THE EVALUATION AND IMPROVEMENT OF SEM INSPECTION TASK IN SEMICONDUCTORS INDUSTRY

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Abstract: Scanning Electron Microscope (SEM) station is one of the main quality control tasks in wafer manufacturing process. The effects of wafer coating condition (non-coating wafer and gold-coated wafer) and LCD monitor size (35.6 cm (14-inch) and 48.3 cm (19-inch) diagonal monitor) on objective visual fatigue measure (critical flicker fusion (CFF) frequency), subjective eye fatigue rating and task performance were evaluated in this study. Twelve SEM inspectors participated in this study. The results indicated that the treatment of gold-coated wafer showed significant effect on reducing objective visual fatigue in CFF change. Using a 48.3 cm diagonal LCD also demonstrated the effect on reducing eye fatigue as well as improving task performance. It is recommended to use a gold-coated wafer and 48.3 cm diagonal LCD monitor to improve SEM inspectors’ visual fatigue problems and increase task performance.

1. INTRODUCTION

One purpose of SEM inspection in semiconductor manufacturing process is to inspect the quality of etching process. Every several lots of wafers after etching in a routine process, the etching shape on a wafer surface have to be measured to monitor the process and enhance yield. When the results of SEM inspection failed for two consecutive times, the same lot of wafers would be discarding, the etching equipment need to conduct maintenance again or the process parameter need to be adjusted. The SEM inspection procedure includes putting wafer sample into a SEM chamber, searching and focusing the edge of etching shape from a monitor, and calculating the shape depth and width with a software.

In optical microscope inspection, eye fatigue, neck, wrist, and back area discomfort of inspector reduced by examining defects on a liquid crystal display (LCD) as comparing to cathode ray tube (CRT) (Wang and Huang, 2004). The semiconductor industry in Taiwan adopted a 12-h work shift system, and the prolonged use of monitor tends to cause eye fatigue problems (Hsu and Wang, 2003). From a preliminary survey of SEM inspectors in this studying semiconductor manufacturing company, over 77% of the SEM inspectors frequently experienced the eye discomfort problems. The symptoms include eye dryness, tension, and gritting feeling. Thus, the objective of this study was to evaluate the effects of wafer coating condition and LCD monitor size on objective visual fatigue measures, subjective eye fatigue rating and task performance.

2. METHOD

An experiment was executed in a SEM inspection workstation of a semiconductor manufacturing company. Twelve female SEM inspectors from a semiconductor company participated in this study. The average age was 33 (± 6.3) years, average body height was 157.3 (± 5.8) cm and average body mass was 47.7 (± 5.6) kg. The average working experience in the wafer fab was 6.8 years. The average experience of the SEM inspectors was 2.4 years.

In SEM inspection, the inspector first takes an 8-inch wafer being produced from the previous station to the SEM station and takes down the product information. According to the specified sampling plan, including the positions of a sample need to be taken and how many samples need to be inspected from a wafer, the inspector divides the 8-inch wafer into several small pieces as inspecting samples. The samples are placed on a metal holder and put into the SEM vacuum. Next, the inspector starts to search and examine the etching shape of wafer surface, measures the depth and width of etching shape with specific magnifying power and records the results. The SEM inspection station used in the study was a Hitachi S-4700 SEM.

For the evaluation of the improved SEM inspection task, a two-factor two-level factorial design was employed. The two independent variables were wafer coating condition and monitor size. The wafer coating condition included non-coating wafer and gold-coated wafer. The test samples were taken from the same
wafer, then some samples were coated 30 second with gold in a sputter (Hitachi E-1030) and some were not. At the same time, a 35.6 cm (14-inch) diagonal LCD monitor and a 48.3 cm (19-inch) diagonal LCD monitor were both evaluated in this study.

The response measures included the following:

1) Objective visual strain measurement: The critical flicker fusion (CFF) frequency was measured to assess the inspector’s eye fatigue.
2) Subjective eye fatigue assessment: The subjective eye fatigue level was assessed by using a 1–20 (from no fatigue to extreme fatigue) rating scale.
3) Task performance: The number of samples that have been measured after each experiment condition was recorded.

Each SEM inspector was requested to participate four experimental sessions in two days. The experiment sequence of the four sessions was randomized. Prior to the experiment, the inspector was instructed about the purpose and procedure of this study. At the beginning of each experiment session, the objective eyestrain measurement was taken by using CFF (TAKEI TK502). This measurement was used as the baseline data for comparison. Each inspector then was asked to perform the SEM inspection task. After 50 minutes inspection task, the subjective and objective visual fatigue measures as well as task performance were taken. For CFF measurement, the difference between before and after the inspection experiment and the difference between before inspection and 5 minutes after inspection were analyzed. The experiment time for one session was about 1 hour.

