

# Software for *Gate Oxide Integrity* Evaluation

*Voltage & Current Ramp  
TZDB Supersequence*



*Gate Oxide Integrity Evaluation  
for Silicon Wafers*



*TaiSoft'2k*

For Windows 95/98, NT  
By Teimuraz Mchedlidze

## **About:**

Company: Komatsu Electronic Metals, Co., Ltd.

Platform: Windows 95/98, NT

Version: 6.2.XXXX (1999-2000)

Author: Teimuraz Mchedlidze

Internet page: <http://www.teimuraz.net>

Email: [teimuraz@imr.tohoku.ac.jp](mailto:teimuraz@imr.tohoku.ac.jp)

## **Contents:**

- [Overview](#) 4
- [Starting](#) 6
  - Set [Printer](#)
  - Settings of [Color scheme](#) for wafer BD map
  - Loading and saving standard [set of parameters](#)
  - Opening [data file](#) with measurement results
- [Calculations](#) 10
  - [Full-automatic](#) regime
  - [Semi-automatic](#) and manual regimes
    - [Preparation](#) for the calculations
    - [Semi-automatic](#) calculations
    - [Manual](#) calculations
    - [Soft BD count](#) option
    - [Statistical check](#) option
    - Oxide [thickness correction](#)
- [Output](#) 16
  - [Evaluation report](#)
  - [All-plot](#) graph
  - [Histogram and cumulative BD count](#) graphs
  - [Mode](#) plot
  - [Box](#) plot
  - [Saving and printing](#) images and data from report
  - Obtaining [BD map](#) for the wafer
  - [Saving and printing](#) of BD map
- [Useful tools](#) 19

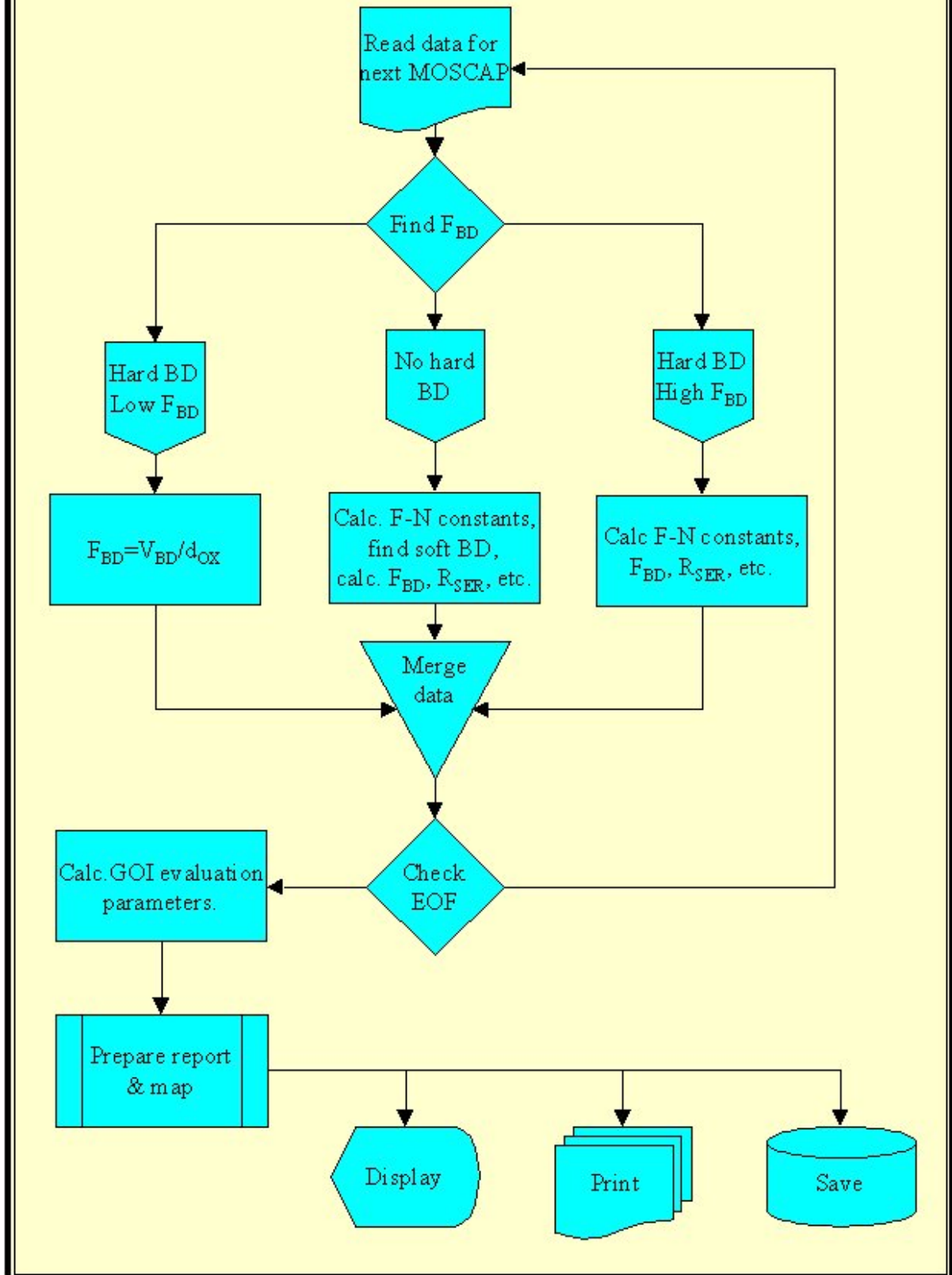
# Overview

SSGOI software was designed to analyze the results of Gate Oxide Integrity (GOI) evaluation measurements performed in the Time Zero Dielectric Breakdown (TZDB) mode using voltage + current ramp sequence. Software sequentially reads I - V data for a MOSCAP from the measurement data file, finds oxide breakdown (BD) values in hard or soft mode, calculates BD electric field and other characteristic parameters using Fowler-Nordhaim (F-N) oxide conductivity model (if applicable). After processing of I - V data for all MOSCAPs measured, software calculates resultant GOI parameters for the wafer (see [Flowchart](#)).

Regular steps of TZDB measurement result evaluation using the SSGOI software include: tuning up of software parameters, calculation of BD fields for MOSCAPs and GOI parameters for the whole wafer, presentation and saving of calculated data in the form of report and wafer BD map. Software also gives possibility to compare GOI evaluation results with the results obtained by the LPD count for the same wafer. The software is capable to analyze results obtained using “Cascade” prober ([MICROTECH](#)) or parametric tester ([AGILENT TECHNOLOGIES](#)). The “SuperSequence TZDB measurements” on the above devices are performed using specially written measurement software and specially designed prober tip arrangement (proprietary of [KOMATSU ELECTRONIC METALS CO., LTD](#)).

