



NanoCalc

Manual

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1 Introduction

NanoCalc is a software to extract thickness and optical parameters of thin, transparent layers on different substrates. NanoCalc uses Ocean Optics / Mikropack microspectrometers.

NanoCalc offers a lot of different options like:

- Simulation and measurement of multilayer systems (weakly absorbing or transparent)
- Optional: A powerful software engine in the background ("SCOUT")
- An easy-to-use "internal" mode for thickness extraction
- A graphical user interface that is very easy to use (recipes)
- Simulation of up to 10 layers (weakly absorbing or transparent)
- Highly accurate thickness measurements between some nanometers up to about 250 µm
- Extraction of dispersion $n(\lambda)$ and $k(\lambda)$, roughness, EMA-fractions and other layer parameters, if using SCOUT add-on
- 3D - mapping mode with a motor driven xy(z)-stage (=function of position)
- Online/multipoint measurements (=function of time)
- Remote control via OLE-commands from external software
- Video
- Combination with ellipsometry ("ElliCalc")

It is possible to measure in **reflection mode** (e.g. SiO₂-Layer on silicon) and in **transmission mode** (e.g. Ti₂O₃ layer on a transparent BK7 glass).

Measurement principle

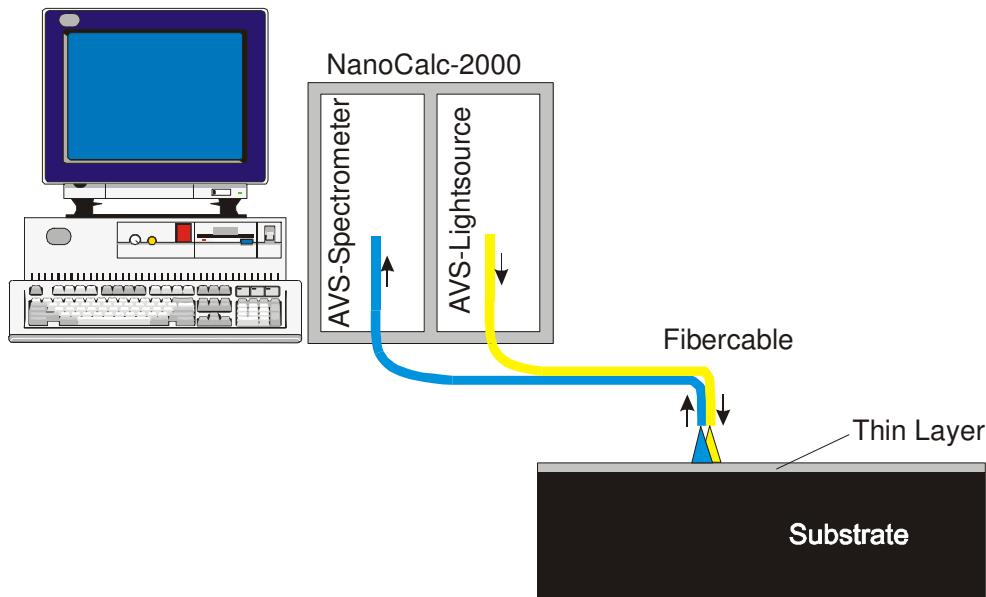
A thin layer is vertically illuminated with **white** light via a fiber and the spectrometer measures the reflected (or transmitted) light as a function of wavelength. NanoCalc software determines thickness of the layer.

NanoCalc has 2 different modes of operation:

1. data extraction via an optional software tool called "SCOUT". This SCOUT software is very powerful and works more or less in the background. SCOUT is able to handle very complicated dispersion curves, but needs some experience with optical modeling. NanoCalc acts as a user interface to simplify the data extraction process. Even without deep understanding of the underlying physics it is possible to measure complex layer systems by using a recipe concept. A layer recipe has to be loaded and the rest is a "one-button-solution" (of course there must be an expert in the beginning to establish this recipe. Ask your software supplier...)
2. data extraction by NanoCalc itself (without SCOUT). In this "internal mode" it is very easy to extract thicknesses and –to some extent- dispersion values without optical modeling. Recipes may be used, but even without recipes it is extremely simple to get results. This "internal mode" does not need an expert, but it is not as powerful as the "SCOUT mode".



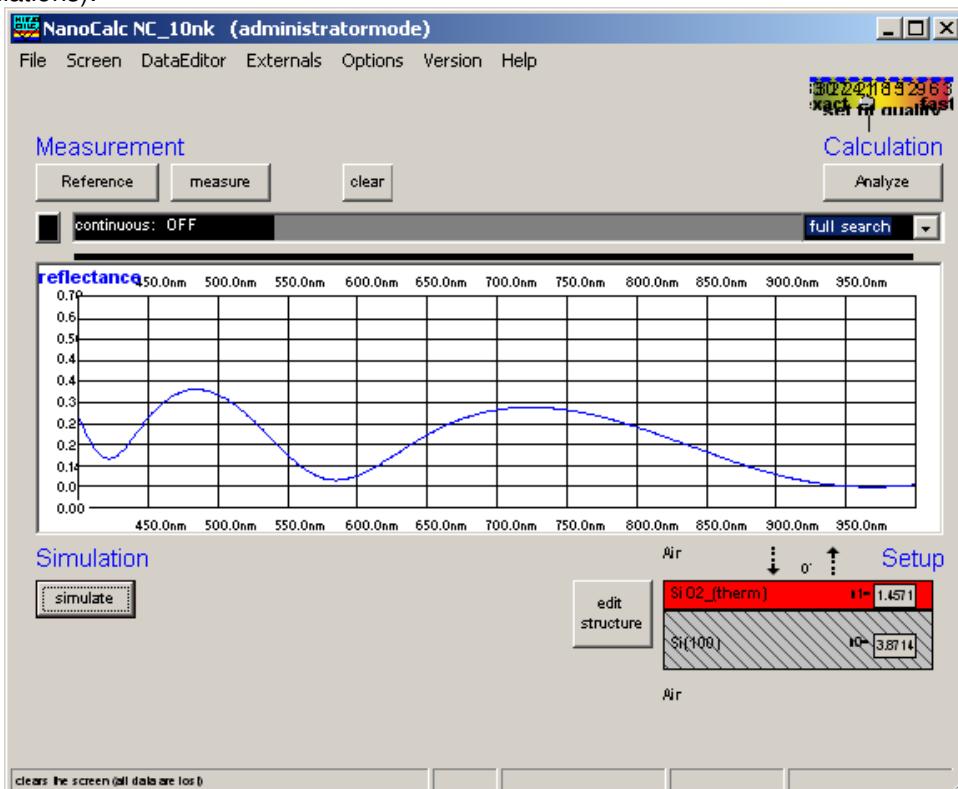
1.1 Measurement setup



A broadband white light source is reflected by a thin layer under vertical incidence (after a calibration measurement). The reflected intensity as a function of wavelength is measured by a spectrometer, a PC extracts the wanted information.

1.2 Measurement signal

The typical modulated signal of such a spectroscopic thin film measurement might look like this (after some data manipulations):

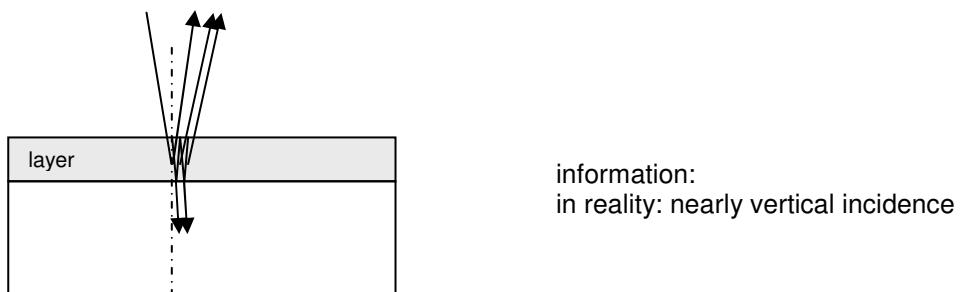


NanoCalc uses this signal to extract thickness (eventually also dispersion) for this (SiO_2) layer on Si.

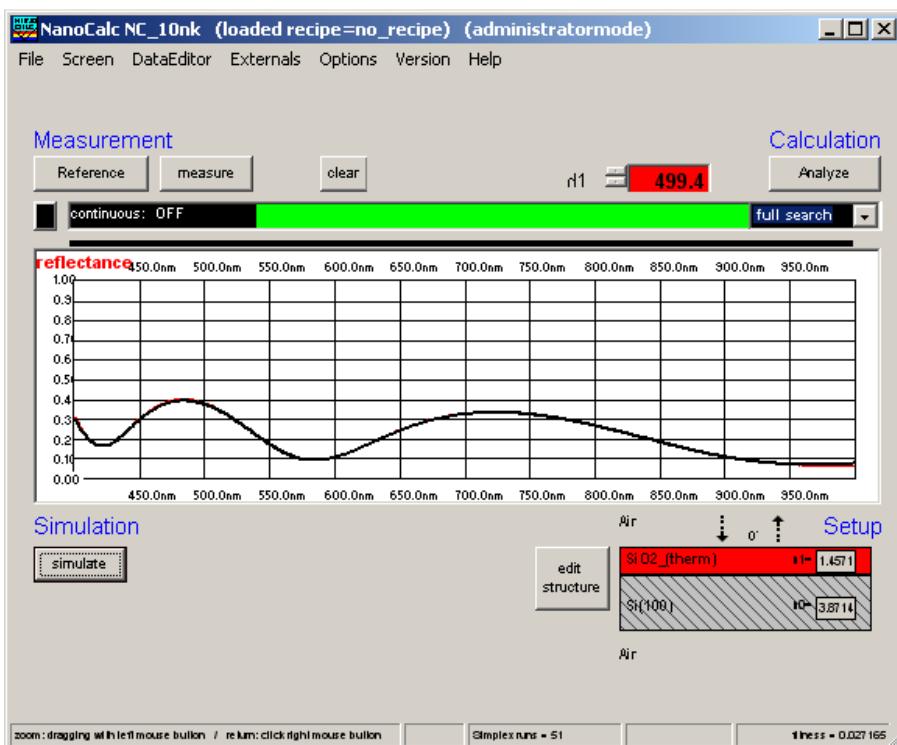


1.3 Physical principle

The measurement principle of NanoCalc is the well-known fact of **interference** of light in thin layers. Light is reflected (and transmitted), resulting in phase shifts and superposition of amplitudes and finally adding up to different intensities for different wavelengths (=different colors). You see these colors in every-day-life, if you observe the colors of thin oil films on water or if you carefully observe the colored anti-reflective coating on lenses of cameras or binoculars.



