRORS

AVERAGE	-0.0205	DEVIATION	0.0063

REFLECTIVITY ERRORS

AVERAGE	0.0768	DEVIATION	0.1148

SAMPLE 7-2 PERFORMANCE SUMMARY

MATERIAL	GE
SUBSTRATE	GLASS
THICKNESS	2.3481 MICRONS
DEPOSITION RATE	970 ANGSTROMS / MINUTE
SPUTTER GAS PRESSURE	10 MICRONS MERCURY

WAVELENGTH (MICRONS)		ERROR	REFLECTIVITY (NORMALIZED)				ERROR	
THEORETICAL	MEASURED	DW / W	THEORETICAL		MEASURED		DR	
			MAX	MIN	MAX	MIN	MAX	MIN
2.1000	XXXXX	XXXXX	0.0408		XXXXX		XXXXX	
2.2200	XXXXX	XXXXX	0.6895		XXXXX		XXXXX	
2.3600	XXXXX	XXXXX	0.0403		XXXXX		XXXXX	
2.5200	2.6100	-0.0357	0.6896		0.6300		0.0596	
2.7000	2.7900	-0.0333	0.0405		0.1200		-0.0795	
2.9100	3.0300	-0.0412	0.6894		0.6100		0.0794	
3.1500	3.2400	-0.0286	0.0404		0.1100		-0.0696	
3.4300	3.5300	-0.0292	0.6895		0.6300		0.0595	
3.7800	3.8800	-0.0265	0.0403		0.0900		-0.0497	
4.2000	4.5000	-0.0714	0.6894		0.6200		0.0694	
4.7200	4.8100	-0.0191	0.0402		0.0600		-0.0198	
5.3800	5.5400	-0.0297	0.6886		0.6700		0.0186	
6.2800	6.3900	-0.0175	0.0402		0.0400		0.0002	
7.5200	8.1300	-0.0811	0.6875		0.7500		-0.0625	
9.4000	9.0900	0.0330	0.0401		0.0010		0.0391	
XXXXX	12.2700	XXXXX	XXXXX		0.6000		XXXXX	

WAVELENGTH ERRORS

AVERAGE	-0.0317	DEVIATION	0.0270

REFLECTIVITY ERRORS

AVERAGE	0.0506	DEVIATION	0.0731

SAMPLE 8-2 PERFORMANCE SUMMARY

MATERIAL	GE
SUBSTRATE	GLASS
THICKNESS	1.7950 MICRONS
DEPOSITION RATE	510 ANGSTROMS / MINUTE
SPUTTER GAS PRESSURE	5 MICRONS MERCURY

WAVELENGTH (MICRONS)		ERROR	REFLECTIVITY (NORMALIZED)			
THEORETICAL	MEASURED	DW / W	THEORETICAL		MEASURED		ERROR DR	
			MAX	MIN	MAX	MIN	MAX	MIN
2.0600	XXXXX	XXXXX	0.0416		XXXXX		XXXXX	
2.2200	XXXXX	XXXXX	0.6896		XXXXX		XXXXX	
2.4100	XXXXX	XXXXX	0.0417		XXXXX		XXXXX	
2.6300	XXXXX	XXXXX	0.6894		XXXXX		XXXXX	
2.8900	2.6500	0.0830	0.0404		0.1500		-0.1096	
3.2100	2.9400	0.0841	0.6896		0.6900		-0.0004	
3.6100	3.2800	0.0914	0.0401		0.1100		-0.0699	
4.1200	3.7500	0.0898	0.6895		0.7100		-0.0205	
4.8100	4.3500	0.0956	0.0401		0.0700		-0.0298	
5.7600	5.2200	0.0938	0.6883		0.7200		-0.0317	
7.2000	6.5100	0.0958	0.0402		0.0300		0.0102	
9.6000	8.7000	0.0938	0.6872		0.8400		-0.1528	
XXXXX	12.4200	XXXXX	XXXXX		0.0900		XXXXX	

WAVELENGTH ERRORS

AVERAGE	0.0909	DEVIATION	0.0046

REFLECTIVITY ERRORS

AVERAGE	0.0531	DEVIATION	0.1163

SAMPLE 9-2 PERFORMANCE SUMMARY

MATERIAL	GE
SUBSTRATE	GLASS
THICKNESS	2.7266 MICRONS
DEPOSITION RATE	545 ANGSTROMS / MINUTE
SPUTTER GAS PRESSURE	15 MICRONS MERCURY

