Application Note

DSA20060406

Signature Analysis and Filter

FEATURES

- Pre-process KLARF data
- Object Signature Recognition
- Feature Extraction
- Comparison to Set of Rules

Si-laz

Introduction

The **Signature Analyzer and Signature Filter** functions in DSA allow the user to define the parameters to identify object signatures in the KLARF data. An object signature is characterized by a set of rules or metadata that defines clusters of defects and describes them by shape, location, orientation and density properties. Object signatures defined in DSA may be saved in an object signature library. Object signature recognition is comprised of three steps:

1. Pre-process KLARF data, which consists of filtering by classification attributes and selection based on defect count;

2. Object signature recognition, which applies syntactical object rules to the defect data;

3. Post-process KLARF data, which consists of keeping, removing or classifying object signatures.

The object signature library may be used by AWB to identify individual object signatures (*see AWB Help - Process Object*) or multiple object signatures (*see AWB Help - Process Signature*).

Pre-process KLARF data

The object signature pre-processing attributes are specified as part of the object signature metadata and stored in the object library. When the user selects an object signature from the library, the pre-processing parameters for *filter by classification* attributes and *defect count range* are loaded into the Signature Analyzer and Signature Filter dialog box.

The input data to the **Signature Anailter** may be **filtered by classification attributes** (e.g., ClassNum). There are two primary types of pre-classified defects: 1) results of k-NN classification; and 2) previously classified signatures. A k-NN filter is often executed prior to a signature analysis in order to remove normal backgrund noise from analysis. With respect to previously classified signatures, once defects have been classified, it is desirable to remove them from further analysis.

There is usually a **defect count range** over which the IDA signature recognition functions are accurate and reliable. When the defect count falls outside of that range, errors are more likely. To address this issue, the user may specify defect count as a wafer selection criteria, specifying the minimum and/or maximum number of defects required to process the wafer. If the defect count falls outside the specified range, the defect data are not analyzed for defect signatures.

Object Signature Recognition

Object signature recognition consists of three steps: object identification or clustering; feature extraction; and comparison to set of rules. The most important of these is the accurate identification of objects or clusters within the KLARF data. The user selects the Processing Parameters tab of the **Signature Analyzer/Filter** dialog box to define the parameters used for object identification or clustering; these parameters are identical to those of the DSA **Object Analyzer** function. Once the user specifies the processing parameters for the function (*neighbor distance*, *density* and *minimum units*), the Signature Analyzer will identify all clusters in the KLARF data that meet the specified criteria. In addition to setting the processing parameters, the user has a number of optional features that enable him to improve the accuracy of the object identification step.

The object **processing parameters** (neighbor distance, density and minimum units) determine the objects to be selected for analysis. (For a detailed description of these parameters, *see DSA Training Workbook, Module 7, IDA Clustering Technique*.) Different processing parameters will often identify objects of differing sizes and shapes in the same data. In the example below, the defect signature is called an edge cluster. Defect density is set to 1; minimum number of units is set to 20; neighbor distance is set to four different values: 5, 10, 15 and 20. In the example below, notice the way that the object size increases as the value of neighbor distance increases.