The software gives possibility to perform calculations in manual and semi-automatic and automatic regimes. In the case of original or first-time evaluation cases we would suggest to start with manual mode of calculations, which allows user to control the F-N current fitting and BD finding process and choose appropriate calculation strategy. For the flow-process measurements, with established conditions, it will be appropriate to use semi-automatic calculation mode. The automatic regime uses data files generated by the parametric tester for several wafers.

# SSGOI Flowchart

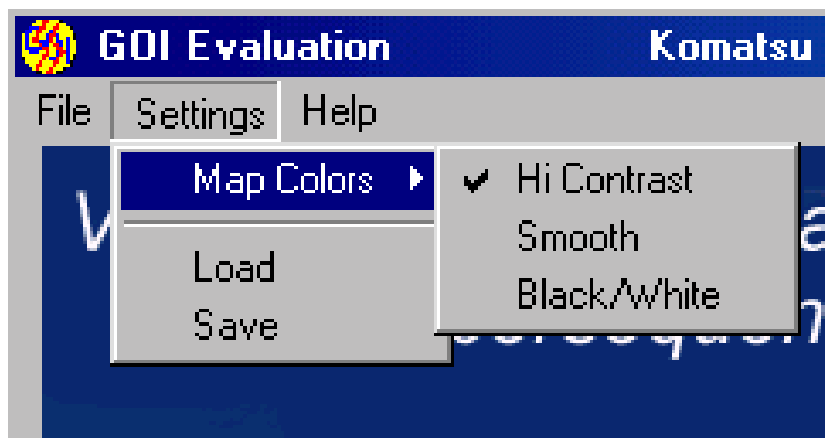


## Starting

- If the user is going to print out analyze report(s) and wafer map(s) on the printer different from the default, it will be appropriate to set printer before he begins the work. Click on the Set Printer command from the File menu and make needed changes.



- Depending on the mode of the printer (B/W or color) and user preferences choose wafer map representation color scheme. Three possible color schemes include High contrast (1), Smooth (2) and Black and white (3) modes.

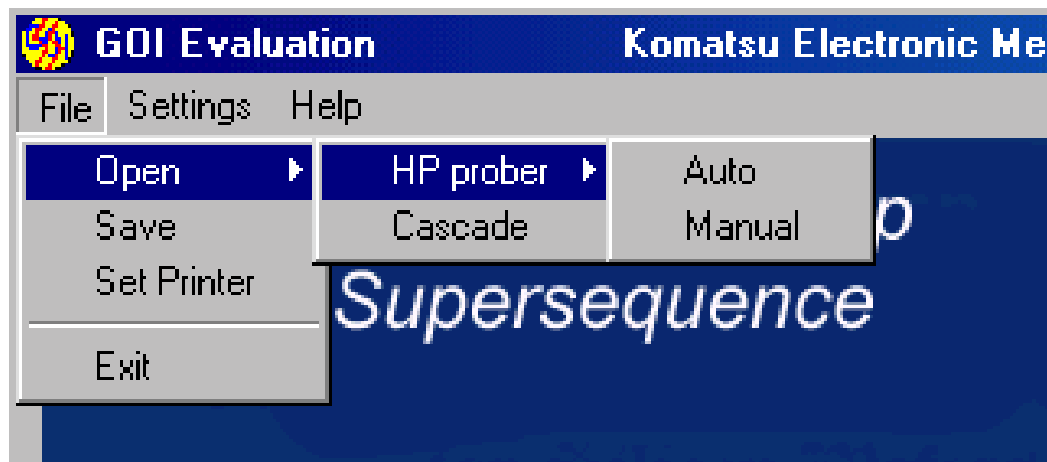




- During analyze of GOI data obtained on CASCADE prober user has to input measurement and wafer related parameters manually. Measurement and wafer parameters can be saved to and loaded from special ASCII format files, with extension "\*.set". Four sets, supplied with the software include high resolution (2800 MOSCAPs) and conventional (415 MOSCAPs) density wafer maps for 8 and 25nm thick oxide films. [Loading and/or saving](#) of the set are possible at any time during the work. User also can change any of the parameters from loaded sets. Loading of a new set or change made in present settings will require recalculation of evaluation

results, obtained prior to load/change (The measurement and wafer related data will be loaded automatically from the related data files during analyze of the results measured on the parametric tester. In this case the parameters can be changed only in semi-automatic or manual calculation modes).

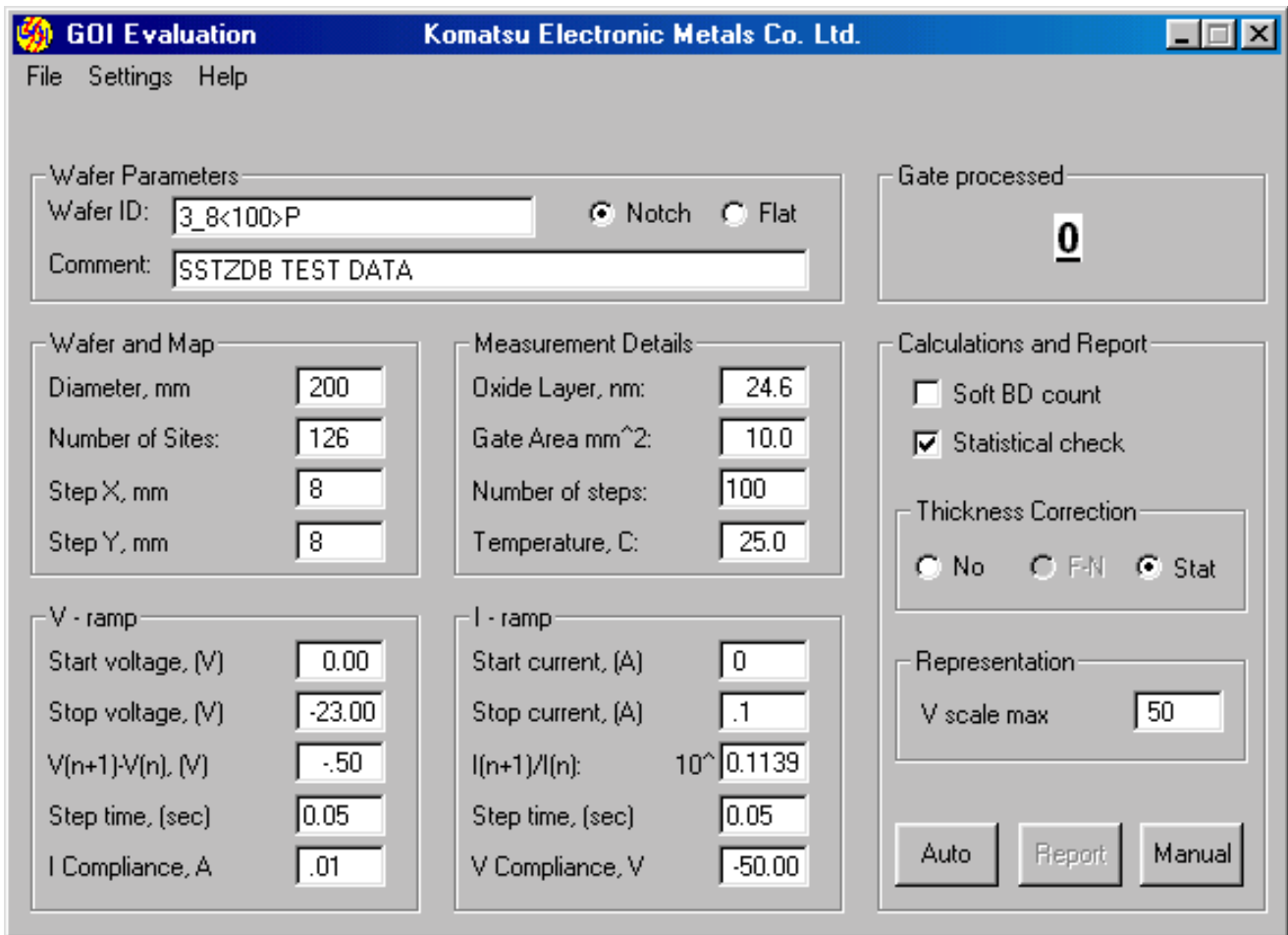
- To open file with measurement results choose “Open” command from the “File” menu and follow the appropriate link:
  - “Open→HP prober→Auto” to analyze the results obtained on the parametric tester in fully automatic regime.
  - “Open→HP prober→Manual” to analyze the results obtained on the parametric tester in semi-automatic or manual regime.
  - “Open→Cascade” to analyze the results obtained on the Cascade prober in semi-automatic or manual regime.