WAVELENGTH (MICRONS) THEORETICAL	WAVELENGTH (MICRONS) MEASURED	ERROR DW / W	REFLECTIVITY (NORMALIZED) THEORETICAL MAX	REFLECTIVITY (NORMALIZED) THEORETICAL MIN	REFLECTIVITY (NORMALIZED) MEASURED MAX	REFLECTIVITY (NORMALIZED) MEASURED MIN	ERROR DR MAX	ERROR DR MIN
2.1900	XXXXX	XXXXX	0.0442		XXXXX		XXXXX	
2.3100	XXXXX	XXXXX	0.6896		XXXXX		XXXXX	
2.4400	XXXXX	XXXXX	0.0427		XXXXX		XXXXX	
2.5800	XXXXX	XXXXX	0.6896		XXXXX		XXXXX	
XXXXX	2.6100	XXXXX	XXXXX		0.1500		XXXXX	
XXXXX	2.7700	XXXXX	XXXXX		0.5100		XXXXX	
2.7400	2.8200	-0.0292	0.0404		0.2100		-0.1696	
2.9200	XXXXX	XXXXX	0.6894		XXXXX		XXXXX	
3.1300	XXXXX	XXXXX	0.0410		XXXXX		XXXXX	
3.3700	3.2200	0.0445	0.6895		0.5100		0.1795	
3.6600	3.5000	0.0437	0.0413		0.1500		-0.1087	
3.9900	3.8000	0.0476	0.6896		0.4700		0.2196	
4.3800	4.1700	0.0479	0.0405		0.0700		-0.0295	
4.8700	4.6100	0.0534	0.6890		0.4300		0.2590	
5.4800	5.1400	0.0620	0.0409		0.0500		-0.0091	
6.2400	5.8700	0.0593	0.6880		0.4900		0.1980	
7.2800	6.7800	0.0687	0.0401		0.0500		-0.0099	
8.7400	8.2600	0.0549	0.6873		0.6900		-0.0027	
XXXXX	9.2800	XXXXX	XXXXX		0.0010		XXXXX	
XXXXX	10.2000	XXXXX	XXXXX		0.3900		XXXXX	
10.9000	XXXXX	XXXXX	0.0402		XXXXX		XXXXX	
XXXXX	11.0300	XXXXX	XXXXX		0.2700		XXXXX	

WAVELENGTH ERRORS			
AVERAGE	0.0453	DEVIATION	0.0260
REFLECTIVITY ERRORS			
AVERAGE	0.1136	DEVIATION	0.1562

SAMPLE 10-2 PERFORMANCE SUMMARY

MATERIAL	GE
SUBSTRATE	GLASS
THICKNESS	3.1339 MICRONS
DEPOSITION RATE	520 ANGSTROMS / MINUTE
SPUTTER GAS PRESSURE	10 MICRONS MERCURY

WAVELENGTH (MICRONS) THEORETICAL	MEASURED	ERROR DW / W	REFLECTIVITY (NORMALIZED) THEORETICAL MAX	THEORETICAL MIN	MEASURED MAX	MEASURED MIN	ERROR DR MAX	ERROR DR MIN
2.0200	XXXXX	XXXXX	0.6887		XXXXX		XXXXX	
2.1000	XXXXX	XXXXX		0.0404		XXXXX		XXXXX
2.1900	XXXXX	XXXXX	0.6894		XXXXX		XXXXX	
2.2900	XXXXX	XXXXX		0.0413		XXXXX		XXXXX
2.4000	XXXXX	XXXXX	0.6896		XXXXX		XXXXX	
2.5200	XXXXX	XXXXX		0.0403		XXXXX		XXXXX
2.6500	2.6000	0.0189	0.6893		0.5200		0.1693	
2.8000	2.7400	0.0214		0.0402		0.1500		-0.1098
2.9700	2.8900	0.0269	0.6893		0.5000		0.1893	
3.1500	3.0800	0.0222		0.0402		0.1500		-0.1098
3.3600	3.2800	0.0238	0.6896		0.5000		0.1896	
3.6000	3.5000	0.0278		0.0402		0.1300		-0.0898
3.8800	3.7600	0.0309	0.6896		0.5200		0.1696	
4.2000	4.0700	0.0310		0.0401		0.1300		-0.0899
4.5800	4.4400	0.0306	0.6892		0.5200		0.1692	
5.0400	4.8400	0.0397		0.0408		0.1000		-0.0592
5.5800	5.4500	0.0233	0.6883		0.5500		0.1383	
6.2800	6.0500	0.0366		0.0401		0.0700		-0.0299
7.1600	6.9700	0.0292	0.6876		0.5900		0.0976	
8.3600	8.0000	0.0431		0.0402		0.0100		0.0302
10.0500	9.0100	0.1035	0.6872		0.7100		-0.0228	
XXXXX	10.2600	XXXXX		XXXXX		0.1900		XXXXX