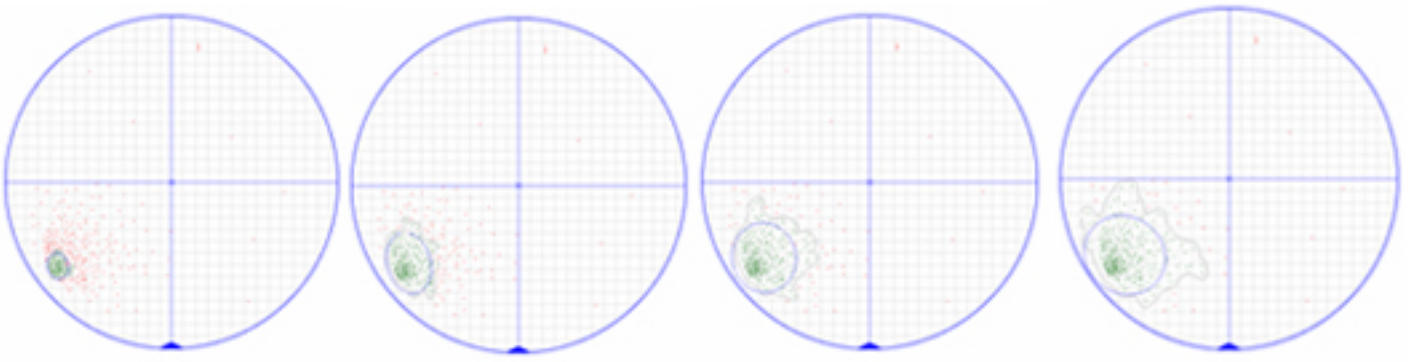


Figure 1 - Object identification is a function of processing parameters; value for neighbor distance increases from left to right (5, 10, 15, 20)

The object **k-NN% filter** allows the user to remove a fixed percentage of defects from every object based on the defect's k-NN distance. This feature is especially useful when a defect signature is separated into several dense regions. A small value for neighbor distance would capture each region separately, but each individual region may not meet the object rule criteria. A large value for neighbor distance would capture all of the regions, but it may also pick up neighbors unrelated to the signature. The internal k-NN% filter allows the user to remove these unrelated defects while retaining the fundamental shape of the signature.

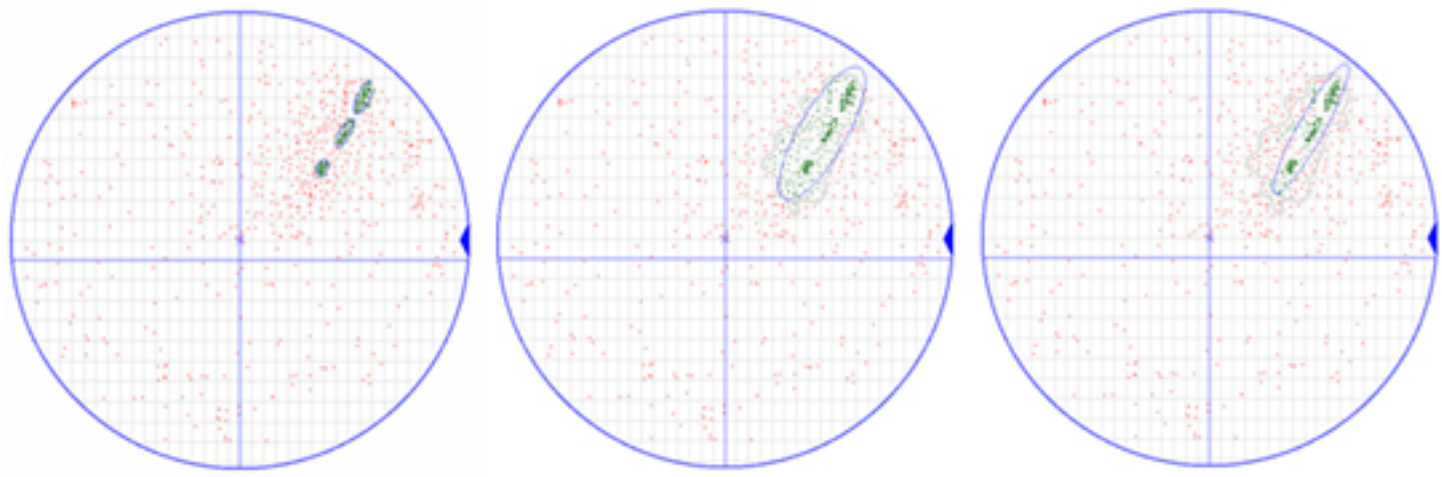


Figure 2 - Object k-NN% filter allows the user to set the neighbor distance high enough to bridge gaps between dense regions of a signature and then eliminate some of the unrelated neighboring defects

In the example above, a streak is separated into three regions. When the neighbor distance is set to 5, each of the three regions is identified; however, none of the regions individually meets the elongation criteria for a streak. When neighbor distance is increased to 10, surrounding defects are identified as part of the object; these extra defects fundamentally change the shape of the object so that it may not be recognized. When the k-NN% filter is applied to the object, the sparsest 25% of the defects are removed from the object, leaving a streak signature with a density shape that can be clearly recognized.