3. RESULTS AND DISCUSSIONS

The ANOVA results are summarized in Table 1. The coating condition had significant effect on the difference in CFF between before and after the inspection ($F_{1,11} = 6.97; p < .05$), but was not significant on the difference in CFF between before inspection and 5 minutes after inspection, subjective eye fatigue rating, and task performance. The difference in CFF between before and after the inspection for the non-coated wafer (1.29 Hz) was significantly greater than the gold coated wafer (0.81 Hz).

On the other hand, the monitor size had significant effect on the difference in CFF between before and after the inspection ($F_{1,11} = 25.48; p < .001$), the difference in CFF between before inspection and 5 minutes after inspection ($F_{1,11} = 4.89; p < .05$), subjective eye fatigue rating ($F_{1,11} = 27.93; p < .001$), and task performance ($F_{1,11} = 16.34; p < .001$). Using a 19-inch LCD caused significantly less eyestrain in CFF difference than using a 14-inch LCD. The eyestrain was reduced about 18% and the task performance was improved 15% while inspectors used a 19-inch LCD than using a 14-inch LCD. The interaction effect between monitor size and wafer coating condition was not significant on all the measurements.

Table 1. The ANOVA Result and Mean Values of subjective, objective visual fatigue and task performance under the two independent variables

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>M</th>
<th>SD</th>
<th>M</th>
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<tr>
<td></td>
<td></td>
<td>CFF&lt;sub&gt;diff1&lt;/sub&gt; (Hz)</td>
<td></td>
<td>CFF&lt;sub&gt;diff2&lt;/sub&gt; (Hz)</td>
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<td>Eye fatigue (1–20 point)</td>
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<td>Monitor size</td>
<td></td>
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<tr>
<td>14-inch</td>
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<td>1.33***</td>
<td>0.92</td>
<td>0.97*</td>
<td>1.28</td>
<td>14.79**</td>
<td>1.71</td>
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<td>Non-coated</td>
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<td>0.84</td>
<td>0.39</td>
<td>1.06</td>
<td>12.87</td>
<td>2.73</td>
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*p < .05, *p < .01, ***p < .001. CFF<sub>diff1</sub> the difference of CFF between before and after inspection experiment; CFF<sub>diff2</sub> the difference of CFF between before inspection and 5 minutes rest after inspection.
Furthermore, Figure 1 shows the mean value of objective visual fatigue measures under four experiment conditions. The CFF changes were found to be greatest in a non-coated wafer with a 14-inch LCD monitor and the smallest value occurred when inspecting a coated wafer with a 19-inch monitor. The values of the other two conditions were similar. A 30% reduction on objective visual fatigue was found when inspecting a coated wafer with a 19-inch LCD monitor than inspecting a non-coated wafer with a 14-inch monitor. After 5 minutes rest, the value of CFF change was 0.06 by using a coated wafer with a 19-inch monitor. The objective eye fatigue measures show that the inspector’s eye fatigue almost recovered after 5 minutes rest.

Figure 2 shows the mean value of subjective eye fatigue and task performance under four experiment conditions. The greatest eye fatigue was happened on 14-inch monitor by non-coated wafer condition, followed by 14-inch monitor by coated wafer condition, 19-inch monitor by non-coated wafer condition, and the smallest was 19-inch monitor by coated wafer condition. The order for task performance was opposite. The performance was best by using a 19-inch monitor and coated wafer, and worst by using a 14-inch monitor and non-coated wafer. The viewing distance of using 19-inch LCD was longer than 14-inch LCD. The eyestrain decreased while the viewing distance changed from close to far. The boundary of target was more clearly by using gold-coated wafer and SEM operators could choose boundary easily and saved visual search time. Overall, using a gold-coated wafer with a 48.3 cm monitor can induce a 25% reduction in eye fatigue rating and a 25% increase in inspection performance.

4. CONCLUSION

The objective of this study was to improve SEM inspector’s visual fatigue and task performance. One experiment was designed to evaluate the effect of gold-coated treatment and display size. The study results showed that using gold-coated wafer significantly reduced objective visual fatigue. More, a 48.3 cm LCD produced less subjective, objective visual fatigue and higher task performance. It is recommended that the equipment engineers and manufacturing department at the company consider changing SEM workstation design to use the gold-coated wafer and a 48.3 cm LCD monitor to reduce visual fatigue and improve task performance.

5. REFERENCES


Figure 2. Mean values of eye fatigue rating and task performance under four experiment conditions.

Figure 1. Mean values of the difference in CFF between before and after the inspection (CFF differ-1) and the difference in CFF between before inspection and 5 minutes rest after inspection (CFF differ-2) under four experiment conditions.

Figure 2. Mean values of eye fatigue rating and task performance under four experiment conditions.