WAVELENGTH ERRORS			
AVERAGE	0.0339	DEVIATION	0.0197
REFLECTIVITY ERRORS			
AVERAGE	0.1110	DEVIATION	0.1354

SAMPLE 11-2 PERFORMANCE SUMMARY

MATERIAL	ZNSE
SUBSTRATE	GLASS
THICKNESS	2.5470 MICRONS
DEPOSITION RATE	395 ANGSTROMS / MINUTE
SPUTTER GAS PRESSURE	5 MICRONS MERCURY

WAVELENGTH (MICRONS)		ERROR	REFLECTIVITY (NORMALIZED)				ERROR	
THEORETICAL	MEASURED	DW / W	THEORETICAL		MEASURED		DR	
			MAX	MIN	MAX	MIN	MAX	MIN
2.0700	XXXXX	XXXXX	0.0406		XXXXX		XXXXX	
2.2500	XXXXX	XXXXX	0.3553		XXXXX		XXXXX	
2.4800	XXXXX	XXXXX	0.0401		XXXXX		XXXXX	
2.7500	2.7200	0.0109	0.3553		0.3000		0.0553	
3.1000	3.1100	-0.0032	0.0401		0.0500		-0.0099	
3.5400	3.5500	-0.0028	0.3555		0.3100		0.0455	
4.1300	4.1200	0.0024	0.0401		0.0400		0.0001	
4.9500	4.9500	0.0000	0.3545		0.3200		0.0345	
6.1800	6.1500	0.0049	0.0401		0.1500		-0.1099	
8.2000	8.9300	-0.0890	0.3501		0.5800		-0.2299	
XXXXX	9.6900	XXXXX	XXXXX		0.0010		XXXXX	
XXXXX	10.8900	XXXXX	XXXXX		0.1350		XXXXX	
XXXXX	12.1200	XXXXX	XXXXX		0.0650		XXXXX	

WAVELENGTH ERRORS			
AVERAGE	-0.0110	DEVIATION	0.0322

REFLECTIVITY ERRORS			
AVERAGE	0.0693	DEVIATION	0.1387

SAMPLE 12-2 PERFORMANCE SUMMARY

MATERIAL	ZNSE
SUBSTRATE	GLASS
THICKNESS	2.9801 MICRONS
DEPOSITION RATE	480 ANGSTROMS / MINUTE
SPUTTER GAS PRESSURE	10 MICRONS MERCURY

WAVELENGTH (MICRONS)		ERROR	REFLECTIVITY (NORMALIZED)			
THEORETICAL	MEASURED	DW / W	THEORETICAL		MEASURED		ERROR OR	
			MAX	MIN	MAX	MIN	MAX	MIN
2.0700	XXXXX	XXXXX	0.0403		XXXXX		XXXXX	
2.2300	XXXXX	XXXXX	0.3554		XXXXX		XXXXX	
2.4200	2.4900	-0.0289	0.0403		0.0500		-0.0098	
2.6400	2.7000	-0.0227	0.3554		0.3100		0.0454	
2.9000	2.9900	-0.0310	0.0401		0.0400		0.0001	
3.2200	XXXXX	XXXXX	0.3554		XXXXX		XXXXX	
XXXXX	4.9500	XXXXX	XXXXX		0.3000		XXXXX	
3.6300	3.7200	-0.0248	0.0402		0.0350		0.0052	
4.1400	4.2600	-0.0290	0.3553		0.3200		0.0353	
4.8300	4.9600	-0.0269	0.0401		0.0200		0.0201	
5.7800	5.9600	-0.0311	0.3535		0.3400		0.0135	
7.2200	7.4300	-0.0291	0.0401		0.0001		0.0400	
9.5500	8.9300	0.0649	0.3480		0.5800		-0.2320	
XXXXX	10.4900	XXXXX	XXXXX		0.0750		XXXXX	
XXXXX	11.6300	XXXXX	XXXXX		0.1500		XXXXX	
XXXXX	13.4200	XXXXX	XXXXX		0.0530		XXXXX	