After some calculations NanoCalc will show a result (here: 499.4 nm) as the best fit to the experimental data (red curve=measured signal, black curve = theoretical curve):





2 Installation

NanoCalc (and SCOUT) is delivered on a CD-ROM.

Insert the CD-ROM in your CD-ROM drive and run „NanoCalc-Setup.exe“ . Do not call “NanoCalc.exe” at this level, if you happen to find it in some subdirectory.

NanoCalc will ask you for a directory (and propose a directory „c:\programs\NanoCalc“).

If you prefer other names, change this to "c:\MyPrograms\NanoCalc" or any convenient directory name).

Deinstallation:

If you want to deinstall NanoCalc from your computer, go to „system control“, „software“ and deinstall NanoCalc.

Do **NOT** just delete it because NanoCalc adds some files to your windows\system directory and to the registry !!

Always de-install the software properly.

3 Product support

Please contact your local distributor for product support. Here you can find additional information:

www.mikropack.de

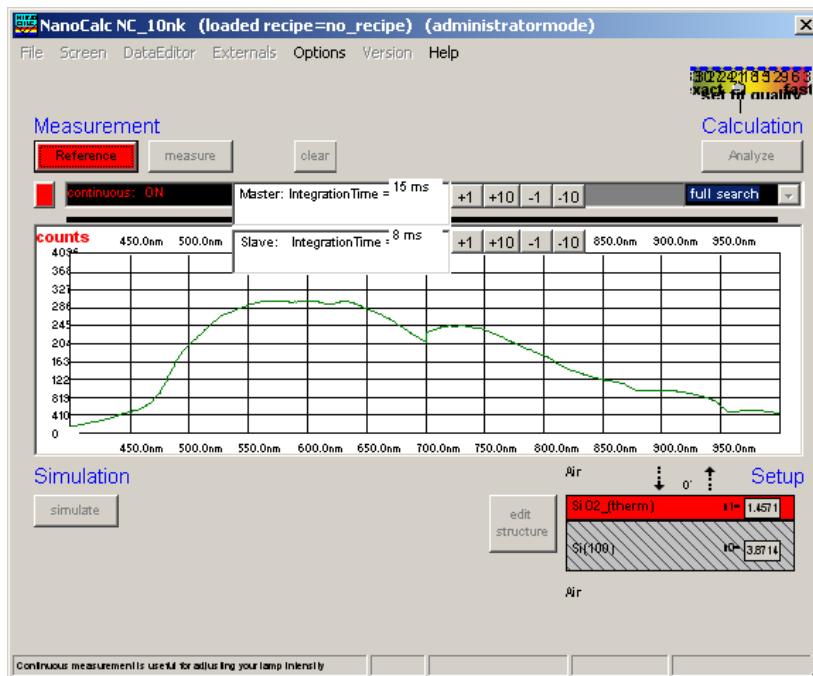


4 Getting started

After installation of your hardware and software you should be ready to make your first measurements.

First example = without SCOUT-software:

1. You need a blank silicon wafer as a reference and a wafer with a thin layer (e.g. 495 nm SiO₂ on Si). It is a good idea to use a special “step wafer” with different oxide thickness as a first test or for calibration purposes. Please ask your hardware supplier for information about step wafers.
Choose an experimental setup with a fiber or a microscope.
2. Then insert your reference wafer, switch on your lamp, start NanoCalc and click on the button „continuous mode“.



This button turns **RED**. Then click on the button “Reference” (this button turns **RED** as well) and you should see the spectrum of your lamp as it measured repeatedly in short time intervals.

You should observe a spectral region comparable to the data of your spectrometer (e.g. 250 -1100 nm, depending on your grating).

It is important to use a “good” amplitude of this signal = not too high and not too low. This means:

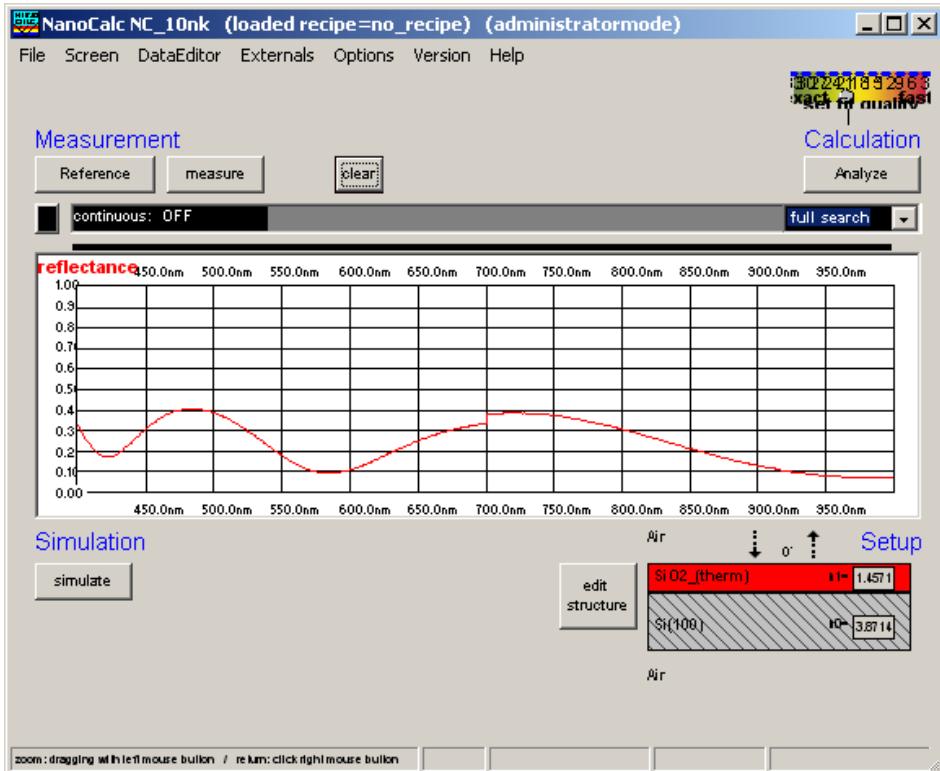
- a. there should be no saturation of the CCD-detector (=a flat region) in the signal.
- b. try to get a signal height of about 50-90% of the scale height for oxide samples (and similar) and about 20% for metallic samples. The exact value is of no concern as long as your signal in the measurement of the real sample does not cause saturation.

There are several possibilities to get a “good” signal amplitude:

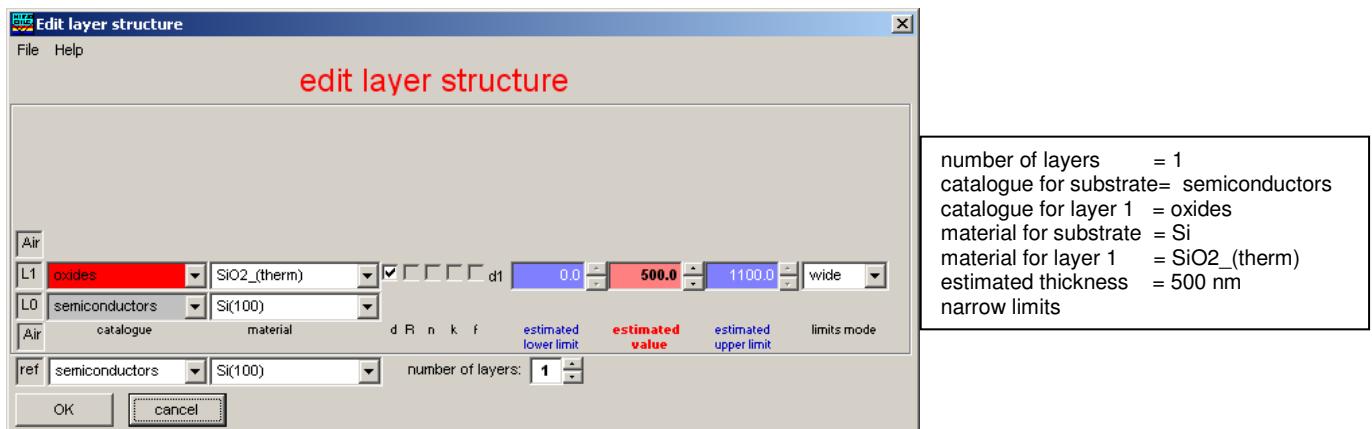
- a. increase or decrease integration time (with the buttons ±1 ms or ±10 ms) to adjust the signal between 20-90%.
 - b. or adjust the lamp intensity (e.g.NanoCalc-2000-VIS/NIR), if this is possible
3. Then click on the button „continuous mode“ again to turn off the continuous mode. Both buttons turn to **BLACK** again. The last reference measurement is saved internally and you can see it on the screen. From now on there is no need to repeat this reference measurement unless you like to control repeatability etc. BUT: from now on you should not change the lamp intensity or the distance to your sample. Your sample should also have the same height as the reference sample.



4. Put your wafer with the thin film onto the Stage and press the button „Measure“. Pay attention not to have dust particles in the region where you measure.
 You should get a spectrum like this (with a different numbers of extrema or even no extrema).



5. Then press the button „Edit Structure“ and choose the correct parameters for your layer setup:



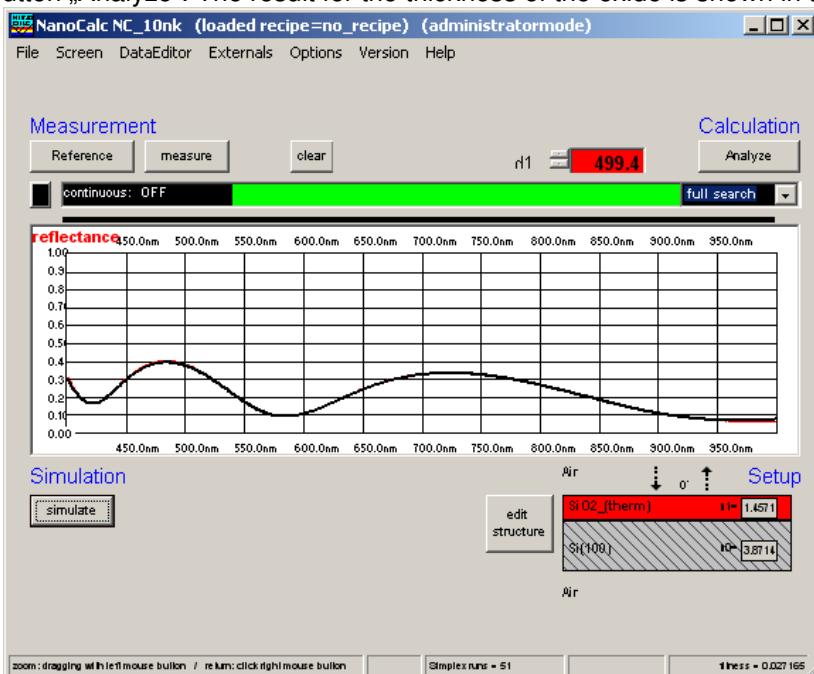
It is not important to choose perfect values for thickness and estimation limits at the moment.

