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Student Project Work in Thin-Film Measurement Systems

By F. L. Jones

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Topical Report

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STUDENT PROJECT WORK IN THIN-FILM
MEASUREMENT SYSTEMS

By F. L. Jones

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Topical Report
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STUDENT PROJECT WORK IN THIN-FILM MEASUREMENT SYSTEMS

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Prepared by F. L. Jones

In summer 1980, an engineering student took part in the development of thin-film thickness measurement systems. His responsibilities included updating a beta-backscatter system operator's manual, conducting a statistical analysis on beta-backscatter equipment, and designing a fixture to improve equipment photolithography techniques. Other work consisted of observations of a television monitoring system and the interface of a microprocessor and computer.

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SUMMARY

The student's summer engineering work was limited in scope and consisted primarily of supervised work on a beta-backscatter system. His responsibilities included updating an equipment operator's manual, performing a statistical analysis to evaluate system capabilities, and designing a fixture to improve beta-backscatter photolithography techniques.

The operator's manual contains listings of current backscatter operating procedures and a section on troubleshooting. The statistical analysis, which was carried out on a blank part with a polyimide film layer, indicated improved accuracy in thickness measurement. The analysis was conducted on 30 test points with five calibrations and three measurements taken for each part. Other work on the backscatter system consisted of an experiment to determine the amount of thickness variation across the surfaces of standards used in calibration of the backscatter. The experiment indicated a significant amount of variation on these surfaces.

A fixture was designed to improve photolithography techniques. This fixture uses mercury lamps to expose different parts of complex geometrics. Other work consisted of observing functions of a closed-circuit television image analysis system.

DISCUSSION

SCOPE AND PURPOSE

The purpose of this summer work was to familiarize a student engineer with engineering responsibilities and the general operations of an engineering group. The work included the creation of operating procedures and a statistical analysis on a beta-backscatter system. Additional work was done on the design of a fixture that uses new exposure techniques in photolithography. Observational work was conducted on image analysis instrumentation, along with other engineering activities.

PRIOR WORK

The present beta-backscatter system has been in operation for two years at Bendix Kansas City. Several capability studies had been conducted and an operator's manual was assembled in the past, but recent systems modifications prompted completing an updated study and a new detailed operator's manual during this work period. Photolithographic fixtures of Bendix Kansas City have been using similar exposure techniques for about 12 years, but the fabrication of several new parts requires more efficient and versatile exposure techniques.

ACTIVITY

A new operator's manual was assembled for a beta-backscatter system. The manual contains a list of recently modified procedures. In addition to the operating procedures, a trouble-shooting section contains a list of solutions to common problems encountered during regular usage of the system. The manual also contains a procedure reconfiguring for different parts measurement. A list of the topics contained in the manual is shown in Figure 1 (Table of Contents).

A capability study was completed on the present beta-backscatter metallic film thickness measurement system. The study was conducted on a 50-cm-diameter blank part with an aluminum film deposited on a polyimide film. There were 30 test points for each measurement and five system calibrations in the study. Three measurements were taken under each calibration. The estimated total error (one standard deviation) for the equipment was $\pm 0.0714 \mu\text{m}$. This value is a significant improvement of the previous $0.0713 \mu\text{m}$. The total error was broken down into two

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Figure 1. Beta-backscatter Operator's
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components: calibrations and replications. The estimated calibration component was $\pm 0.0214 \mu\text{m}$ which was not statistically significantly smaller than the $\pm 0.0354 \mu\text{m}$ of the previous study. The estimated replication component was $\pm 0.0680 \mu\text{m}$, which was an improvement from the previous estimate of $\pm 0.0739 \mu\text{m}$. The inability of the beta-backscatter equipment to repeat a measurement is still the largest error component, but overall, the system has improved its accuracy. Statistical estimates of error components for each of the thirty positions were tabulated and are in Table 1. This between-positions data within the part may be compared to the part's averages in the 15 replications of the study, as shown in Table 2.

Work on the beta-backscatter system also included an experiment on the standards of the calibration procedure. The experiment consisted of rotating the off-center aluminum standards in their holders after each measurement. The standards were rotated in 45° intervals. The purpose of the experiment was to map the variation in the thickness measured over the surface of the standards. The results indicated significant variation on the standards surfaces, which could affect the entire calibration of the beta-backscatter. Graphs of two standards are mapped in Figures 2 and 3.

In addition to the beta-backscatter work, preliminary design concept work was done on a fixture that would use new exposure techniques in photolithography.