WAVELENGTH ERRORS

AVERAGE	-0.0176	DEVIATION	0.0293

REFLECTIVITY ERRORS

AVERAGE	0.0446	DEVIATION	0.0970

SAMPLE 13-2 PERFORMANCE SUMMARY

MATERIAL	ZNSE
SUBSTRATE	GLASS
THICKNESS	2.6647 MICRONS
DEPOSITION RATE	320 ANGSTROMS / MINUTE
SPUTTER GAS PRESSURE	15 MICRONS MERCURY

WAVELENGTH (MICRONS)		ERROR	REFLECTIVITY (NORMALIZED)				ERROR	
THEORETICAL	MEASURED	DW / W	THEORETICAL		MEASURED		DR	
			MAX	MIN	MAX	MIN	MAX	MIN
2.1600	XXXXX	XXXXX	0.0402		XXXXX		XXXXX	
2.3600	2.5100	-0.0636	0.3554		0.3200		0.0354	
2.5900	2.7500	-0.0618	0.0404		0.0400		0.0004	
2.8800	3.0700	-0.0660	0.3554		0.2800		0.0754	
3.2400	3.4500	-0.0648	0.0401		0.0200		0.0201	
3.7100	3.9400	-0.0620	0.3554		0.3100		0.0454	
4.3200	4.5700	-0.0579	0.0401		0.0200		0.0201	
5.1800	5.4200	-0.0463	0.3543		0.3300		0.0243	
6.4600	6.8700	-0.0635	0.0401		0.0001		0.0400	
8.5800	8.5500	0.0035	0.3496		0.5900		-0.2404	
XXXXX	10.2000	XXXXX	XXXXX		0.0300		XXXXX	
XXXXX	11.2400	XXXXX	XXXXX		0.1100		XXXXX	
12.7500	12.5500	0.0157	0.0401		0.0400		0.0001	

WAVELENGTH ERRORS

AVERAGE	-0.0467	DEVIATION	0.0287

REFLECTIVITY ERRORS

AVERAGE	0.0502	DEVIATION	0.0964

SAMPLE 14-2 PERFORMANCE SUMMARY

MATERIAL	ZNSE-GE
SUBSTRATE	GLASS
THICKNESS	1.5407 -.9384 MICRONS
DEPOSITION RATE	Aprox. 375 ANGSTROMS / MINUTE
SPUTTER GAS PRESSURE	10 MICRONS MERCURY

WAVELENGTH (MICRONS) THEORETICAL	WAVELENGTH (MICRONS) MEASURED	ERROR DW / W	REFLECTIVITY (NORMALIZED) THEORETICAL MAX	REFLECTIVITY (NORMALIZED) THEORETICAL MIN	REFLECTIVITY (NORMALIZED) MEASURED MAX	REFLECTIVITY (NORMALIZED) MEASURED MIN	ERROR DR MAX	ERROR DR MIN
2.5000	XXXXX	XXXXX	0.0401		XXXXX		XXXXX	
2.7500	2.5600	0.0691	0.5732		0.4100		0.1632	
XXXXX	2.8000	XXXXX	XXXXX		0.1700		XXXXX	
XXXXX	2.9600	XXXXX	XXXXX		0.6200		XXXXX	
3.0000	XXXXX	XXXXX	0.3693		XXXXX		XXXXX	
3.3000	2.9600	0.1030	0.5734		0.6200		-0.0466	
XXXXX	3.7200	XXXXX	XXXXX		0.4400		XXXXX	
3.7500	3.4900	0.0693	0.0401		0.3600		-0.3199	
4.3400	XXXXX	XXXXX	0.5730		XXXXX		XXXXX	
XXXXX	5.0100	XXXXX	XXXXX		0.6400		XXXXX	
5.0000	5.7900	-0.1590	0.3692		0.3400		0.0292	
5.6800	5.5600	-0.1156	0.5718		0.5500		0.0218	
7.4500	8.1800	-0.0955	0.0401		0.0200		0.0201	
10.2000	9.3000	0.0882	0.5671		0.6500		-0.0829	
XXXXX	10.5000	XXXXX	XXXXX		0.4200		XXXXX	
XXXXX	12.0000	XXXXX	XXXXX		0.5500		XXXXX	