When should you use “narrow limits” or “wide limits” or “user limits” ?

- if you have no knowledge about the thickness of your layer (but layer thickness should be MORE than about 5 micrometers in thickness), choose "user limits"
- if you have no knowledge about the thickness of your layer (but layer thickness should be LESS than about 5 micrometers in thickness), choose "wide limits"
- if you have GOOD knowledge about the thickness of your layer (within about 50-100 nm), choose "narrow limits"



6. After changing the layer structure please check the spectral range again.
Use a smaller range for a thicker layer (and shifted more to VIS/NIR), and a range as wide as possible for thin layers, e.g. 250 - 1100nm.
7. Press the button „Analyze“. The result for the thickness of the oxide is shown in the upper right text window.



Second example = with SCOUT-software:

Now it is assumed that you own the SCOUT software and want to use this powerful tool for extracting data. This mode does not work, if SCOUT is not installed on your PC !

1. Get a reference spectrum in the same way as described above in steps 1 – 3
2. Now load an appropriate recipe with the menu “File\Load recipe”. You will be asked for the name of the recipe. In the case of an oxidized silicon wafer we use the recipe: “Cauchy on Si.lrc” which is in the list of delivered recipes. This recipe contains a Cauchy model for the dispersion $n(\lambda)$ of SiO₂ and will also deliver the oxide thickness.
After loading this recipe you can see the layer structure. The button EditStructure is still accessible, but it is only possible to change the reference material. All details of the layer system and all extraction limits etc are contained in the SCOUT recipe and can only be modified within SCOUT (which needs some knowledge of optics and some experience with the SCOUT software)
3. Now press the button „Analyze“. The result for the thickness and the refraction index of the oxide is shown in the upper right text window. (comment: the thickness values for measurements with and without SCOUT are slightly different because a Cauchy model is not the same dispersion as table values)



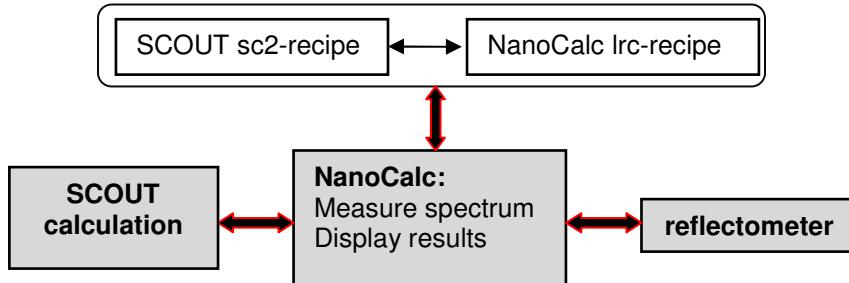
5 Usermodes of NanoCalc

NanoCalc has two different usermodes, the “**SCOUT-mode**” and the “**NanoCalc internal mode**”. At the moment the “internal-mode” is the normal mode, the “SCOUT mode” may be used but an extra SCOUT software has to be purchased.

5.1 SCOUT mode

NanoCalc works as a graphical user interface for a sophisticated film software “**SCOUT**” working in the background.

The whole process is necessarily driven by recipes.

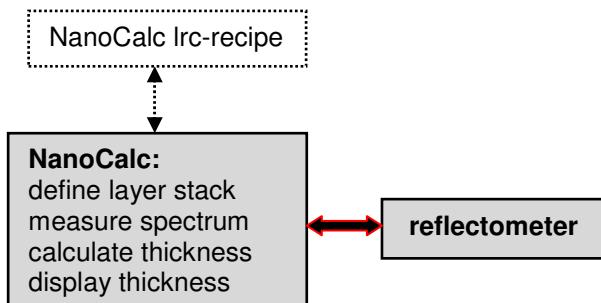


- within NanoCalc you have to load a “**recipe**”, e.g. “SiO₂ on Si.lrc”. This ASCII-readable recipe contains a link to a SCOUT recipe like “SiO₂ on Si.sc2”. All necessary layer informations are contained in this SCOUT recipe and are read by NanoCalc, but only for display purposes.
- NanoCalc now controls the hardware, measures the sample and sends the measured reflectivity-values to SCOUT (via a file NC_Data.xy in directory “NanoCalc\Internal_Files”).
- SCOUT does the calculation of all parameters
- the results are given back to NanoCalc via OLE-connection. The main fit parameters (thickness, refraction, absorption, roughness and EMA-fractions) are displayed by NanoCalc, as well as all other SCOUT fit parameters.

This SCOUT mode relies totally on good SCOUT recipes. So there must be someone (you or the administrator or Mikropack) in the background being familiar with the details and the physics of SCOUT. The advantage is a “one-button-reflectometry” for the user and an enormous calculation power !

5.2 Internal mode

In this (normal) internal mode the user can create own layer stacks and does not need the external SCOUT software at all. There is no need to work with recipes, but it is recommended. BUT: At the moment only thickness values can be extracted, in one of the next releases also dispersion extraction will be possible (not as exact as SCOUT, but maybe good enough)



5.3 Combiversion with NanoCalc

If you bought a combiversion ElliCalc + NanoCalc (= ellipsometry and reflectometry) you will see an extra menu “version”. Here you can switch from one application to the other.



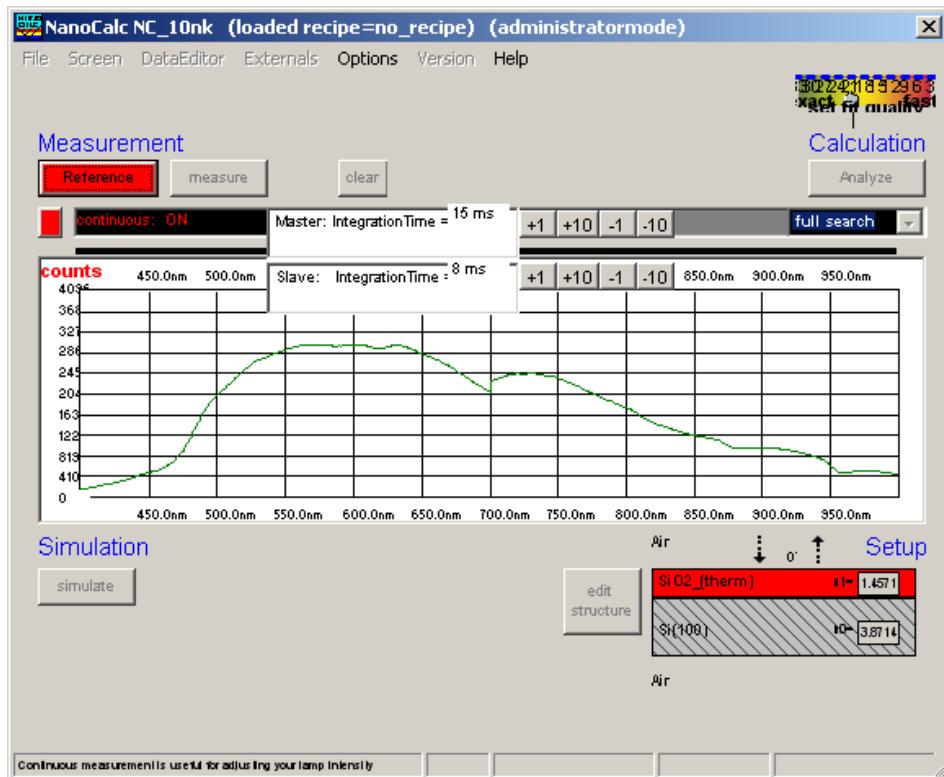
5.4 List of all menus and buttons

Main menu	Sub-menu	SCOUT mode	Internal mode
FILES menu	Load file		x
	Load Scout layer recipe	x	x
	Load NanoCalc layer recipe	x	x
	Save as file		x
	Save as layer recipe		x
	Save as reference system		x
	Change layer recipe	x	
	Save reference and dark		x
	Load reference and dark		x
	Export raw data	x	x
	Import raw data	x	x
	Show SCOUT results	x	
	Print report	X	x
	Exit	x	x
SCREEN menu	Spectrometer data	x	X
	Limits	x	x
	Dispersion	x	x
	Pixel resolution		x
	Show intensity	x	x
EXTERNALS	Mapping	x	x
	Analyze mapped data	x	x
	Online/multipoint	x	x
	Analyze online data	x	x
	RS232	x	x
	Video camera	x	x
	Show plot	x	x
OPTIONS	Change buttons	x	x
	Roughness	(x)	x
	Data manipulations		x
	Fit parameters		x
	Some setups (overflow)	x	x
	Some setups (change colors)	x	
	Merasurement mode	X	x
	Operator mode(Admin/User)	x	x
VERSION	NanoCalc_1	x	x
	NanoCalc_10nk	x	x
	ElliCalc	X	x
HELP	Contents	x	x
	About	x	x
EDIT STRUCTURE			x



6 Basic features of NanoCalc

6.1 Reference



This button „freezes“ the reference spectrum and sets internal flags („there is a valid reference spectrum“). So this spectrum is valid until you decide to measure again.

hint:

Pay attention not to run into saturation of the spectrometer ! (= a (nearly) horizontal part in the spectrum very near to the upper limit of the plot). There is an option in menu “data extraction” to give a warning.