Feature Extraction

Each identified object is characterized by a set of features that can be used to formulate rules to recognize similar objects. The rules may be characterized into five categories: general information, density shape, object shape, shape boundary and density distribution.

Of the five categories of features, the most important is the ***density shape***, which is an ellipse that models the density distribution of the defects within the object. The density shape provides key information regarding the orientation of the object with respect to the edge of the wafer or the horizontal and vertical axes. Another key attribute is the ***ratio between the major and minor axes' length of the density shape***; this is especially useful in recognizing elongated signatures, like scratches and streaks.

The figure below describes some of the Density Shape Properties:

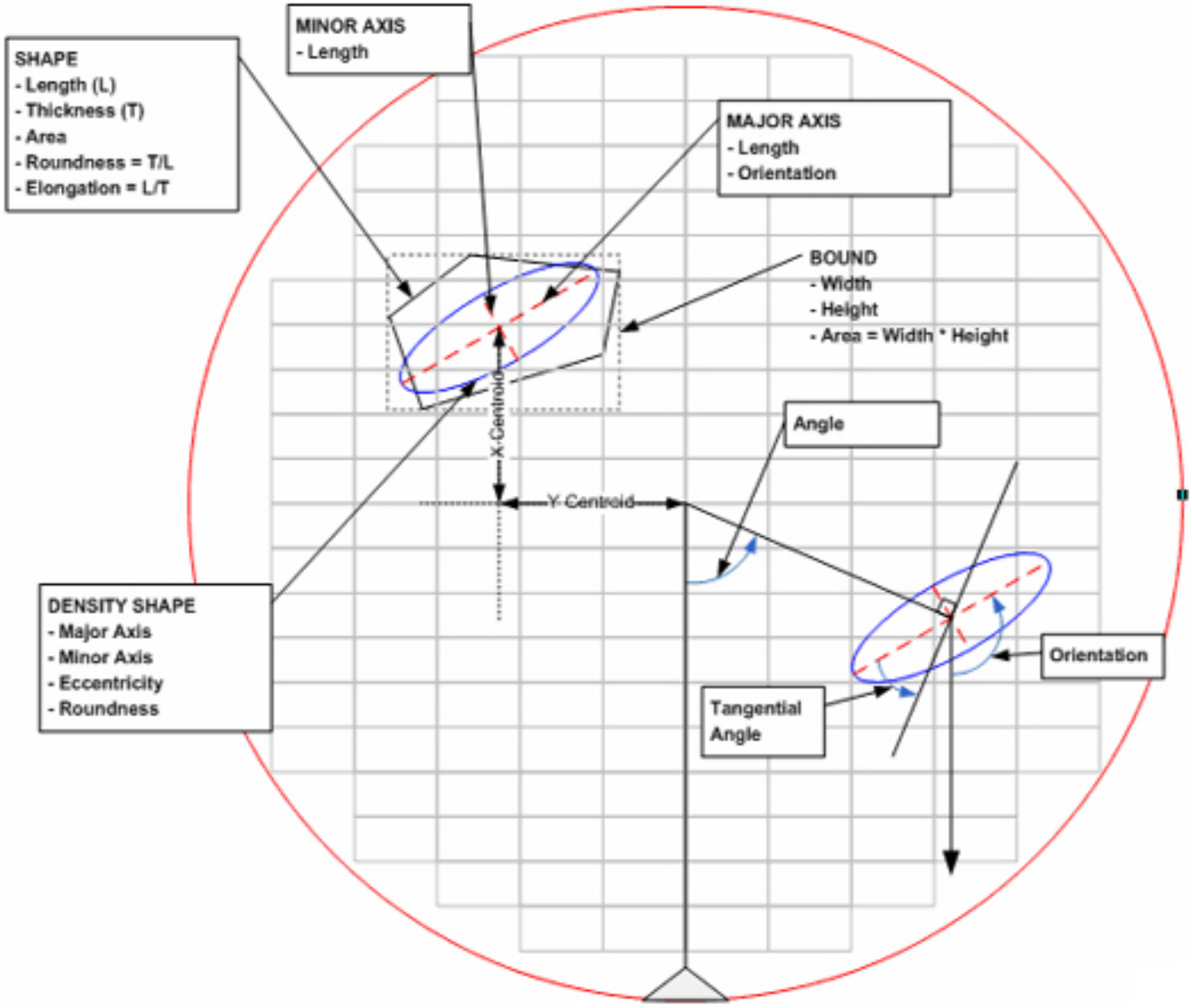


Figure 3 - Illustration of Density Shape Properties

The table below provides description of some of the important object parameters:

No.	Object parameters	Definition
1	DEFECT_NUM	Number of defects in object.
2	DEN_SHAPE_CENTROID_DISTANCE	The distance from density shape's centroid to wafer center.
3	DEN_SHAPE_MAJOR_LENGTH	The major axis length of density shape.
4	DEN_SHAPE_MAJOR_ORIENTATION	The major axis orientation of density shape.
5	DEN_SHAPE_MAJORMINOR_RATIO	The ratio between density shape major axis length and minor axis length.
6	DEN_SHAPE_MINOR_LENGTH	The minor axis length of density shape.
7	DEN_SHAPE_XCENTROID	The X distance from the center of wafer to the density shape centroid (left hand coordinate system).
8	DEN_SHAPE_YCENTROID	The Y distance from the center of wafer to the density shape centroid (left hand coordinate system).
9	NORMALIZED_DENSITY	The average defect density in the object divided by the average k-NN distance.
10	OBJECT_ANGLE	The angle between the horizontal axis and the line from wafer center to object center.
11	SHAPE_AREA	The area of object shape.
12	SOLIDNESS	An indication of the uniformity of defect distribution within the object. A lower solidness number indicates an open area in the object.

Comparison to Set of Rules

An object signature is characterized by a set of rules based on the object parameters. There are two types of rules: the single object rule and the group object rule; for the result of the signature analysis to be TRUE, the identified object must meet the conditions of both the single and group rules.

The user may define single object rules by selecting the “Filter Conditions” tab in the Signature Analyzer dialog box. Each single object rule may be comprised of several sets of syntactical statements involving object parameters. A very simple if-then rule below, the single object rule has been defined to recognize a streak. The streak is characterized by the following syntactical statements:

IF Major axis length of the density shape is greater than 40,000 microns AND

Minor axis length of the density shape is greater than 8,000 microns AND

Major axis length to minor axis length of the density shape is greater than 3.5 AND

Number of defects in the object is greater than 100 AND

Major axis orientation of the density shape is greater than 3 degrees from orthogonal

THEN

It is a “Streak”.

The set of statements that define this rule can be input to the Filter Conditions dialog box, as shown below:

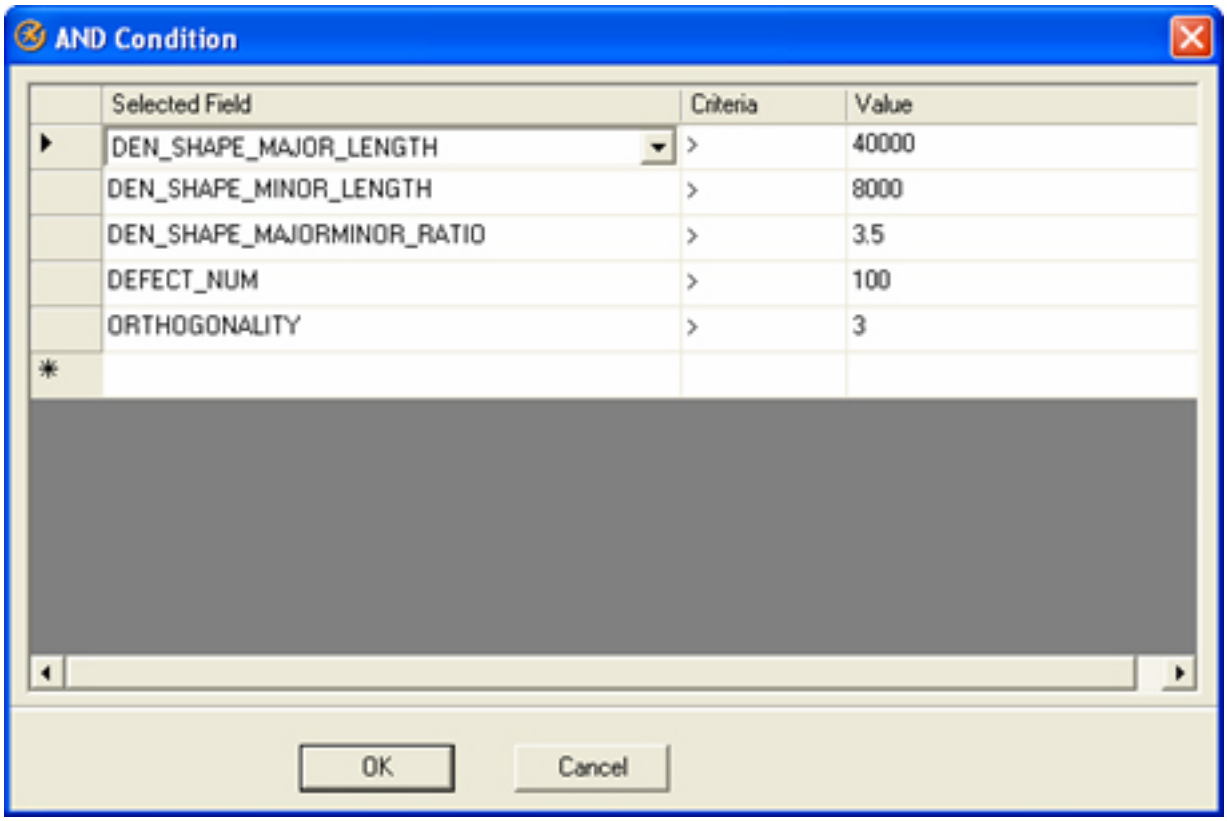


Figure 4 - Input to Object rule Filter Conditions

The **Signature Analyzer** function compares the parameters from each identified object to the corresponding parameters (syntactical rules) in the object signature. When the parameters from the object meet all of the specified if-then rules, the result is TRUE. The “Filter Conditions” may contain more than one set of if-then rules; if the object meets one set of rules, then the object is a signature. In the example below, the wafer image on the left shows the object that was identified using the processing parameters; the ***Object Information*** window (right) shows the object parameters for the identified object. Comparing the object parameters to the set of object statements (above), you will see that the object parameters satisfy all of the statements.