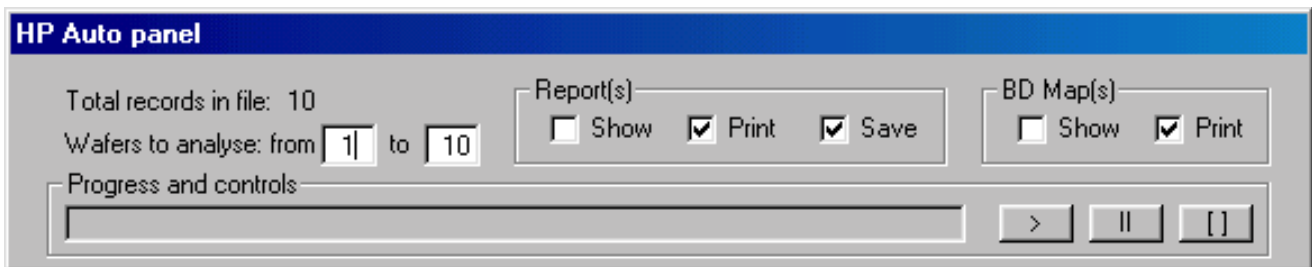
- When loading the measurement results obtained on the parametric tester the user will be prompted to data files twice. The first file contains the measurement and wafer related parameters (HP map file - “MAPS11 MEAS DATA”) and the second the I - V measurement results (SSTZDB measurement results – “SS TZDB”).



- After the file(s) are loaded the working window(s) will appear, allowing user to start the calculations.



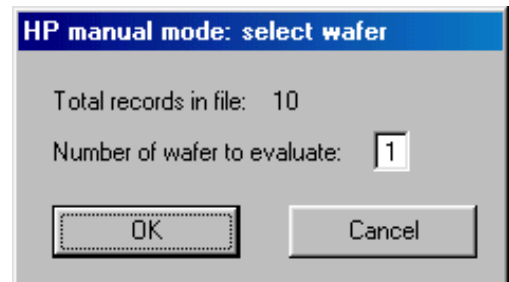
(1) Work-Window for Semi-automatic and Manual regime.



(2) Work-Window for fully-automatic regime (for the parametric tester only).

# Calculations

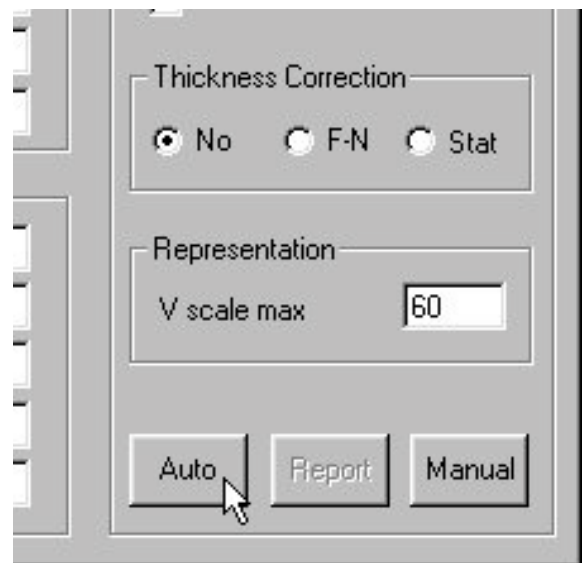
- In fully-automatic regime operator checks and changes (if desired) the parameters in the related work-window (2). The number of loaded wafers is indicated in the “Total records in file” line. User can choose which wafers to analyze making changes in appropriate “from” and “to” positions. Checking the appropriate checkboxes for the “Report(s)” and “BD Map(s)” frames will define if the report(s) and BD map(s) will be exposed, printed and saved during the calculation. “Show” option displays recently calculated report (BD map) for the wafer on the PC screen for 5 seconds for inspection purposes. “Print” option will allow printing of recently calculated report (BD map) on the default/chosen printer. “Save” option will initialize the saving of calculated report data to the ASCII format file. The file will be saved in the same directory from which the data were loaded. For the names of saved files the ID information of relevant wafers will be used.
- Clicking the “>” button will initialize the calculation process. The calculation process can be paused (“||” button) or terminated (“[]” button) at any moment. To continue the paused calculations click on “||” button once more. The progress-bar shows overall progress in the calculations.
- In the semi-automatic and manual regime for the parametric tester results after the opening of needed files, the user is prompted to input the number of wafer he wants to evaluate. After inserting of the desired number click on the “OK” button.
- Before starting with calculations in the semi-automatic and manual regime, it will be appropriate to check and correct all the settings in [working window](#). Check and correct (if desired) the values inside "Wafer parameters", "Wafer and map", "Measurement details", "V-ramp" and "I-ramp" frames (If you will make the changes after the calculations, you will need to recalculate results once more!). User should also determine calculation options, such as "soft BD mode" detection, statistical



and/or oxide thickness correction and maximal value of voltage scale for I - V curves.