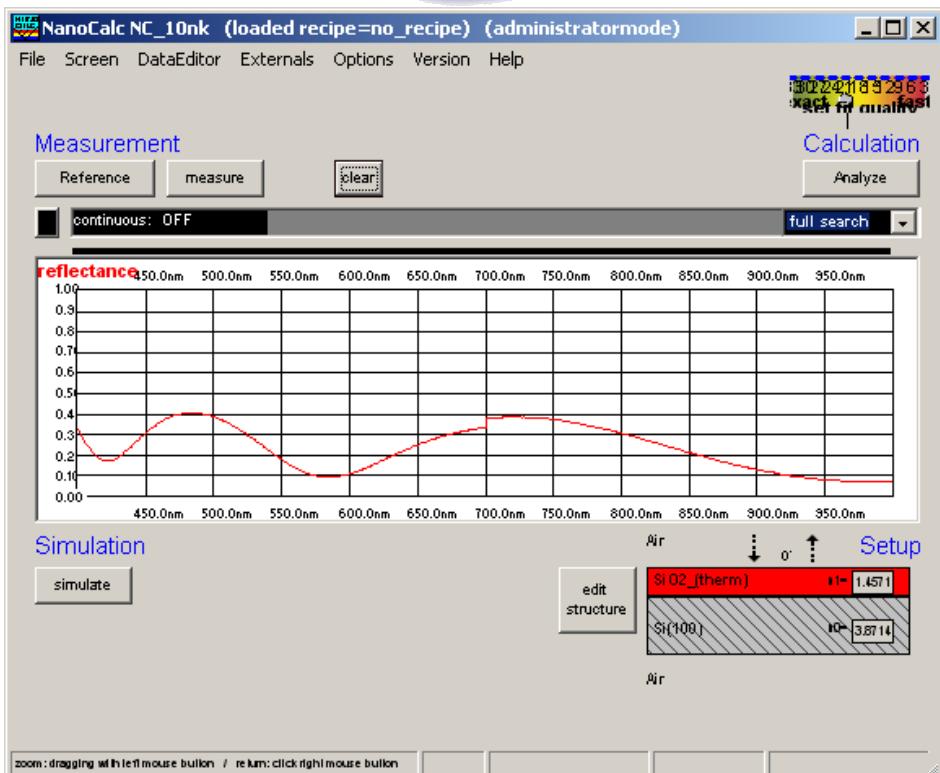
If you want to measure precisely (especially for extremely thin layers) repeat this reference from time to time (drift of lamps and so on).

If you use a double spectrometer, you have to adjust the crossover wavelength. Below this wavelength the data are collected from spectrometer channel A, above they are collected from spectrometer channel B.

You may use a **different** material for referencing than your substrate (but pay attention: do not run into saturation in either mode !)

6.2 Measure

This routine measures the spectrum of your test device and performs the following calculation:

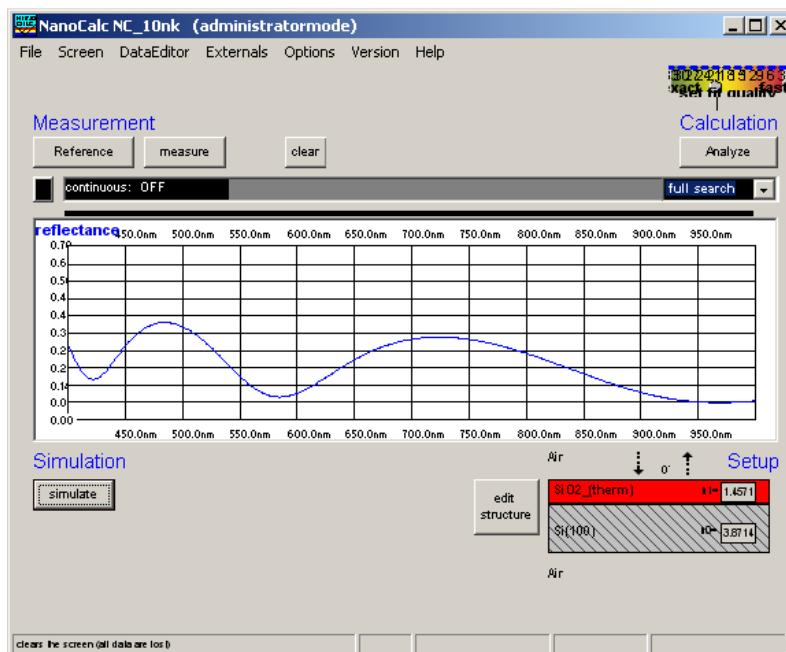


Reflectivity: $R = \frac{Meas - D}{Ref - D} \cdot R_{substrate}$

With:

Meas = measured spectrum
 Ref = reference spectrum
 D = dark spectrum
 $R_{Substrate}$ = reflectivity of an uncoated substrate

As a result you get the theoretical reflectance (or transmittance) of your coated substrate.
 If you are using a SCOUT-recipe the measured data are transferred to SCOUT. This takes some time



6.3 Simulate

This routine simulates a spectrum from the estimated thickness from „Edit Structure“. The structure that is simulated may be changed with button „Edit Structure“, if you do not use SCOUT. Otherwise you need SCOUT experience.

Hint:

If you want to have a short check which structure is simulated at the moment, put the mouse cursor over the appropriate layer for some seconds and you see the layer thickness.

OR:

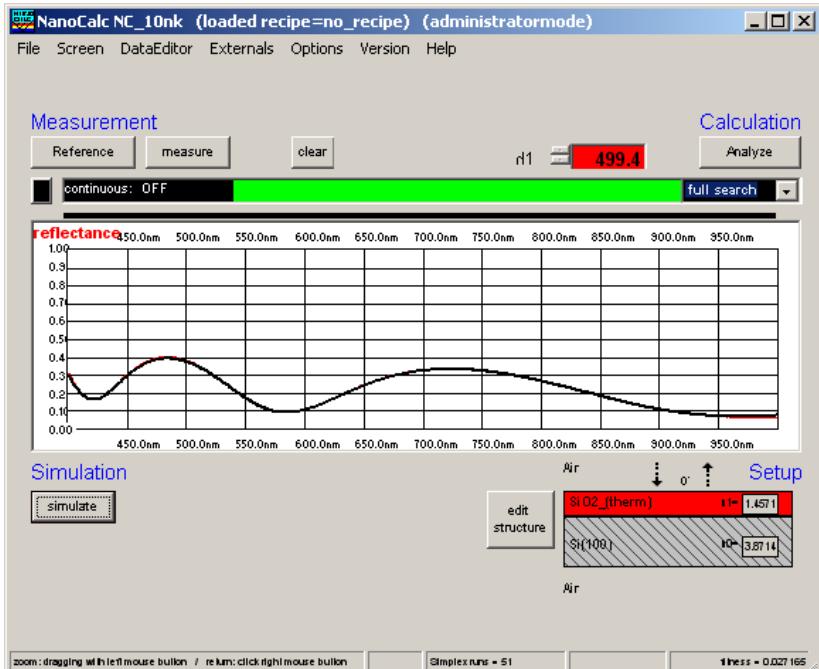
Leave your mouse cursor for some seconds over the button SIMULATE and look at the text in the status bar.

If you are using a SCOUT-recipe the calculation is done by SCOUT. This takes some time to transfer the data.....



6.4 Analyze

This routine analyzes a spectrum (either simulated or measured) within the data extraction limits. The structure that is simulated may be changed with button „Edit Structure“, if you do not use SCOUT.



Hint:

To have a short check which structure is simulated at the moment, put the mouse cursor over the appropriate layer for some seconds and you see the layer thickness.

OR:

Leave your mouse cursor for some seconds over the button SIMULATE and look at the text in the status bar.

If you are using a SCOUT-recipe the calculation is done by SCOUT. This takes some time to transfer the data.....

6.5 Continuous mode

The continuous button switches between continuous: ON (=red button) and “continuous: OFF” (button =black). To use this option you have to switch either to “Reference” or “Measure” or “Analyze”. Then there will be a continuous measurement of the reference signal (very useful to adjust the intensity of your lamp) or there will be a continuous measurement or even analyzing of your signal (very useful if you want to move your sample to different positions).

All others buttons of NanoCalc are disabled until you finish the continuous mode.

You may adjust integration time by using the buttons -1/-10 /+1/+10 msec (separate for channel A and channel B spectrometer)

6.6 Measurement mode

There are different data extraction modes in NanoCalc (internal mode):

Full search

NanoCalc uses the lower and upper limit of your guess in EditStructure and tries to find the best fit to the measured values by testing all simulated curves in narrow intervals of 1 nanometer. This is the preferable method in most cases, although it is not optimized concerning speed.

Fast search

NanoCalc extracts information from the (guessed) values in EditStructure to calculate thicknesses as precise as possible. The search region is still determined by your choice of narrow, wide or user limits. This is the fastest method in most cases, nevertheless it may fail.



FFT

This method is very fast and applicable only for relatively thick layers, but not very precise !! It may be refined by pressing the check box “use extended search after FFT or failure” in menu FitParameters.

You will see the fouriertransformed spectrum on the screen with different peaks. As your original signal is NOT a sum of harmonic functions, there are peaks that do not correspond to a layer thickness (e.g. typically there is a peak corresponding more or less to the sum of all thicknesses). All peaks that can be identified are marked with a colored circle.

The scale in FFT mode is a scale of optical thickness (=product of geometrical thickness and refraction index), not of geometrical thickness. If you SHIFT+Click on the values of refraction index (below the word “SETUP” in main menu, the FFT scale will be recalculated for the value of the corresponding layer.

You have the choice between different options in menu EditStructure (“FixedLimits”, “NarrowLimits”, “WideLimits” and “UserLimits”)

“FixedLimitsMode”

In this mode the values of low and high limits of your estimate are made equal to the thickness. This means that this layer is regarded as perfectly well-known.

Such a layer is excluded from data extraction algorithms.

“NarrowLimitsMode”

NanoCalc uses the value of your thickness estimation to calculate low and high limits which are quite narrow (about ± 100 nm). A search is done ONLY within these limits. If your limits were to narrow this search will fail and you have to try wider limits (like WideLimitsMode)

“WideLimitsMode”

The low limit and high limit is set according to the Editstructure setup menu:

1. relative wide limits: a symmetrical region is given, like ± 500 nm
2. absolute wide limits: the values of lower and upper wide limits are given as absolute values

In any case: a search is done ONLY within these limits. This means that the user does not need any knowledge about the thickness. This option MAY be slow (but not necessarily !)

“UserLimitsMode”

NanoCalc fits the spectrum between low and high limits which were input by the user. Here the maximum thickness is 300 micrometers.

6.7 Fitness

Any extraction of parameters is accompanied by a value of “**fitness**”. This is the sum of the mean square deviations between measured and simulated curve (normalized to the range of extraction). The fitness is a rough guide whether your thickness value is “good” or not.

In the file “Thinfilm.ini” you will find 3 entries in section [fit]:

```
Failure_RedLevel=1  
Failure_YellowLevel=0.1  
RYG_LevelsAreDisplayed=False
```

If you change the variable RYG_LevelsAreDisplayed from “False” to “True” (in main menu “Fitparameters”), the usual rainbow pattern on the screen will disappear and a simple color will show up.

- If the fitness is below Failure_YellowLevel=0.1 you will see a GREEN color.
- If the fitness is between Failure_YellowLevel=0.1 and Failure_RedLevel=1 you will see a YELLOW color.
- If the fitness is above Failure_RedLevel=0.1 you will see a RED color

Attention:

If you measure very thick layers (with a good correlation between maxima positions, but bad correlation between signal heights) you may end up with high values of fitness, but nevertheless the thickness results may be o.k.