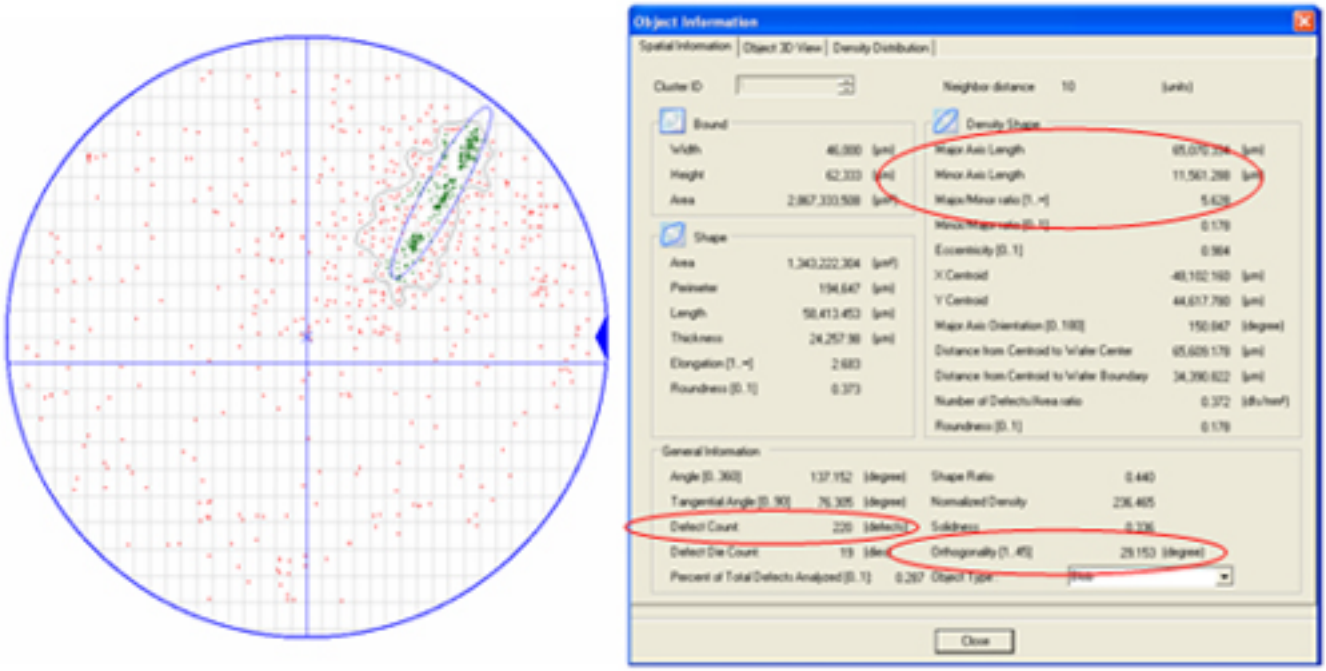


Figure 5 - Identified object (left) meets all of the syntactical If-Then rules of the object signature

In addition to the single object rules, the user may specify group object rules by selecting the "**GROUP BY Conditions**" tab. The group object rules allow the user to specify the minimum number of objects that meet the single object rules; the group object rules also allow the user to specify that one or more parameters for all of the objects fall within a specified range.