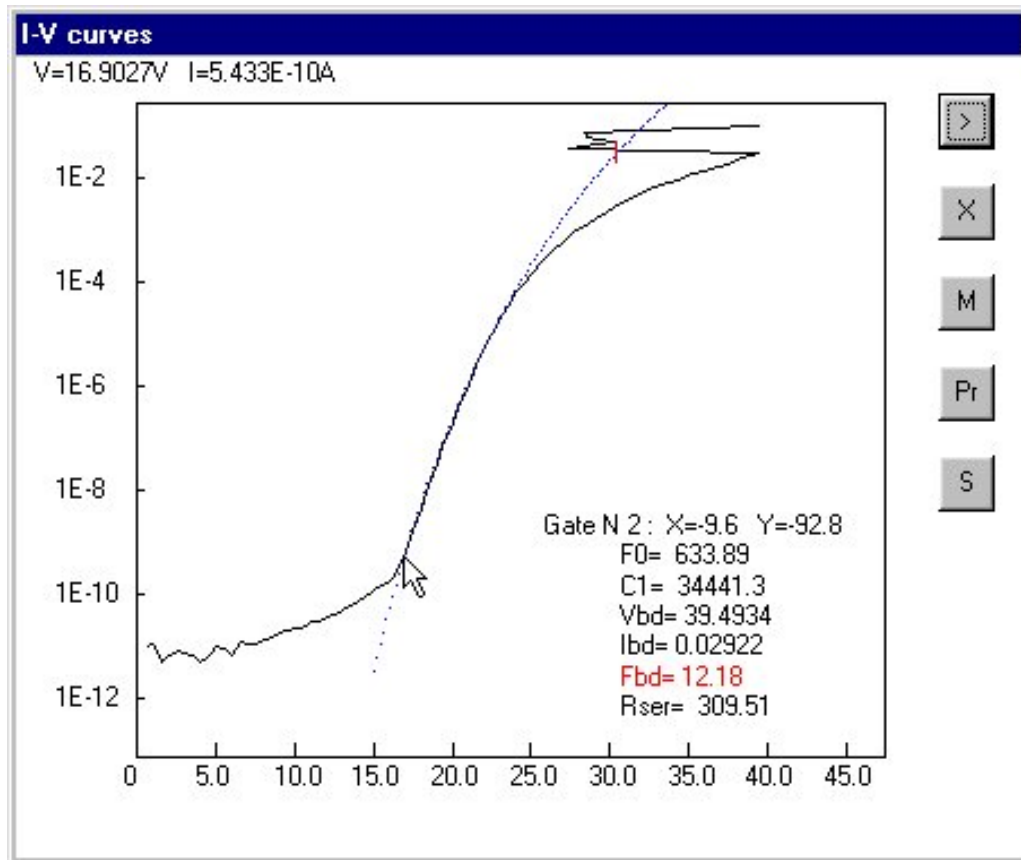
- In the frame ["Representation"](#), the value of **"V scale max"** determines the maximal value of voltage on all the I - V graphs. This value is not used in calculations, but determines the outlook of I - V graph in the report. We suggest setting this value slightly above the breakdown voltage characteristic for the oxide on the wafer. The best way to determine the appropriate value is to proceed with manual calculation for several MOSCAPs, while **"V scale max"** is set to the compliance voltage value. The appropriate value should be slightly (5-10%) higher than the maximal source voltage needed for BD.

- To start calculations of breakdown field for MOSCAPs in a **semi-automatic regime** click the ["Auto"](#) button. During the automatic calculations user does not control the calculation details. Data for all MOSCAPs on the wafer are processed and a report is compiled. User can interrupt the calculation process by pushing "s" key on the keyboard. In such a case the result summary for processed number of MOSCAPs will be reported (this number of already processed gates appears in the ["Gates processed"](#) frame during the calculations).



- To start calculations of breakdown field for MOSCAPs in a **manual regime** click the ["Manual"](#) button. Manual regime allows user to control all process of MOSCAP BD field calculations. The I - V curve for individual MOSCAP (solid line) is represented in special [window](#), together with the F-N curve (dotted line) calculated for the same MOSCAP. Under the curves the measured and calculated data for the MOSCAP are shown. The calculated real breakdown voltage is shown by short vertical line, which crosses the F-N curve. If the user is satisfied with calculated results he can proceed to the calculations for the next MOSCAP by clicking on ">" button. For fast **browsing**

of I-V curves push "n" key on the keyboard. To change the value of BD voltage for the MOSCAP, first click on "M" button. Moving the cursor inside the I-V graph, choose the desired value (position) for BD event (the current and voltage values are instantly indicated in the upper left corner of the window) and push the left mouse button. New values for the MOSCAP will appear inside the window. The process could be repeated desired number of times. To go to the next MOSCAP, click on ">"

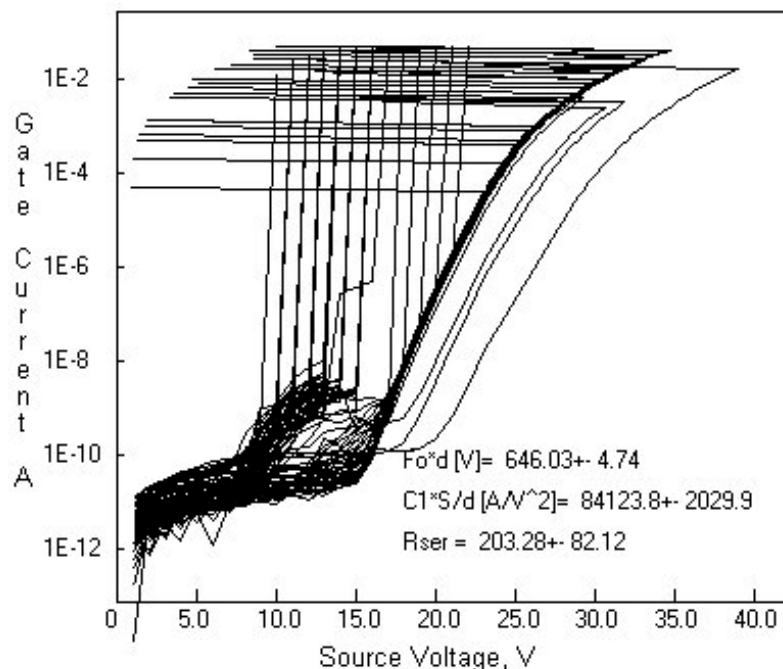
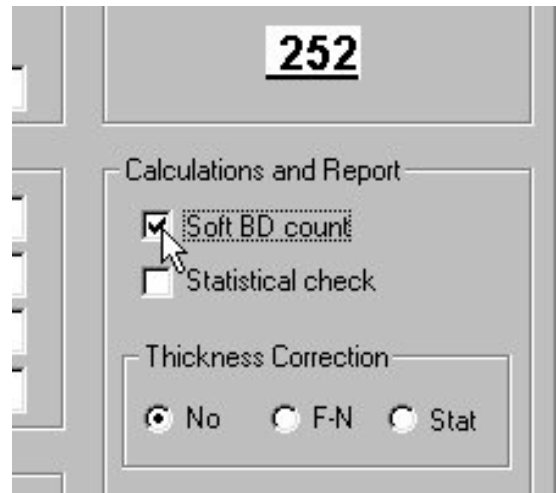


button. To exclude data for the current MOSCAP from further consideration push "X" button, data for the next MOSCAP will appear in the window. To print out I-V curve for current MOSCAP click on "P" button. To stop calculations and get report for processed number of MOSCAPs click on "S" button.