WAVELENGTH ERRORS
AVERAGE -0.0058 DEVIATION 0.1038

REFLECTIVITY ERRORS
AVERAGE 0.0977 DEVIATION 0.1864

SAMPLE 15-1 PERFORMANCE SUMMARY

MATERIAL ZNSE-GE
SUBSTRATE GLASS
THICKNESS 1.5407-.9324 MICRONS
DEPOSITION RATE APROX. 375 ANGSTROMS / MINUTE
SPUTTER GAS PRESSURE 10 MICRONS MERCURY

WAVELENGTH (MICRONS) THEORETICAL	MEASURED	ERROR DW / W	REFLECTIVITY (NORMALIZED) THEORETICAL MAX	THEORETICAL MIN	MEASURED MAX	MEASURED MIN	ERROR DR MAX	ERROR DR MIN
2.5000	2.5900	-0.0360	0.0401		0.3500		-0.3099	
XXXXX	2.6800	XXXXX	XXXXX		0.2800		XXXXX	
2.7500	XXXXX	XXXXX	0.3732		XXXXX		XXXXX	
3.0000	XXXXX	XXXXX		0.3693		XXXXX		XXXXX
3.3000	3.0500	0.0758	0.5734		0.6300		-0.0566	
XXXXX	3.4500	XXXXX		XXXXX		0.2300		XXXXX
XXXXX	3.6600	XXXXX	XXXXX		0.3500		XXXXX	
3.7500	4.0200	-0.0720		0.0401		0.1800		-0.1399
4.3400	4.8300	-0.1129	0.5730		0.6500		-0.0770	
5.0000	5.7100	-0.1420		0.3692		0.2300		0.0792
5.8800	6.5500	-0.1139	0.5718		0.4600		0.1118	
7.4600	8.0000	-0.0724		0.0401		0.0100		0.0301
10.2000	9.1700	0.1010	0.5671		0.7000		-0.1329	
XXXXX	10.6000	XXXXX		XXXXX		0.4500		XXXXX
XXXXX	11.9000	XXXXX	XXXXX		0.5500		XXXXX	

WAVELENGTH ERRORS
AVERAGE -0.0465 DEVIATION 0.0838

REFLECTIVITY ERRORS
AVERAGE 0.1172 DEVIATION 0.2202

SAMPLE 16-2 PERFORMANCE SUMMARY

MATERIAL	ZNSE-GE
SUBSTRATE	GLASS
THICKNESS	1.5407-.9324 MICRONS
DEPOSITION RATE	APROX. 375 ANGSTROMS / MINUTE
SPUTTER GAS PRESSURE	10 MICRONS MERCURY

WAVELENGTH (MICRONS) THEORETICAL	MEASURED	ERROR DW / W	REFLECTIVITY (NORMALIZED) THEORETICAL MAX	THEORETICAL MIN	MEASURED MAX	MEASURED MIN	ERROR DR MAX	ERROR DR MIN
2.5000	2.7300	-0.0920		0.0401		0.0600		-0.0199
2.7500	XXXXX	XXXXX	0.5732		XXXXX		XXXXX	
3.0000	XXXXX	XXXXX		0.3693		XXXXX		XXXXX
3.3000	3.5500	-0.0756	0.5734		0.6700		-0.0966	
3.7500	4.0600	-0.0827		0.0401		0.2100		-0.1699
4.3400	4.7100	-0.0853	0.5730		0.4600		0.1130	
5.0000	5.3200	-0.0640		0.3692		0.2400		0.1292
5.6800	6.4500	-0.0969	0.5718		0.5400		0.0318	
7.4500	7.9700	-0.0684		0.0401		0.1500		-0.1099
XXXXX	8.9700	XXXXX	XXXXX		0.3900		XXXXX	
XXXXX	9.9500	XXXXX		XXXXX		0.0300		XXXXX

WAVELENGTH ERRORS			
AVERAGE	-0.0807	DEVIATION	0.0112
REFLECTIVITY ERRORS			
AVERAGE	0.0959	DEVIATION	0.1553