7 Detailed features of NanoCalc

7.1 Main menu “File”

Internal mode

File	Screen	DataEditor	Externals	Options
Load file				
Load Scout layer recipe				
Load NanoCalc layer recipe				
Save as file ...				
Save as layer recipe ...				
Save as reference system				
Save reference and dark				
Load reference and dark				
Export raw data				
Import raw data				
Print report				
Exit				Ctrl+X

SCOUT mode

File	Screen	Externals	Options	Version
Load Scout layer recipe				
Load NanoCalc layer recipe				
Save as reference system				
Change layer recipe				
Save reference and dark				
Load reference and dark				
Export raw data				
Import raw data				
Print report				
Show Scout results				
Exit				Ctrl+X

7.1.1 Load file

(internal mode only)

This routine loads a measured or simulated spectrum that has been saved earlier (extension: .nan). Do not change the extension .nan.

It is assumed that all .nan-files are in the default directory “NanoCalc\data\nan_Files”, but you can change the directory path to any other directory on your PC.

The *.nan-file is an ASCII file that contains most parameters of the software and the measured or simulated values of reflectance (or transmittance) as a function of wavelength (or pixel) within the plot limits.

If you load a recipe instead of a *.nan-file you will not see any curve on the screen, but a change in the setup or the limits. The only difference between a recipe and a *.nan-file is the additional list of data values.

7.1.2 Load layer recipe

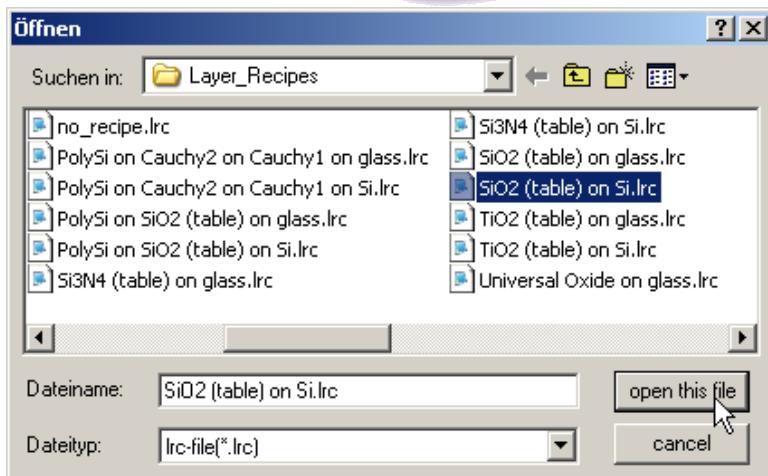
(internal mode and SCOUT mode)

This routine loads a layer recipe that has been saved earlier (extension: .irc). Do not change the extension .irc.

In SCOUT mode you may either load another SCOUT recipe (“load Scout layer recipe”) or you may switch to NanoCalcs internal mode (“Load NanoCalc layer recipe”). See the screenshots above.

In SCOUT mode all buttons captions are in *italic*, otherwise in normal.

It is assumed that all .irc-files are in the default directory “NanoCalc\recipes\layer_recipes”, but you can change the directory path to any other directory on your PC (provided that you did not use "UseLastFile-names_NC=False" in section [Filenames_NC] in Thinfilm.ini).



There is a section [Scout] in this layer recipe with an entry for "Scout_Recipename_NC". This entry is a **link** to the corresponding SCOUT .sc2-recipe in the directory "c:\programs\scout\scout_sc2_recipes" (or similar directory name).

If this linked .sc2-recipe is existent, SCOUT will be used for calculations = "SCOUT mode". If this link is empty, NanoCalc will calculate without SCOUT = "internal mode" (at the moment only for thickness !)

Example for SCOUT-mode (in ellipsometry):

```
[Scout]
Scout_DirPath=c:\programs\scout
ScoutStopTime=15
Scout_RecipeName_NC=SiO2 (table) on Si.sc2
Scout_RecipeName_EC=
```

Example for NanoCalc internal mode:

```
[Scout]
Scout_DirPath=c:\programs\scout
ScoutStopTime=15
Scout_RecipeName_EC=
Scout_RecipeName_NC=
```

The *.lrc-file is an ASCII file that contains most parameters of the software, but NO measured or simulated values of psi/delta (or tan(psi) /cos(delta)) as a function of the wavelength.

If you load a recipe you will not see any curve on the screen, but a change in the setup or the limits.

7.1.3 Save as file

(internal mode only)

This routine saves the measured or simulated file as an ASCII file with the extension .nan. The name of the file may be chosen arbitrarily. Do not use any other extension than .nan.

The *.nan-file is an ASCII file which contains most parameters of the installation and reflectivity $R(\lambda)$ as a function of wavelength (or pixel) within the plot limits.

7.1.4 Save as layer recipe

(internal mode only)

This routine saves all layer and screen settings as an ASCII file with the extension .lrc. The name of the file may be chosen arbitrarily. Do not use any other extension than .lrc.

The *.lrc-file is an ASCII file which does **NOT** contain and reflectivity $R(\lambda)$ as a function of wavelength (or pixel) within the plot limits.



7.1.5 Save reference and dark

(internal mode and SCOUT mode)

This routine saves the current reference data to the file "NanoCalc\data\ref_files\name.ref" and/or to "NanoCalc\data\ref_files\name_pixel.ref". If the screen was switched to pixel resolution both of these files are saved.

If the dark button was active also 1-2 dark files are saved

This function is easily accessible through function key **F8**.

7.1.6 Load reference and dark

(internal mode and SCOUT mode)

This routine loads a reference from the directory "NanoCalc\data\ref_files". If you choose to load a pixel reference, both references will be loaded (eventually also dark files)

Which of these two files is displayed depends on the pixel or nanometers resolution.

This function is easily accessible through function key **F9**.

7.1.7 Load last measurement

(internal mode only)

This function is easily accessible through function key F11.

7.1.8 Load last saved file

(internal mode only)

This function is easily accessible through function key F12.

7.1.9 Import raw data

(internal mode and SCOUT mode)

You are asked for an import- directory. The imported values are displayed in blue (=similar to measured values).

The scale of the screen is not adjusted.

7.1.10 Export raw data

(internal mode and SCOUT mode)

If a curve was produced by simulation or measurement it may be exported as ASCC-file ("raw data"). This file has a very simple structure: (lambda, value)

350,0.455
351,0.467
352,0.479
353,0.490
354,0.501
355,0.512
356,0.522

You are asked for a directory to save this file. Please use the default directory \RawData_Files\Reflectometry

7.1.11 Print report

This routine allows you to enter some user data (names of operator, of sample and so on), shows a preview and prints on the Windows standard printer. Changing the printer is possible only within Windows itself.

Entering of user data: you may also change the names of the labels (empty labels: this line is not shown on the final print). In the preview window you may zoom in and out. After pressing the print button you have the chance to change some printer options.

If you want to get a printout of the complete screen or parts of it:

It is recommended to use a hardcopy program to print the different parts of the software with enough options to change colors, resolution etc.

We recommend a shareware "HC.EXE" (<http://www.sw4you.de>) and on the CD-ROM in : tools\general), which will include a small button in every (!) window of your system near to the close button.



For online-users: we recommend to buy the OPTION NanoCalc-Online for printouts of Multipoint Measurement, Result-Windows with Statistic Data's and Excel-Connection.

7.1.12 Show Scout report

(SCOUT mode only)

See chapter "Special features for SCOUT mode"

7.1.13 Exit

This routine exits NanoCalc and SCOUT and closes all windows. All important data have been written to the Thinfilm.ini -file before and will be reloaded in the next run.

Important warning:

Do NOT close SCOUT separately !!! This would break the OLE-connection between SCOUT and NanoCalc. The only way to restore this connection is to exit NanoCalc and restart the software !

7.1.14 Function keys

If you click on the buttons **F2 - F7** different spectra or recipes together with their layer data are loaded (for demonstration purposes or to get a faster access to recipes than by loading them via "files\load recipe"). You should be able to analyze these demonstration spectra by a simple click on the Analyze button.

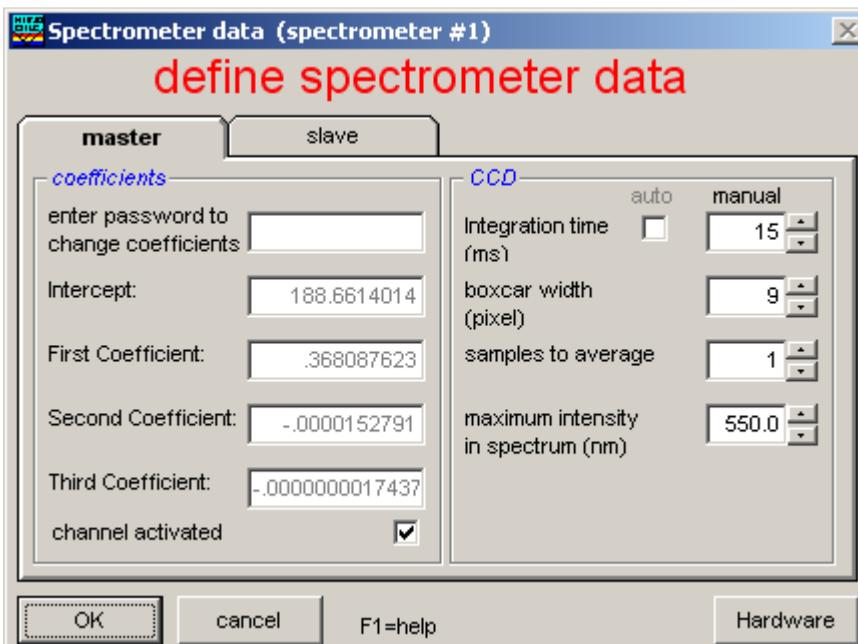
How to add your own recipes to function keys:

Step 1: carefully adjust all parameters in EditStructure and all plot and extraction limits. Do not forget roughness parameters if necessary.

Step 2: save this setup with menu "files\save_as_recipe" as usual BUT save it to menu "data\internal_files" instead of saving it to menu "recipes\layer_recipes" AND save your setup with the name of the function key, e.g. save F4.nan or F6.nan (NOT F6.lrc !!). Recipes stored in function keys have the file extension .nan and not the extension .lrc (as usual layer recipes). Check for correct names with Windows Explorer !

7.2 Main menu "Screen"

7.2.1 Spectrometer data



The 4 spectrometer coefficients are displayed for information purposes. They are automatically set by the Thinfilm.ini file which is specific for each single system.

Changing these values will screw up the system and is therefore password protected and only accessible for technical service.