- **Soft BD count** mode option can be used in the case of high value of series resistance ( $R_{SER}$ ). Usually the BD event in the I-ramp mode is detected by the source voltage drop between the successive current value steps (hard DB). For the case of high series resistance value and high electric field the source voltage is

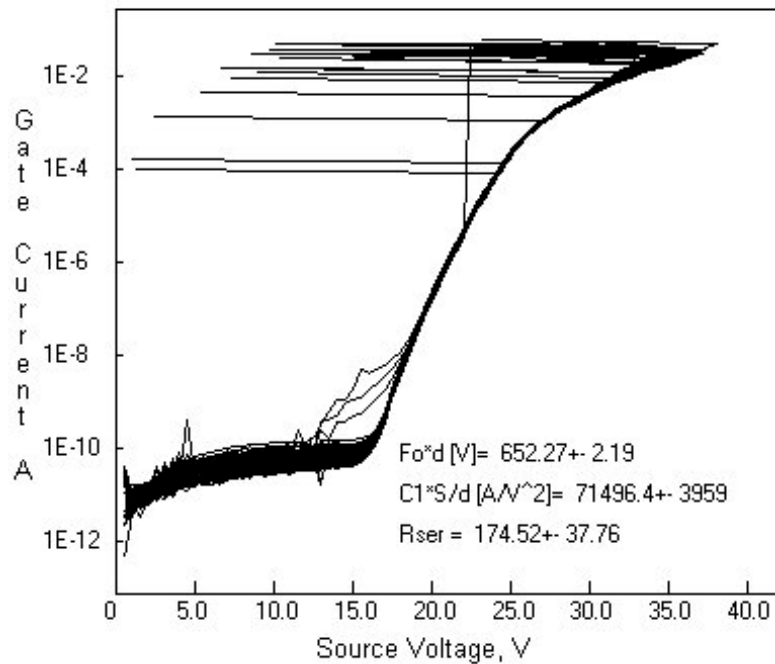
almost equally applied to the oxide and  $R_{SER}$ . Usually BD event in such a situation does not lead to a detectable drop in the source voltage between successive current steps, but causes the change in I - V curve derivative (soft BD). The software detects such a change in the absence of hard BD event for the MOSCAP. If the **Soft BD count** mode option is unchecked, the data for MOSCAPs without hard BD will be excluded from further calculations.

- if checked, the **statistical check** mode option will exclude from the results the data for the MOSCAPs, for which the coefficients of F-N fitting differ on 5% and more from the average value. Reason for such a difference can be the irregular thickness of oxide film for the MOSCAP, noise during the measurements, etc. This option is useful when results for F-N fitting on one or several gates are drastically different from average values and the reason cannot be established (see example below).



Irregular I-V All-plot. Oxide thickness is scattered.

- For the regular cases of GOI evaluation oxide **thickness correction** is not necessary. The exact value of the thickness should be entered to the "Oxide layer" position in the [measurement details](#) frame. The **thickness correction** options are used if the [thickness of oxide is scattered](#) on the wafer surface, causing scatter of the I - V curves. Two possible ways of thickness correction are provided.

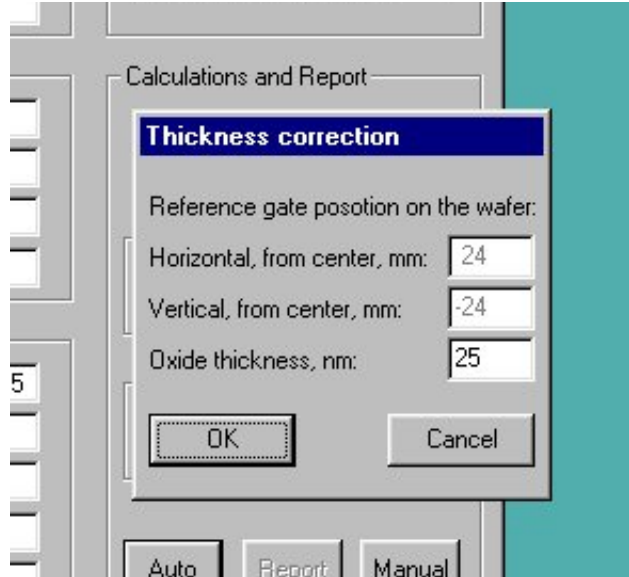


Regular I-V all plot.

- Statistical correction ("**Stat**") will find the average values for the F-N coefficients and recalculate the BD fields for the MOSCAPs, for which deviation is greater than 5%. The value entered to the "Oxide layer" position in the [measurement details](#) frame will be used as a reference thickness.



