INTRODUCTION OF STATISTICAL DECISION MAKING AND MEASUREMENT CONTROL CHARTS INTO RIT CLEANROOM FACILITY

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ABSTRACT

A computer program was written that would enable the user to generate measurement control charts or make statistical decisions based on the means or variations of two sets of data. Statistical t-test and F-test results were obtained using an experimental example, indicate how this program could be used to aid in engineering decision making. Cleanroom parameters such as temperature, humidity and particle counts were obtained and plotted.

INTRODUCTION

There are a variety of situations when decisions concerning change are involved. You will need to make an evaluation if some new process method or policy has instituted a genuine change over the existing one. In certain situations a change may appear overwhelming, and it's often an open and shut case that something is different. In other cases however, it may appear that some improvement has been made, but it's not an overwhelming change. It is these situations where decision making becomes more difficult. A decision to endorse or institute a new procedure or process in such a situation, based on data from a small amount of samples, can be tricky business (1). A second important situation is to know when a process has changed significantly from its average operating point, so that steps may be taken to remedy the situation. Also, the source of the change must be determined as being either random flucuations or actual changes in a manufacturing process such as of deterioration of machine parts or mistakes of employees (2).

Statistical quality control methods allow us to obtain maximum benefit out of production and inspection data and at lower cost.In statistical quality control the "process" that is to be studied may be, a single fixture or element of a machine, a single human being or a single motion performed by a human being; a piece of test equipment or a method of measurement or assembly. In its narrowest sense, the term "process" refers to the operation of a single cause. In its broadest sense it may refer to the operation of a very complex "cause system"(3).

Many quality characteristics cannot be conveniently represented numerically. In such cases, each item inspected is classified as either conforming to specifications on that quality characteristic or nonconforming to specifications. Quality

characteristics of this type are called attributes. An example of quality characteristics that are attributes are the proportion of nonfunctional semi-conductor chips in a production run. This paragraph is presented for informational purposes only as this type of quality control will not be included in this study to any major degree.

A single measurable quality characteristic, such as a dimension, weight, or volume, is called a variable. When dealing with a quality characteristic that is a variable, it is standard practice to control both the mean value of the quality characteristic and its variability. Control of the process average or mean quality level is usually done with control charts for means, or the x-bar chart. Process variability or dispersion can be controlled with either a control chart for standard deviation called the S chart, or a control chart for the range, called the R chart. The R chart is more widely used. Usually separate x-bar and R charts are maintained for each variable of interest (dimension, volume or weight). The x and R (or S) charts is one of the most important and useful on-line statistical process-control techniques.

One of the principal benefits of control charts is that it is possible to determine scientifically, just where a process should run. Control charts tend to make the jobs of technical people easier. In addition, charts have a definite knowledge of the capability of the machine or process. This means that they have better answers to the questions which arise when something goes wrong. Also, they are one of the simplest methods for dealing with large amounts of sequential information.

Fluctuations in data obtained are caused by a large number of minute variations or differences: differences in materials, equipment, atmospheric conditions, the physical and mental reactions of people. It is possible to study differences by means of simple calculations based on well-known statistical laws. By making use of certain equations, derived from statistical laws it is possible to calculate "limits" for any given pattern. If a pattern is natural, its fluctuations will fit within these limits. If a pattern is unnatural, its flucuations will not fit these limits.

Almost any process will benefit by a control chart program. Presented below are some general guidelines which prove helpful in implementing control charts.

1. Choose the proper "type" (variable or attribute) of control charts.
2. Determine which process characteristics to control.
3. Determine where the charts should be implemented in the process.

These guidelines are applicable to both measurement and attribute control charts. However, control charts are not just for process surveillance as they can used as an active, on-line method for reduction of process variability.

Several methods from statistics are availible to aid in the study of change. The "t-test", which tests the differences between two means, and the F-test, which tests the differences between two variations, enable an engineer to decide, to a degree of certainty that is selected by the engineer, whether or not a genuine difference exists between one set of data and another. In the fabrication of semiconductor devices these decisions can be quite crucial.

EXPERIMENTAL

Five wafers were obtained and each was coated with Shipley microposit 1400-27 resist. Wafer 1 (control wafer) was coated using a spinspeed of 4000 rpm for 40 seconds, wafer 2 was coated using 3000 rpm for 40 seconds and wafers 3-5 were coated at 4000 rpm but for 10, 20 and 30 seconds respectively. The wafers were softbaked at 90 C for 20 minutes and exposed with approximately 60 mj/cm2 of energy. Please note that all wafers were exposed for the same amount of time and energy. The resist was patterned with the RIT/AMI resolution mask and the resulting linewidths (spaces and lines) were measured on the Nanoline III in the cleanroom facility. The measurement programs used were nanoline internal programs (ESP 4 and 5) and the 40x objective was used. For all wafers the 5 um and 25 um resist line and space patterns were measured. Also, 10 die per wafer were measured starting one die in from the edge an moving columnwise down 10 die towards the flat of the wafer. Thus, a total of 40 measurements per wafer were obtained.