In the example below, the group object rule specifies that the object signature must contain a minimum of objects that meet the single object rules; in addition, the group rule specifies that the distance between the center of the wafer and each object centroid must be within 2000 microns for the object signature to be TRUE. This means that each of the objects falls within 2000 microns of the circumference of a circle.

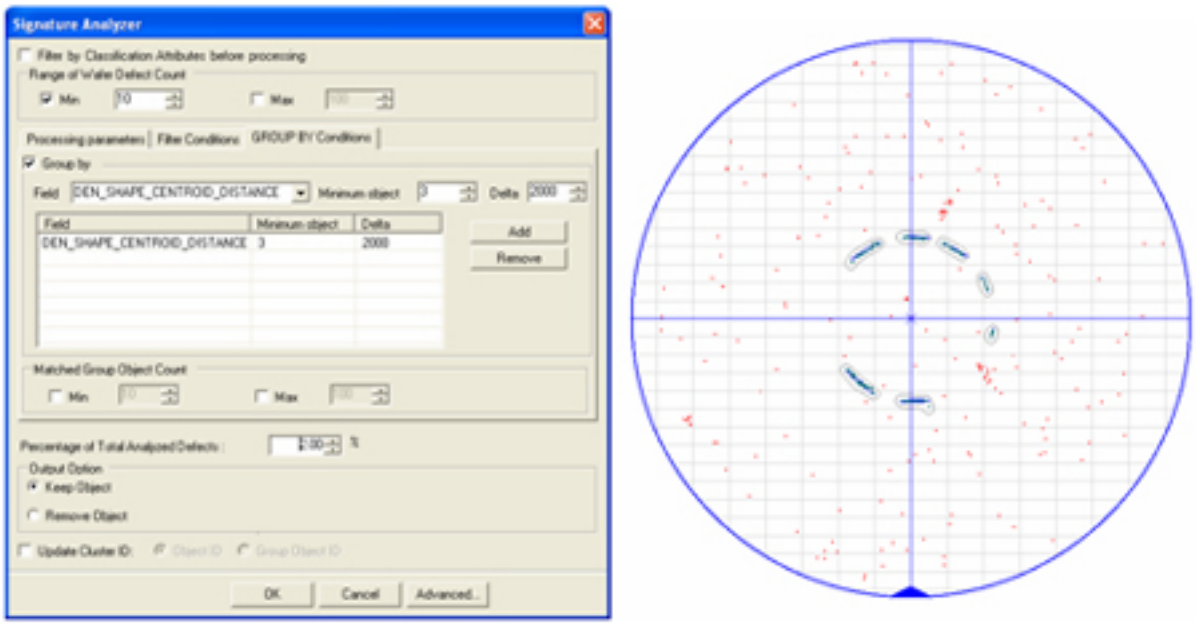
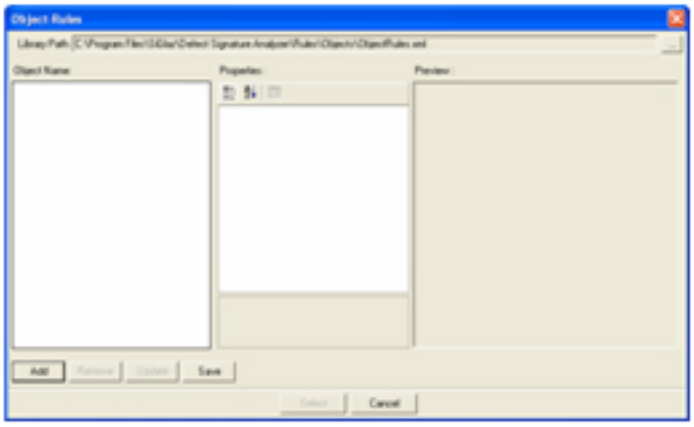