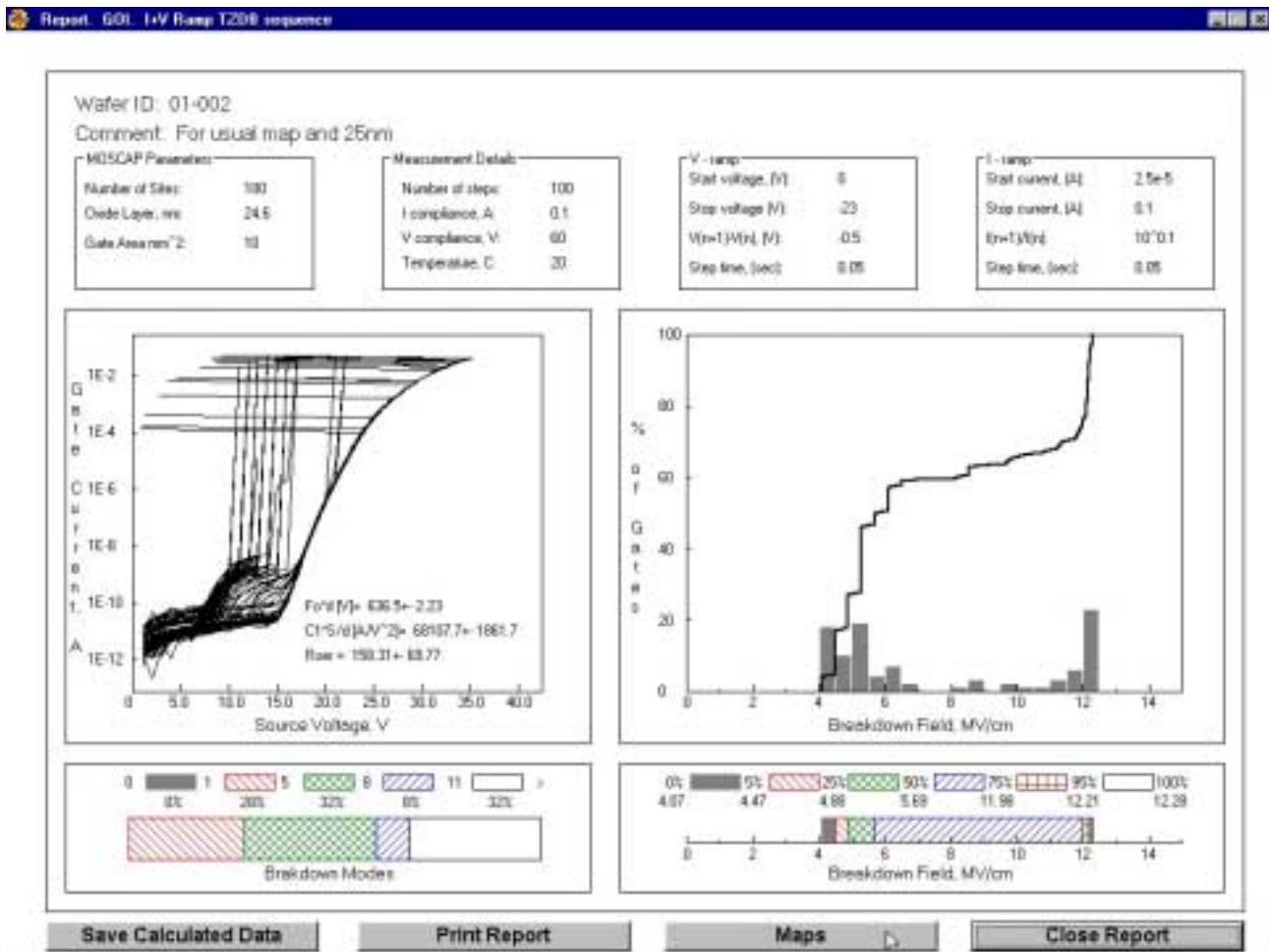
- The "F-N" correction will find MOSCAP, the closest to the center of the wafer, with calculated F-N coefficients and [prompt](#) the user to input the measured oxide film thickness for the reference MOSCAP position. After the value will be entered the BD field data for all MOSCAPs will be corrected using recalculated values for the F-N coefficients. This correction method



cannot be used in fully automatic calculation mode for parametric meter results. The "F-N" thickness correction seems to be more precise, but can lead to large errors, if the F-N fitting or thickness measurement data for the reference MOSCAP would be incorrect.

## Output

- A [report](#) for the all MOSCAPs processed is prepared automatically after finishing of I - V curves processing. The report contains four graphic windows and general information. In general information (upper part of the report) the measurement and wafer details are given.



- An "All plot" graph represents experimental I - V curves from all processed MOSCAPs. Beneath the curves averaged calculated parameters of F-N fitting and  $R_{SER}$  are shown with corresponding errors.



- **BD histogram and cumulative BD count** graphs are positioned to the right from the "All-plot" graph. Histogram plot resolution is set to 0.5MV/cm value for electric field axis. Resolution for cumulative BD plot has no preset.
- The **BD mode plot** graph, contains relevant percentage for five BD modes. "A" mode BD is assigned to the MOSCAP if it was damaged by the electric field lower than 1MV/cm ( $F_{BD} < 1\text{MV/cm}$ ), "B" mode BD to the MOSCAP damaged in the electric field diapason from 1 to 5MV/cm, "B+" - for diapason 5-8MV/cm, "C" mode BD - 8-11MV/cm and "C1" mode BD for  $F_{BD} > 11\text{MV/cm}$ .
- The **Box** plot gives information about BD field, characteristic for number of MOSCAPs. Namely, the left border of each box (same color area) represents an electric field strength values to which the relevant amount of MOSCAPs (in percents) survived BD.
- A report can be printed by clicking the "Print Report" button positioned in the lower row of the screen under the report. Button "Save Calculated Data" will prompt user to the "save file" window. Software will create ASCII format file containing all calculated results. This file can be accessed by any of known graphical programs (Excel, Origin, etc.) to create maps or graphs for presentation. The file consists of the table with calculated values (MOSCAP number, X and Y position on the wafer, BD field, BD current, BD Source voltage, F-N fitting parameters,  $R_{SER}$  values), histogram and cumulative count chart data, mode and box plot data. Besides that every of four graphs may be saved and printed separately. To do so user should double-click inside the part of the report, he wants to save or print. Appearing panel allows saving relevant image to file,