The t-test program was tested by comparing the average resist linewidth of imaged wafers 1 and 2. These two wafers had different thicknesses of resist due to different spinspeeds but they were given the same exposure. In theory, the average linewidths should be different, the extent of the difference and its significance can be determined by the t-test.

The F-test program was tested by comparing the resist linewidth uniformity of imaged wafers 3, 4 and 5 coated for different apply times. In theory, the wafers spun for the for the least amount of time should have the worst resist thickness uniformity. Therefore, these wafers should have the worst linewidth uniformity. The differences in variation can be determined and compared with the F-test.

RESULTS/DISCUSSION

First of all it should be noted that no linewidths could be obtained from wafer 3. Therefore, the results from wafer 3 have been omitted.

The results of the t-test performed on wafers 1 and 2 show that for a confidence level of 95 % that the mean linewidth, for both the 5um and 25um (lines and spaces) was significantly different.

The results of the F-test performed on wafers 1 versus 4 and 1 versus 5 are tabulated below. A yes in the right most column indicates that there was significant linewidth variation between the wafers.

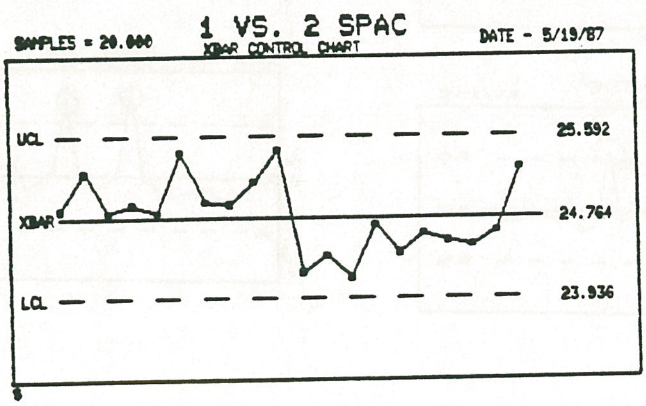
F-TEST RESULTS OF WAFERS 4,5 VERSUS 1 BY MASK LINEWIDTH

WAFER	MASK LINEWIDTH	SPIN TIME	F-TEST RESULTS
4	5 LINE	20 SEC	YES
4	5 SPACE	20 SEC	NO
4	25 LINE	20 SEC	YES
4	25 SPACE	20 SEC	YES
5	5 LINE	30 SEC	YES
5	5 SPACE	30 SEC	YES
5	25 LINE	30 SEC	NO
5	25 SPACE	30 SEC	NO

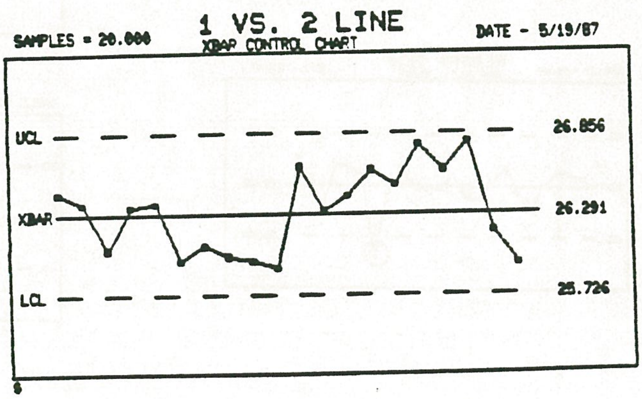
It can be seen from the above table that the only case in wafer 4 where the linewidth variation was not significantly greater than the control (wafer 1) was for the 5 um space. It can also be seen that for wafer 5, the linewidth variation of the 5 um features varied significantly more than the 25 um features when compared to wafer 1.

Control chart results for wafers 1 and 2 for the 25 um lines and spaces are presented on below.