For calibration purposes you may change these values (with a password and only within several percent deviation from your original values).



physical meaning:

These 4 numbers are the coefficients in a formula that shows the dependence between wavelength (in nanometers) and pixelnumber of your spectrometer according to the following formula:

$$\lambda = I + C_1 \cdot P + C_2 \cdot P^2 + C_3 \cdot P^3$$

with:

I	= intercept
C ₁	= first coefficient
C ₂	= second coefficient
C ₃	= third coefficient
P	= pixelnumber

Hint: Ask your hardware supplier if you have the impression that it might be necessary to recalibrate the spectrometer (a red HeNe-laser should show 632.8 nm)

7.2.1.1 Integration time

Whenever you change this value, it is written to disk (in file "Thinfilm.ini") and will be used as a startup value.

How to change integration time:

1. method:

To check integration time rapidly, use continuous mode button. You may change the value of integration time by +1 msec or +10 msec or -1 msec or -10 msec within a mouse click. Try to achieve a maximum signal of 20 - 90 % of total range. This value will depend very much on the reflectivities of your reference materials, your substrate material and your layer material.

An example:

If you use silicon as reference and substrate material and you want to measured silicon oxide thickness you should try to get reference signals of 80 - 90 %. An oxidized silicon wafer will NOT produce signal saturation and your signal-to-noise-ratio will be as high as possible.

If you use a metalized surface as a reference (and you want to measure oxidized silicon wafers later on) you need to start with LOW reference intensities (like 20 %) to avoid saturation in your measured signal. Of course you get a lower signal-to-noise-ratio in this case.

After switching off continuous mode button, you do not have to press the reference button again as the last signal has been saved.

2. method:

use the menu "options/spectrometer data" and check by pressing the reference button once.

Tips:

Try to use short values of integration time while keeping the lamp intensity as high as possible (to get short measuring times). This is especially important in mapping mode.

If your integration times are too short, you will have problems with signal-to-noise. If your integration times are too long, you will get saturation of the signal and this may cause errors in data extraction.

You may check the value of integration time at any time without entering the menu OPTIONS: Put your mouse cursor over the button REFERENCE or MEASURE and wait for about 2 seconds: a small window will pop up to inform you about integration time, samples to average and boxcar width.

These values correspond to the **channel A** spectrometer if you use a double spectrometer.

7.2.1.2 Boxcar width

physical meaning:

The Ocean Optics / Mikropack spectrometer is able to average over some pixels to increase signal/noise-ratio. A boxcar width of 1 pixel means no averaging at all. This has to be used if you want to measure very thick layers (like 50 micrometers of resist)



A boxcar width of 5 pixels means an averaging over 2 pixels on the left side and 2 pixels on the right side (= 5 pixels altogether). This averaging routine is shifted from the left side of the simulated spectrum to the right side with a step size of 1 pixel only. Values of 5-9 are recommended if you want to measure films in the range of 1 micrometer or less as you get a better signal-to-noise ratio. Use a value of 1 for very thick layers.

hint:

You may check boxcar width at any instance without entering the menu OPTIONS: Put your mouse cursor over the button REFERENCE or MEASURE and wait for about 2 seconds: a small window will pop up to inform you about integration time, samples to average and boxcar width.

These values correspond to the **channel A** spectrometer if you use a double spectrometer.

7.2.1.3 Samples to average

Whenever you change this value, it is written to disk (in file "Thinfilm.ini") and will be used as a startup value.

physical meaning:

The Ocean Optics / Mikropack spectrometer is able to average over some runs to increase signal/noise-ratio.

Tips:

Try to use small values for Samples To Average while keeping the lamp intensity as high as possible (to get short measuring times). This is especially important in mapping mode.

You may check Samples To Average at any instance without entering the menu OPTIONS: Put your mouse cursor over the button REFERENCE or MEASURE and wait for about 2 seconds: a small window will pop up to inform you about integration time, samples to average and boxcar width.

7.2.1.4 Internal correct for dark

If you choose this option, dark current is corrected automatically (see Button measure).

The Ocean Optics / Mikropack Spectrometer is able to measure the dynamic dark current internally within a couple of pixels that are NOT irradiated by external light, and is correcting dynamically.

7.2.1.5 Dark button

If you choose this option, dark current is corrected mathematically. This is necessary if you can't protect your system against ambient light or stray light.

7.2.1.6 Maximum intensity

This value describes the maximum intensity in the spectrum of your (halogen ?) lamp.



This value helps NanoCalc to achieve an automatic adjustment of the reference spectrum within the limits of the screen (=without saturation)

If you use a double spectrometer there are TWO such wavelengths corresponding to the different sensitivities of the two spectrometers and your light source.

7.2.1.7 Crossover wavelength

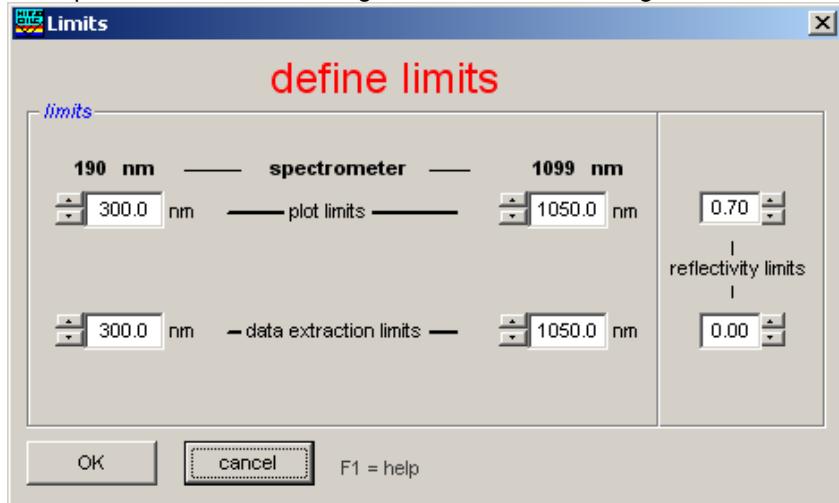
If you use a double spectrometer with different sensitivity regions (e.g. 200-600 nm for the CHANNEL A spectrometer and 500-1100 nm for the CHANNEL B spectrometer), NanoCalc **joins** the 2 spectra to get a single spectrum (200 - 1100 nm). The wavelength where the two overlapping spectra are joined is called crossover wavelength. (any value in your overlap range of the two channels is possible, 550 nm would be a good choice in this case).

7.2.2 Hardware settings

Please find these settings in Appendix A at the end of this handbook.
 (This window may look slightly different, depending on the latest version of the driver)

7.2.3 Limits

The spectrometer limits in magenta colors are showing the maximum range of your specific system.



7.2.3.1 Plot limits

The plot limits are the left and right side of the plot on your screen and coincide with limits of measurement.

The adjustable values of the plot limits depend on the grating in your Ocean Optics / Mikropack Spectrometer and are noted in the calibration sheet of your system.

The plot limits may be changed within NanoCalc in steps of 1 nm.

1. normal mode to change the limits:

open the menu “spectrometer data \ limits” and enter numbers or use the up-down arrows

2. fast and rough method to change the limits:

If you click in the field near the **LOWER** numbers you may change the plot limits without entering the menu option/limits:

If you click in the **LEFT** half with your LEFT mouse button you will decrease the lower plot limit.

If you click in the **LEFT** half with your RIGHT mouse button you will increase the lower plot limit.

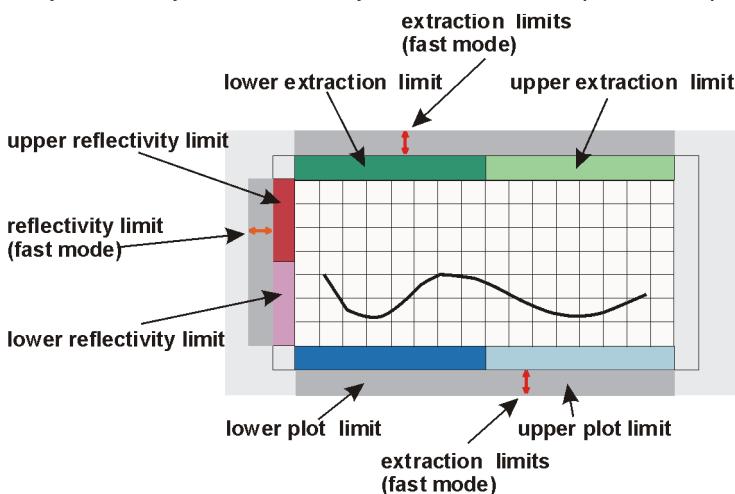
If you click in the **RIGHT** half with your LEFT mouse button you will decrease the lower plot limit.

If you click in the **RIGHT** half with your RIGHT mouse button you will increase the lower plot limit.

The same feature applies to plot limits and reflectivity limits.

3. fast and precise method to change the limits:

If you move your mouse very near to the lower part of the plot window (but still in the grey part) you will see a little vertical arrow and the value of the wavelength is displayed. If you now click with the left mouse button, you are able to change the lower plot limit (right mouse button=upper plot limit). The same applies to the other 2 grey zones = extraction and reflectivity limits (see picture)



little vertical arrow and the value of the wavelength is displayed. If you now click with the left mouse button, you are able to change the lower plot limit (right mouse button=upper plot limit). The same applies to the other 2 grey zones = extraction and reflectivity limits (see picture)



4. Zoom

You may zoom by dragging the mouse from one point to another within the plot area.

If you click with the right mouse button a small popup window will appear with the chance to undo this zoom.

You can also change the plot limits back to the full range (according to your spectrometer limitations).

You can also set the current plot limits as a standard or return to a previously set standard.

ATTENTION:

to be consistent with data handling, ALL materials files contain n and k data between 150 nm and 1100 nm. Usually only *parts* of these data are measured data (e.g. between 206 nm and 840 nm or between 300 nm and 1100 nm). If you simulate, the valid part of the curve is shown in *black* while the rest is shown in *grey* (and you get a message).

Extraction limits are restricted to the range of valid n and k data.

7.2.3.2 Extraction limits

These limits cannot be larger than the plot limits. Try to use a large extraction range as long as your signal is "good".

1. normal mode to change the limits:

open the menu "spectrometer data \ limits" and enter numbers or use the up-down arrows

2. fast and rough method to change the limits:

If you click in the field near the **UPPER** numbers you may change the extraction limits without entering the menu "spectrometer data \ limits".

If you click in the **LEFT** half with your LEFT mouse button you will decrease the lower extraction limit.

If you click in the **LEFT** half with your RIGHT mouse button you will decrease the lower extraction limit.

If you click in the **RIGHT** half with your LEFT mouse button you will decrease the lower extraction limit.