0.1	Stop voltage (V):	-23	SI
60	V(n+1)-V(n), (V):	-0.5	It
20	Step time, (sec):	0.05	SI

**Save, Copy & Print Results**

Picture      Data      Close

%

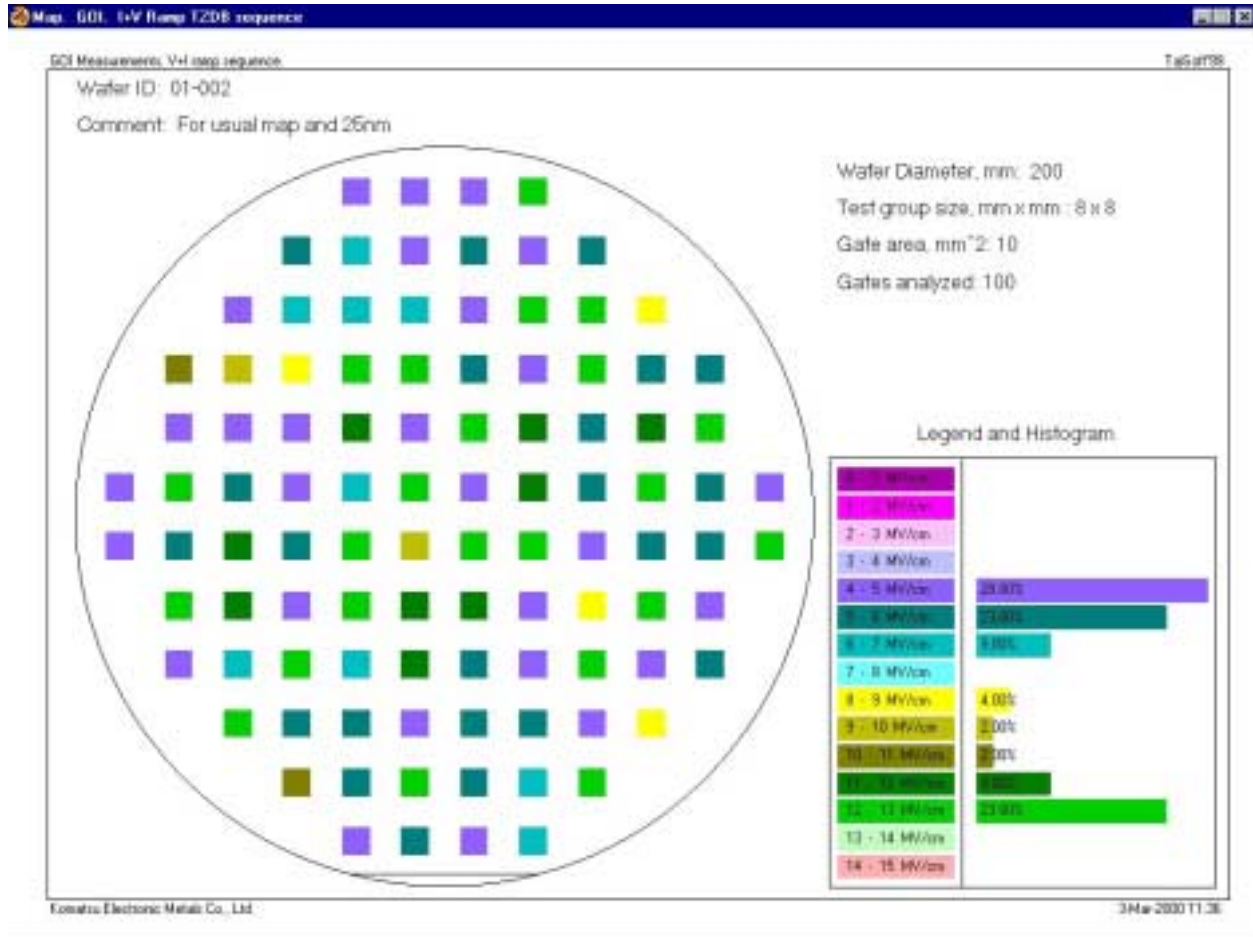
0 60

f

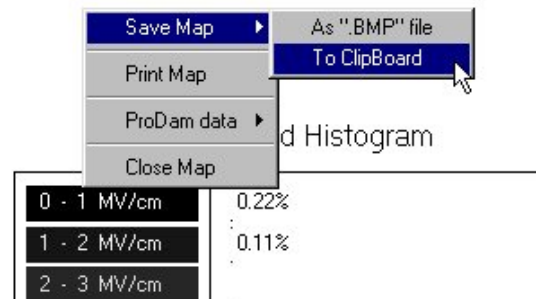
G

place it to the clipboard, print it or save relevant data to the ASCII format file.

- Clicking on "Maps" button in the lower row, beneath the report will bring forward the **BD map window**. Map colors depend on the [settings](#). Legend and BD histogram (resolution 1MV/cm) are also presented in the same window.

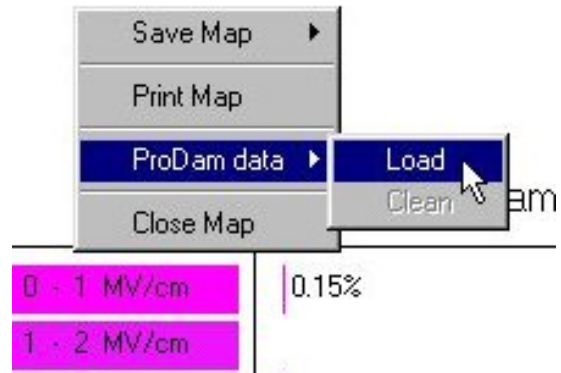


- To **print out or save image of wafer BD map** double click inside the window. Appearing pop-up menu includes commands, which allow to place the map image to the clipboard, save the image to \*.BMP format file and print out the map.



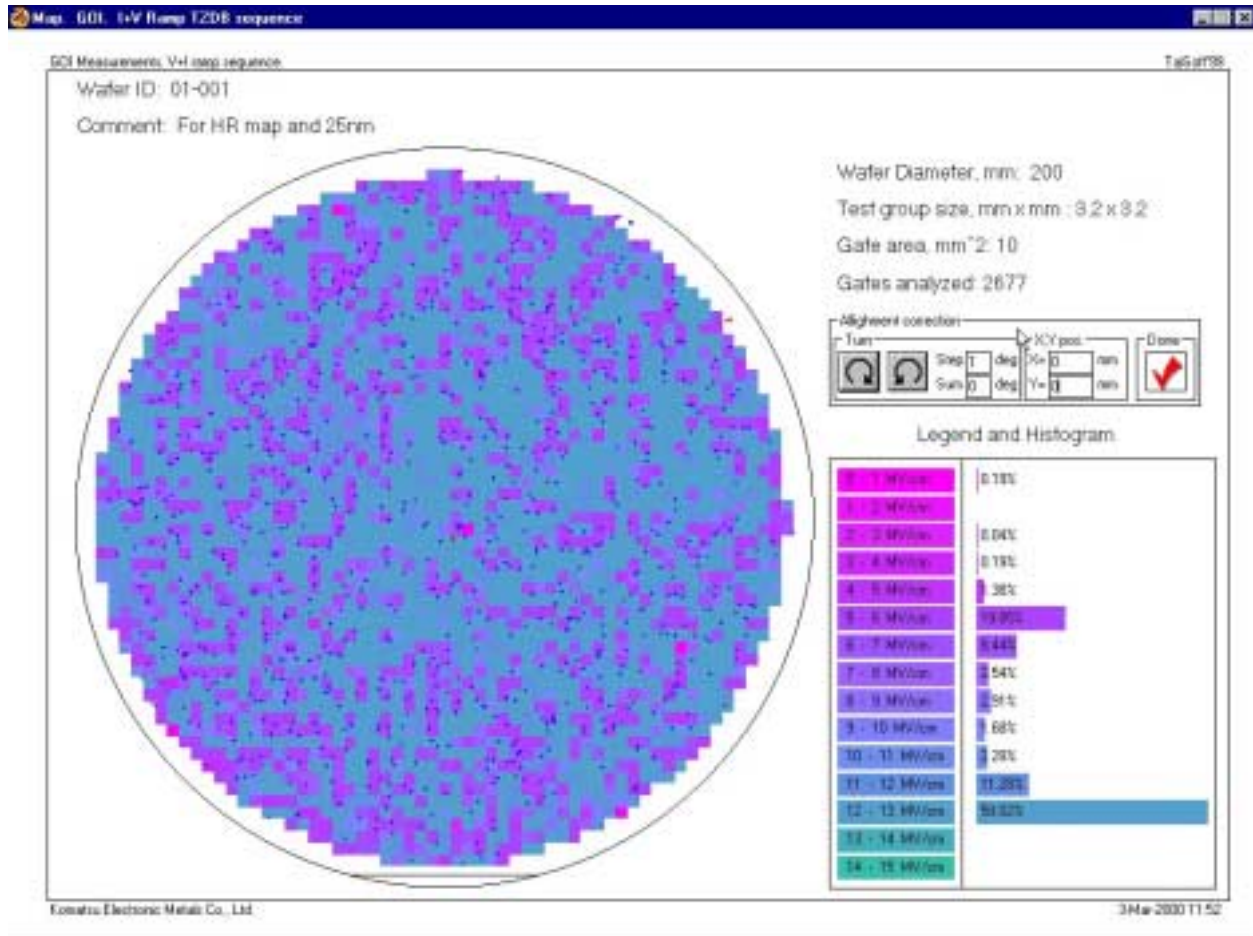
## Useful tools

- It is possible to compare **defect map (LPD map)** obtained by means of particle counter to the BD map compiled by the SSGOI software. To use this possibility the LPD data, obtained from particle counter, should be processed by the [PRODAM](#) software (TaiSoft'99 ©) and saved in ASCII format data file using PRODAM soft. Loading of the LPD \*.dat file can be fulfilled from the pop-up menu in the map window. Double click mouse button at any position inside the map window to get the pop-up menu and click on the Load item. After this operation the comparison map can be saved and printed out in the same way as the BD map. To get rid from the LPD image choose "Clean" item from the pop-up menu.