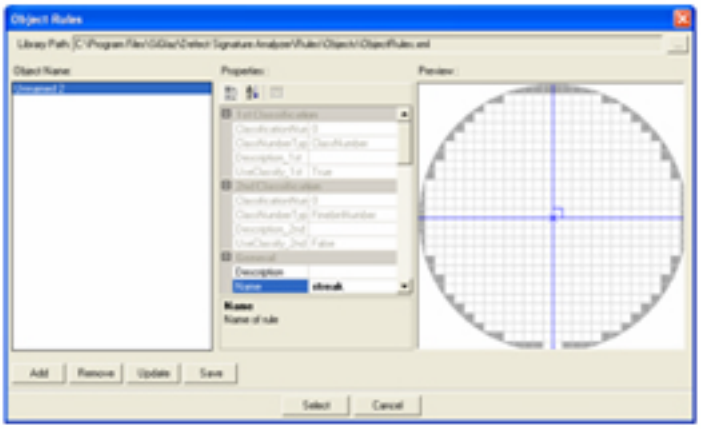
Figure 6 - Use "GROUP BY Conditions" to specify signatures composed of multiple objects with common parameters that fall within a specified range

After all of the object signatures have been identified using single object rules and group object rules, the user may specify one additional parameter to check that the total number of defects that have been identified as an object signature is greater than a specified percentage of the total defects analyzed. This parameter is useful when an object signature is the dominant source of defects on the wafer.

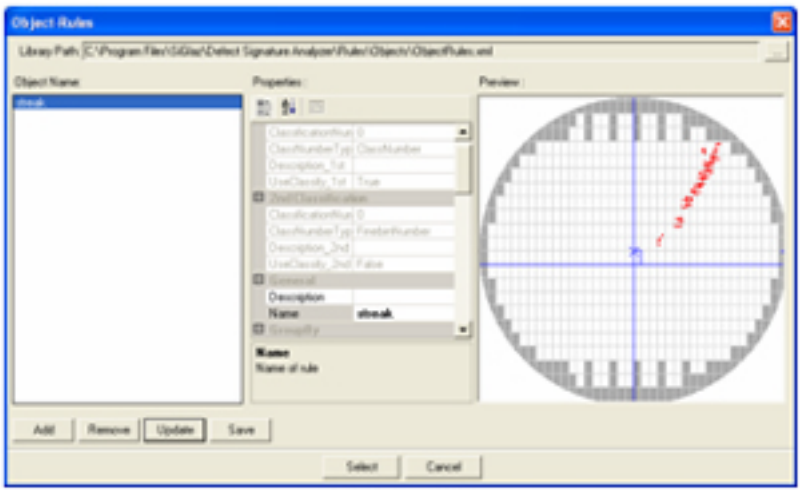
The Signature Analyzer Advanced Function allows the user to save object signature metadata into a library. The library may be an existing file or a new one; the library file name is specified using the Browser function. After the process parameters and object rules have been defined, the user may save the object signature to a new library, as follows:



Step 1: Select file path for object signature library



Step 2: Click "Add" and enter object name



Step 3: Click "Update" to move the object rules to the specified object name; click "Save"

When the Advanced Function is recalled at a later time, the user may select the object name (highlight). Clicking "Select" will load the object signature parameters into the Signature Analyzer dialog box.

The final step of the Signature Analyzer/Filter function is the post-process step, or the output of the results. Since the result of the Signature Analyzer function is a display, the user has the choice of displaying the signatures or removing the signatures. The Signature Filter has three output options: 1) keep only the object signatures in the current results file; 2) remove the object signatures from the current results file; or 3) assign a classification attribute to the object signatures.

In the Signature Analyzer, the result of the analysis is displayed as follows:

- Analyzed defects are displayed in a different color (default is green); if "***Keep Object***" is selected the objects are displayed in green; if "***Remove Object***" is selected, all defects except objects are displayed in green.
- The object shape boundary is drawn around the defects of each object.
- The density shape (blue ellipse) for the object signature is displayed for each object.

Examples of various "Keep Object" displays are shown below. The user may display only the object defects (analyzed defects) by clicking on the "Show Analyzed Data" button in the KLARF Browser toolbar. The user may remove the display of the shape boundary and density shape by clicking on the "Select Analyzed Object" button in the KLARF Browser toolbar.

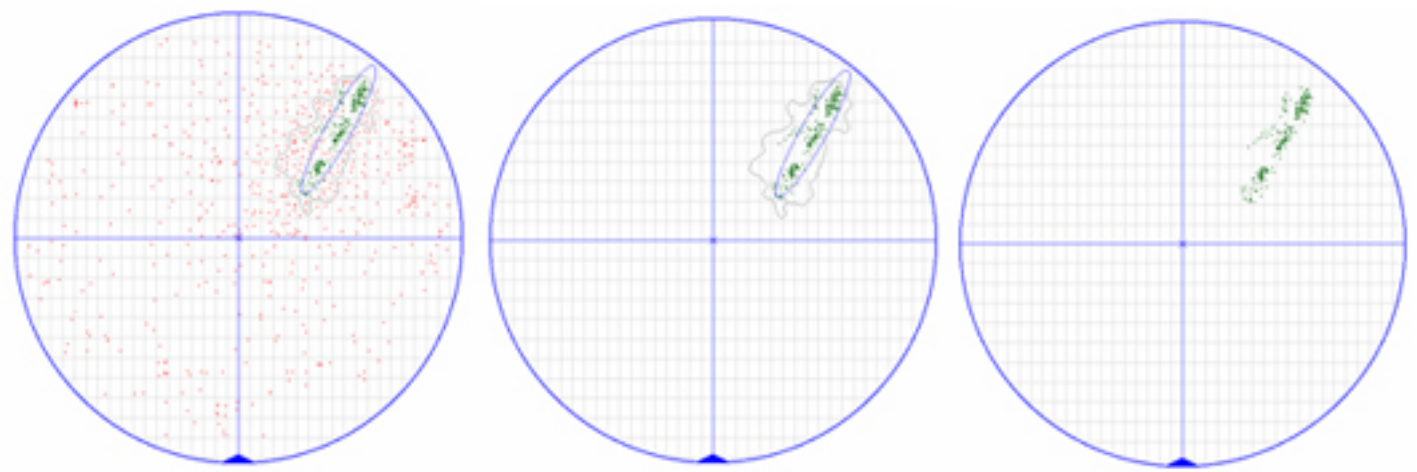


Figure 7 - Various "Keep Object" displays after Signature Analyzer