The purpose of this design work was to create a fixture that would allow optimum exposure for several parts in one fixture instead of the present system, which requires three separate exposure fixtures. Two designs were considered for the fixture. One design incorporates two mercury lamps and two mirrors in a photolithographic fixture. The mirrors were to be positioned at an angle to the adjustable lamps attached to the fixture wall. One set of mirrors and lamp is at the top and the other set is at the bottom, as shown in Figure 4. This technique would have exposed the entire part as it turned on a rotating table, but was discarded because of the difficulty in positioning the mirror. The second design consisted of adjustable mercury lamps and a rotary table. These adjustable lamps would be positioned in the top and bottom of the fixture. This technique involved rotation of the part on the rotary table, the mercury lamps exposing the part as it moved in an arch-like path during the exposure period (Figure 5). This technique is similar to the present exposure techniques of photolithography.

The final activities of the summer period included observations on the instrumentation of an image analysis system and on a microprocessor. This observational work on the image analysis

Table 1. Estimates of Measurement Error Components

Calibration			Repeats		Total
Position	μm	Percent of Total Variance	μm	Percent of Total Variance	μm
1	0	0	0.08596	100	0.08596
2	0	0	0.05913	100	0.05913
3	0.04358	57.24	0.03766	42.76	0.05760
4	0.01595	6.13	0.06240	93.87	0.06440
5	0.01868	4.11	0.09026	95.89	0.09217
6	0	0	0.06850	100	0.06850
7	0	0	0.04934	100	0.04934
8	0.02661	12.57	0.07017	87.43	0.07505
9	0	0	0.06389	100	0.0638
10	0	0	0.07372	100	0.0737
11	0.02658	31.33	0.03936	68.67	0.04750
12	0	100	0.07002	100	0.07002
13	0	0	0.05215	100	0.05215
14	0	0	0.08736	100	0.08736
15	0.02599	11.16	0.07333	88.84	0.07780
16	0.01882	10.55	0.05483	89.45	0.05797
17	0	0	0.06099	100	0.06099
18	0.92611	13.89	0.06500	86.11	0.07005
19	0	0	0.07721	100	0.07721
20	0	0	0.08200	100	0.08200
21	0.03589	21.14	0.06932	78.86	0.07806
22	0.02955	14.98	0.07038	85.02	0.07633
23	0	0	0.06240	100	0.06240
24	0	0	0.07272	100	0.07272
25	0	0	0.07628	100	0.07628
26	0.01317	2.68	0.07930	97.32	0.08039
27	0.03289	24.35	0.05798	75.65	0.06666
28	0	0	0.07408	100	0.07408
29	0	0	0.06477	100	0.06477
30	0.02312	15.81	0.05336	84.10	0.05815
Equipment	.02137	8.99	.06799	91.01	.07127

Table 2. Average Part Thickness Data

Measurement	Average Thickness (μm)	Standard Deviation (μm)
Calibration 1		
1	11.2421	0.0810
2	11.2633	0.1162
3	11.2877	0.1185
Calibration 2		
1	11.2843	0.1171
2	11.2866	0.1047
3	11.2980	0.1098
Calibration 3		
1	11.2413	0.1064
2	11.2491	0.1338
3	11.2536	0.1079
Calibration 4		
1	11.2563	0.1173
2	11.2699	0.1124
3	11.3113	0.1222
Calibration 5		
1	11.2095	0.1000
2	11.2399	0.1081
3	11.2558	0.0992

Figure 2. Thickness Variation Across Second Standard

Figure 3. Thickness Variation Across Third Standard

Figure 4. First Exposure Fixture Design

Figure 5. Second Exposure Fixture Design

system involved learning about the operation and the usage of the instrumentation, which employs closed-circuit television to inspect miniature electronic circuitry. Microprocessor work involved gaining experience in the design and operating procedures and exposure to its capabilities. Other work consisted of designing and troubleshooting.

ACCOMPLISHMENTS

A detailed operator's manual and a capability study were completed on a beta-backscatter system. An experiment conducted on the beta-backscatter system that evaluated the calibration procedure standards of the system determined the amount of variation in the thicknesses as measured across the surface of the standards.

Two design concepts were surveyed for a fixture that employs improved photolithography exposure techniques. The student learned about instrumentation of image analysis systems microprocessors and gained experience in general engineering techniques such as designing and troubleshooting. This experience was beneficial for repairing a computer.

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SPECIAL PROJECTS: Beta-backscatter System

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