If you click in the **RIGHT** half with your RIGHT mouse button you will decrease the lower extraction limit.

The same feature applies to plot limits and reflectivity limits.

3. Fast and precise method to change the limits:

If you move your mouse very near to the upper part of the plot window (but still in the grey part) you will see a little vertical arrow and the value of the wavelength is displayed. If you now click with the left mouse button, you are able to change the lower extraction limit (right mouse button=upper extraction limit)

ATTENTION:

to be consistent with data handling, ALL materials files contain n and k data between 150 nm and 1100 nm. Usually only *parts* of these data are measured data (e.g. between 206 nm and 840 nm or between 300 nm and 1100 nm).

If you simulate, the valid part of the curve is shown in *black* while the rest is shown in *grey* (and you get a message).

Extraction limits are restricted to the range of valid n and k data.

7.2.3.3 Reflectivity limits

Reflectance (and transmittance) are defined between 0 and 1.

To zoom in the plot and to see some more details you may change the reflectivity limits. In most cases you will not need this option.

1. normal mode to change the limits:

open the menu "spectrometer data \ limits" and enter numbers or use the up-down arrows

2. fast and rough method to change the limits:

If you click in the field near the **LEFT** numbers you may change the reflectivity limits without entering the menu option \ limits:

If you click in the **LOWER** half with your LEFT mouse button you will decrease the lower reflectivity limit.

If you click in the **LOWER** half with your RIGHT mouse button you will decrease the lower reflectivity limit.

If you click in the **UPPER** half with your LEFT mouse button you will decrease the lower reflectivity limit.

If you click in the **UPPER** half with your RIGHT mouse button you will decrease the lower reflectivity limit.

The same feature applies to plot limits and reflectivity limits.

3. Fast and precise method to change the limits:

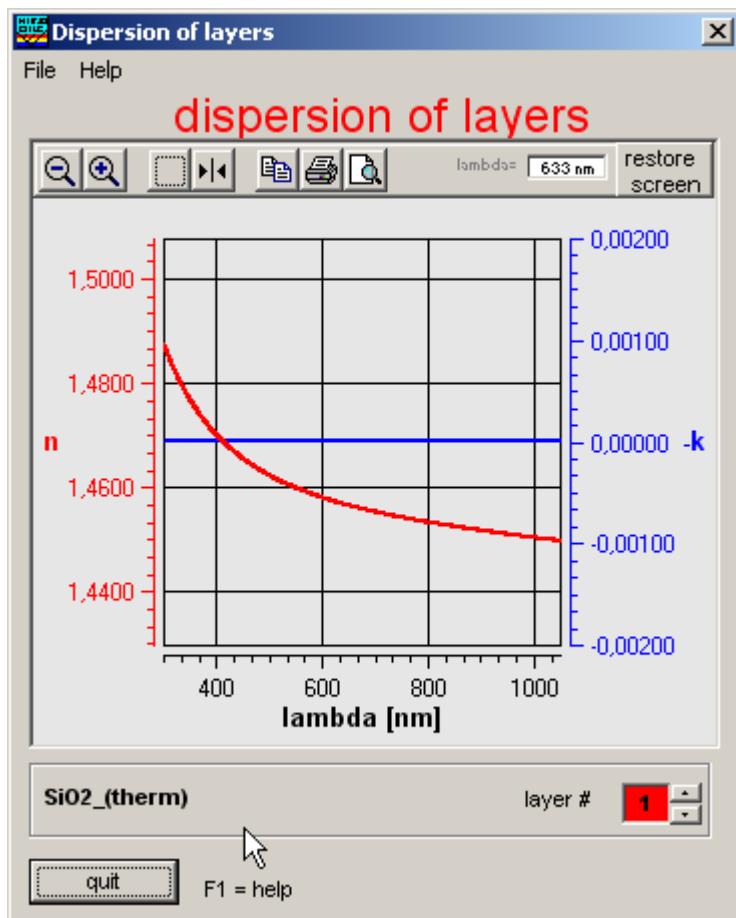
If you move your mouse very near to the left part of the plot window (but still in the grey area) you will see a little horizontal arrow and the value of the wavelength is displayed. If you now click with the left mouse button, you are able to change the lower reflectivity limit (right mouse button=upper reflectivity limit)

7.2.4 Dispersion

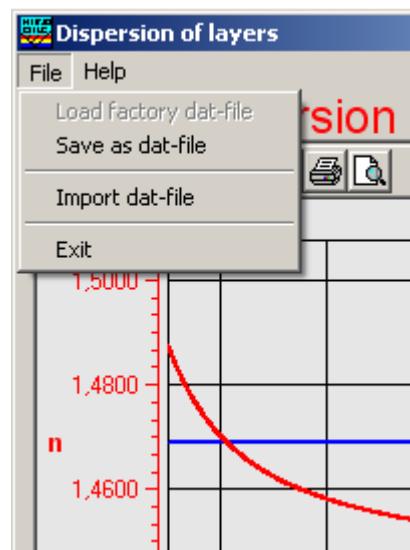
This form shows the refraction index $n(\lambda)$ and the absorption index $k(\lambda)$ (within the plot limits) for different layers.

This form is just a tool to control your data, nothing can be changed in this form.

- You may use 2 cursors (symbol #4). At start time of the cursors both cursors are painted on top of one another, move them with the mouse. The cursor values are shown in blue ($= k(\lambda)$) and red ($= n(\lambda)$)
- You may also zoom in and out and in an area (symbols #1 - #3)



You may also save these dispersion values as a dat-file, but be very careful about the target directory !!



ATTENTION:

to be consistent with data handling, ALL materials files contain n and k data between 150 nm and 1100 nm. Usually only *parts* of these data are measured data (e.g. between 206 nm and 840 nm or between 300 nm and 1100 nm). If you simulate, the valid part of the curve is shown in *black* while the rest is shown in *grey* (and you get a message).

Extraction limits are restricted to the range of valid n and k data.

7.2.5 Pixel resolution

This option is only useful for very thick films. If you use the option pixel resolution the software will acquire and display all data in spectrometer pixels and no more in nanometer resolution.



With pixel resolution data are displayed at exactly those wavelengths where there is a pixel in your spectrometer. If you own a high resolution spectrometer there is a spectral resolution down to 0.2 nanometer or less. For more precise information consult your hardware supplier.

The same option is also accessible via menu “data extraction \ sampling”.

7.2.6 Show intensity

If you use this option you will observe a value of "total intensity" in one of the panels in the status bar. This value is just the sum of all intensities between the extraction limit with a spacing of 5 nm.

Example:

$$I(\text{total})=234.45$$

So this figure gives a very rough information about the area under the measured or simulated curve. This might be used to maximize some intensity.

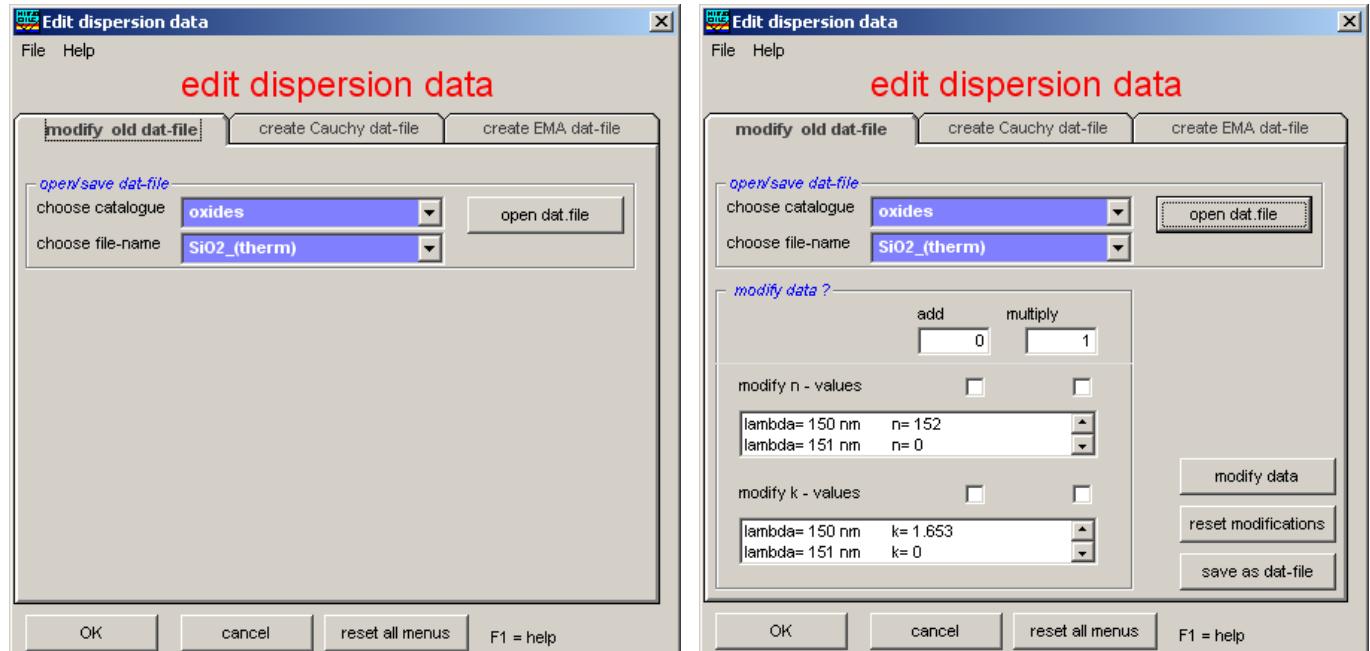


7.3 Main menu “Data Editor”

7.3.1 Modify old .dat-files

Modifying existing dat-files:

1. At first you will see two combo-boxes to choose a catalogue and a material.
2. Then click “open file”. Some new features become visible: either a list with cauchy coefficients or a table with dispersion data



If you like to change these old data (=adding of constants or multiplying with a factor), just click on ADD or MULTIPLY in the appropriate row. It is possible to change each cauchy coefficient separately, but not a single value in a table. If you want to change table values, you have to do this with an external text editor.

3. After adding or multiplying click on “save dat-file” or click “reset modifications”
Then the software will automatically switch to the page “save dat-file”.

7.3.2 Save DAT-files

Be careful where you save this “new” material !