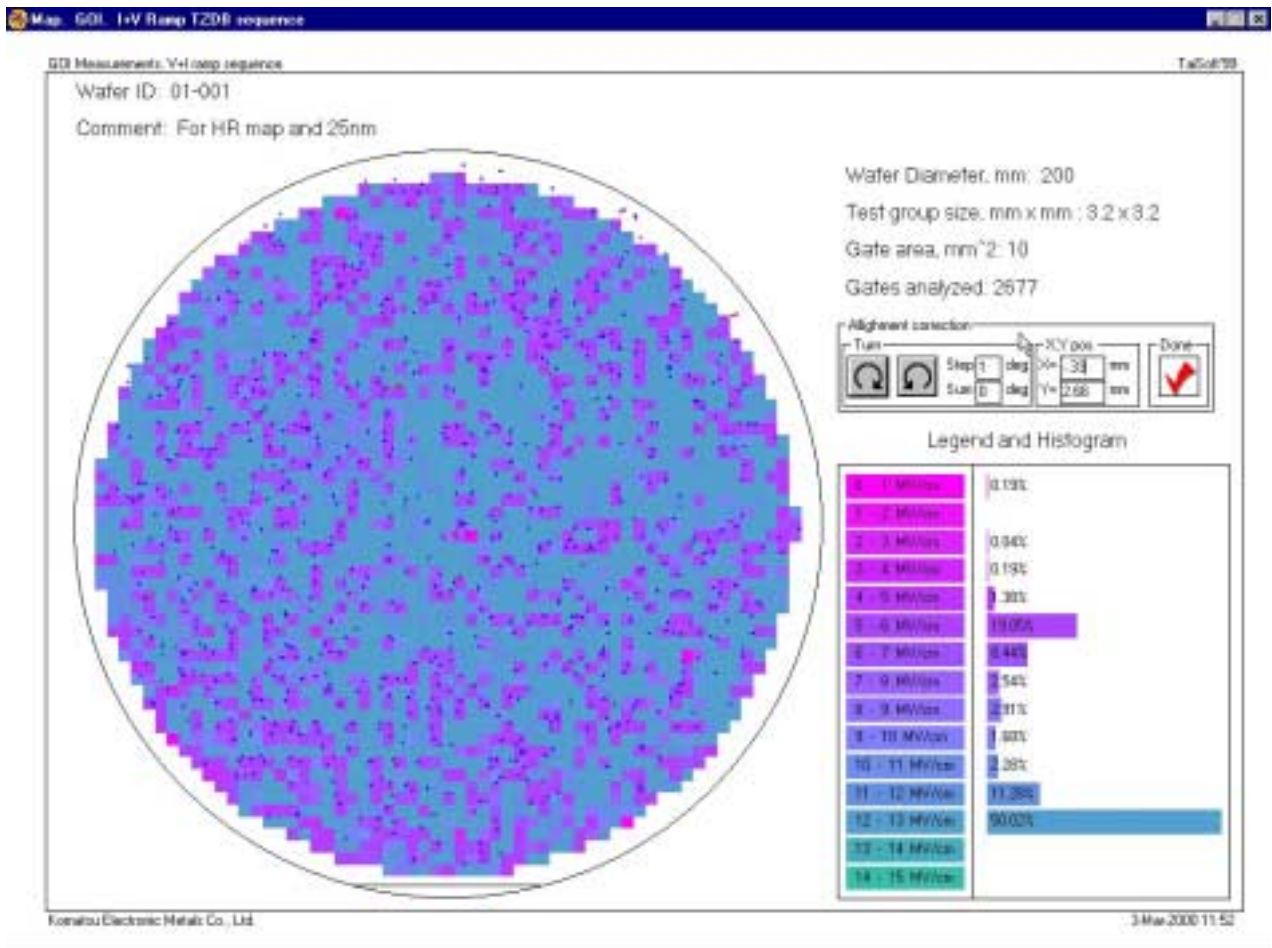
- Usually the **absolute positions of the BD and LPD maps may differ**, due to MOSCAP fabrication process precision and alignment. To adjust the LPD map position to that of the BD map special [adjustment panel](#) appears to the right from the map image after the LPD data loading process is finished.
- Rotation** of the LPD map image (clockwise and anti-clockwise) is fulfilled by clicking on appropriate buttons with round arrows. User can set the rotation step in degrees (click in the rectangular area to the left of "step" label and enter desired number). The sum of all rotations will appear beneath the step value. If user will insert the desired rotation angle ("+" clockwise or "-" - anti-clockwise) in the sum area and click mouse inside the panel, the LPD map will be rotated to the entered angle by one step.

- To move the LPD map in **vertical and/or horizontal** directions enter desired distance (+ or - from the current position in relevant areas in the panel (same as in the case of angle step) and click outside the frame (inside the panel).



Loaded LPD map over the BD map

- Interactive movement** of the LPD map is possible by pushing down the right mouse button inside the map image and dragging the pointer to the desired position. After user will free the mouse button, the image position will be adjusted.
- To **restore** the starting position of LPD map insert zero values to the Angle sum, X pos. and Y pos. areas and click mouse inside the panel.
- After **finish** of the adjustment process user should click on "Done" button inside the panel to **fix** the result.



LPD and BD maps with correlated positions.

- **Several LPD maps** (different channel LPD measurement results, etc.) can be loaded and adjusted to the same BD map image successively. To do this, user should load and adjust all desired LPD data files one after another. Software remembers final adjustment values used with the previous LPD map. Thus, to fulfill similar adjustment, user should just click inside adjustment panel after the next LPD map was loaded. Notice, that "clean" command in pop-up menu removes all loaded LPD maps simultaneously.
- **Relative position of cursor** towards the center of the map appears above the map image while cursor moves inside the map image. Pushing on right mouse button

over colored area inside the map will display the corresponding [MOSCAP characteristic parameters](#) (center position and BD field) instead of cursor position.