X-BAR CONTROL CHART OF 25 UM RESIST LINEWIDTHS AND LINESPACES BY POSITION FOR WAFERS 1 AND 2



Wafer 1 versus Wafer 2
25 um resist spaces

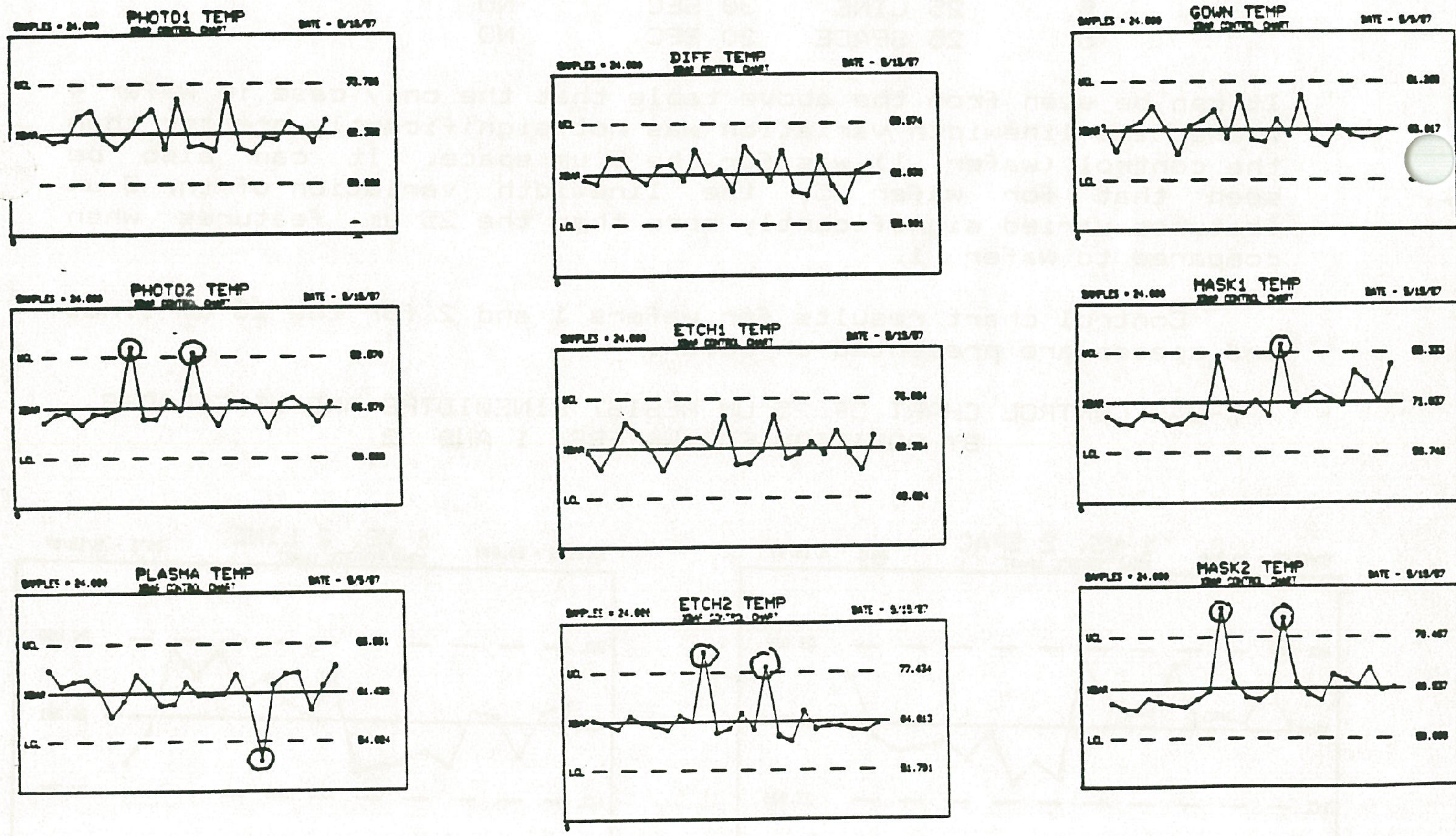


Wafer 1 versus Wafer 2
25 um resist lines

The x-bar control chart plots of the 25 um linewidth (lines and spaces) readings from wafers 1 and 2 show how the control chart can be used in conjunction with the statistical tests to make appropriate decisions. The first 10 readings on each chart are from wafer number 1 and the next 10 readings are from wafer 2. The dramatic change in linewidth is accentuated when using the control chart technique. In addition, the control chart shows a trend in linewidth measurements 9 and 10 for both wafers. These measurements were taken near the flat of each wafer. Since the increase in linewidth (decrease for spaces) occurs on both wafers, it seems likely that this may be a mask problem. In other words, rows 10 and 11 of this mask may have above nominal linewidths. A problem like this may not be as easily seen if the data is presented as a group of numbers.

As examples of monitoring cleanroom parameters, control chart results for the cleanroom temperature by area for the last 3 weeks of April are presented below. Out of control conditions are circled.

CONTROL CHARTS OF CLEANROOM TEMPERATURE BY FACILITY AREA



The current cleanroom temperature specification is 64 ± 2 C. The specification limits were not included on the charts in order to avoid confusion during interpretation.

CONCLUSIONS

The conclusions from the t-test and F-test experiments show that the results agree with the theory. The real value of the t-test and F-test comes from the type of conclusions that can be made. Furthermore, it can be seen from the control chart data that data presented in this fsahion is highly informational, simple to interpret and quick to understand.

ACKNOWLEDGEMENTS

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LITERATURE SEARCH

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