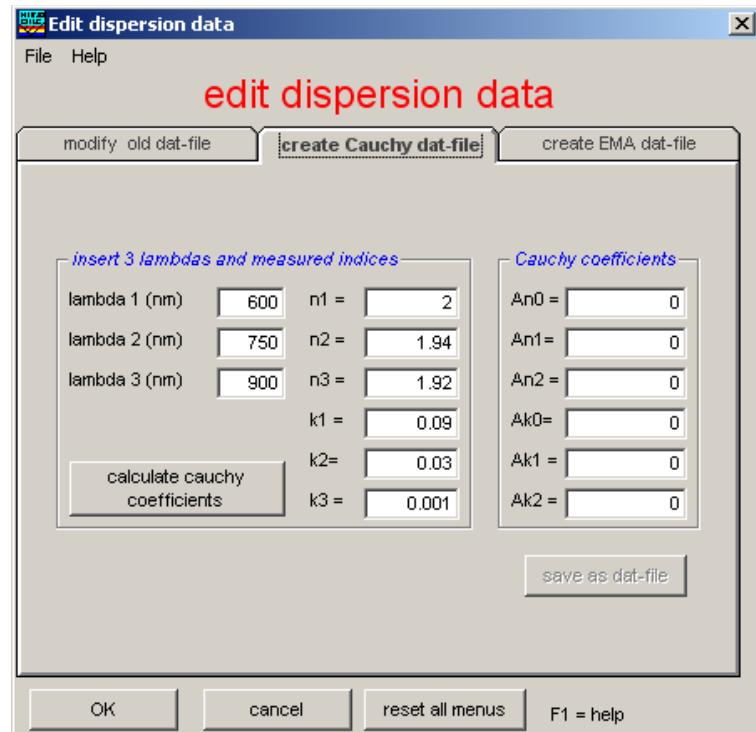


7.3.3 Create Cauchy .dat-file

Creating new Cauchy dat-files:
It is only possible to create new DAT-files with cauchy coefficients, not as a table of index data. To create a table you have to use an external text editor.

1. At first you will see three wavelengths and 6 Cauchy coefficients n0, n1, n2, k0, k1and k2
2. change these values according to your information. You have to add **ALL** three values.
3. click on create Cauchy coefficients
4. then click on “save DAT-file” or click “reset modifications”

Then the software will automatically switch to the page “save DAT-file”.



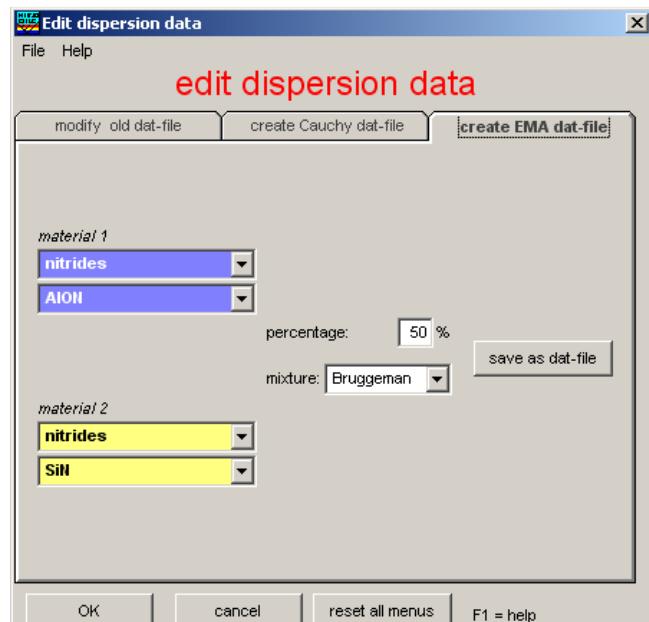
7.3.4 Create EMA dat-file

Creating new EMA dat-files:
An EMA-file is a mixture of 2 different dispersion values. There are different mixture algorithms in the literature. In NanoCalc only the simple Looyenga method (=a linear mixture) and the Bruggeman method are implemented.
The structure of an EMA dat-file is rather similar to 2 added normal dat-files. Here you see an example for Poly-silicon as a mixture of [crystalline silicon](#) and [amorphous silicon](#) (it is also possible to construct such a file manually with every texteditor)

```

Si_cr.100(Aspnes_mod.)
633,3.8714,0.0158
150,1100
EMA_Mixture=Si_(100),a_Si,Bruggeman,50.0_Percent
Table
150,0.5100,2.1500
151,0.5000,2.1500
152,0.5000,2.1500
...
...
1098,3.5559,0.0014
1099,3.5557,0.0014
1100,3.5554,0.0014
a_Si(SOPRA_amorphousSilicon)
633,4.517,0.2312

```





240,840
EMA_Mixture=Si_(100),a_Si,Bruggeman,50.0_Percent
Table

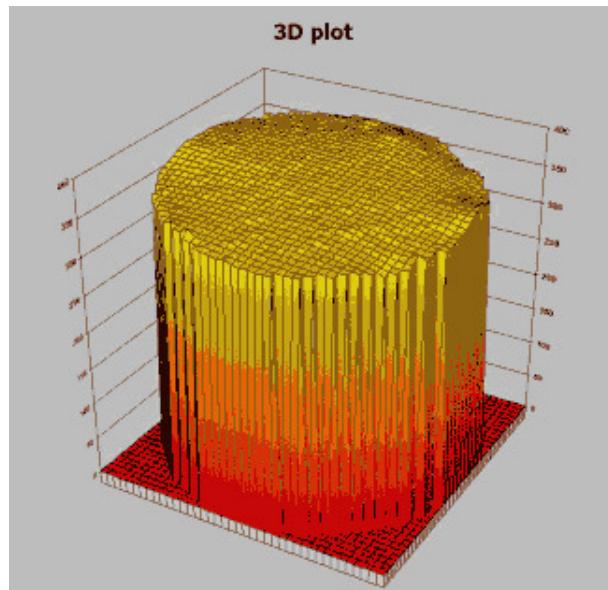
150,1.6844,3.3312
151,1.6844,3.3312
152,1.6844,3.3312
153,1.6844,3.3312
154,1.6844,3.3312

Be careful where you save this “new” material !

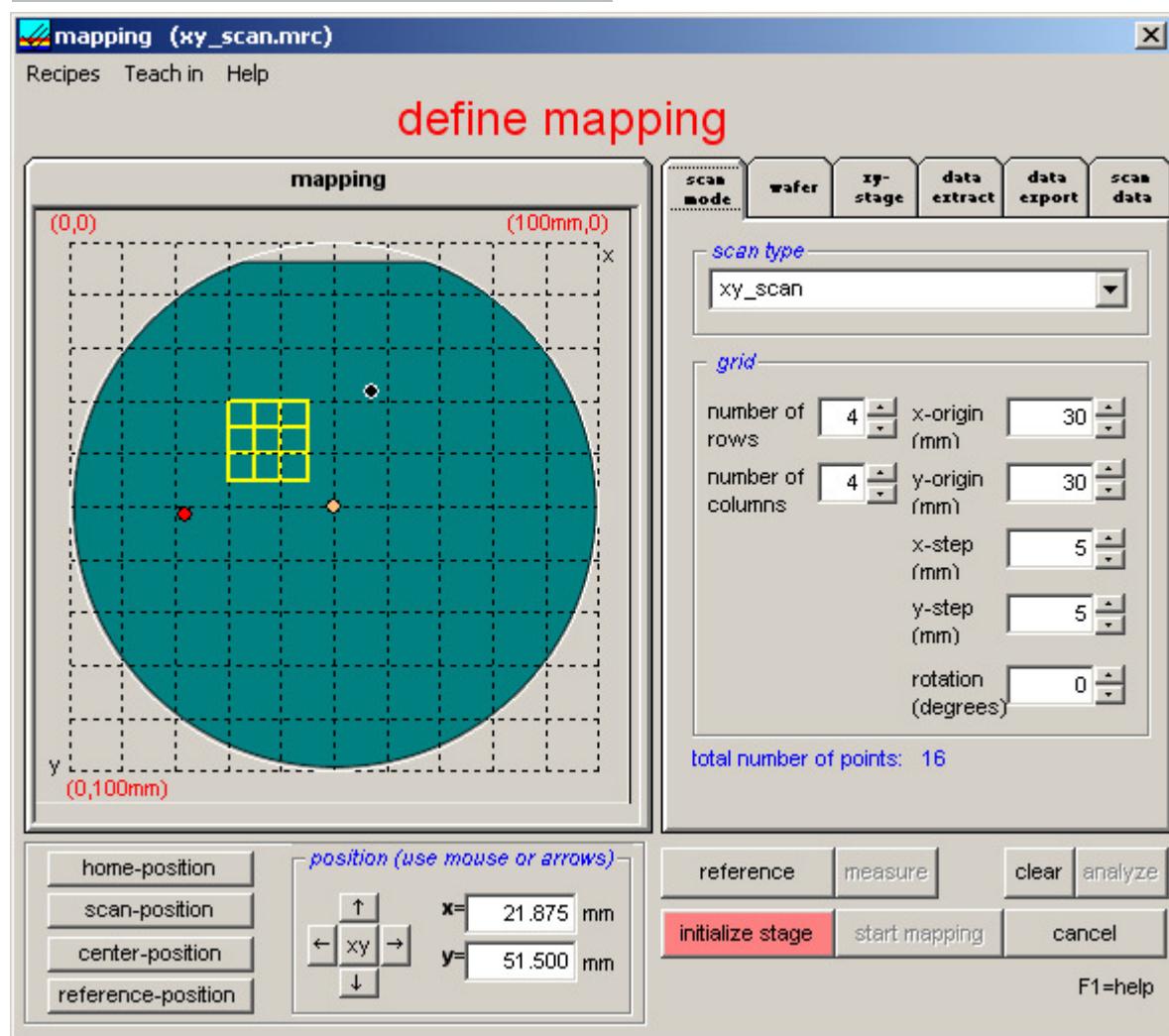


7.4 Main menu “Externals”

7.4.1 Mapping



You need a mapping-xy-stage and a special mapping add-on software for NanoCalc to measure in mapping mode. In this mode it is possible to measure and display your film parameters as a function of x and y.





main menus of mapping mode

1. menu "Recipes"

- Save as map recipe
- Load map recipe

Here you may save or load ALL the settings you have done in all the various possibilities. It is recommended to save your usual settings in a recipe. It is possible to use a special recipe name like "myownRecipe". Recipes for mapping will receive the extension ".mrc" and will be saved in menu "Recipes\Map_Recipes"

2. menu "Teach in"

This will be explained later in a following section

3. menu "help"

this is the usual access to help functions

main buttons (lower right side)

reference

you can take a reference with a blank reference wafer (right mouse button=time adjuastments possible)

measure

you can take a real (test) measurement with your sample. Thus you can control all settings before you start the mapping

clear

clears the screen

analyze

you can analyze the layer thickness your sample. Thus you can control all settings before you start the mapping

initialize stage:

After starting mapping mode you have to initialize the mapping stage first.

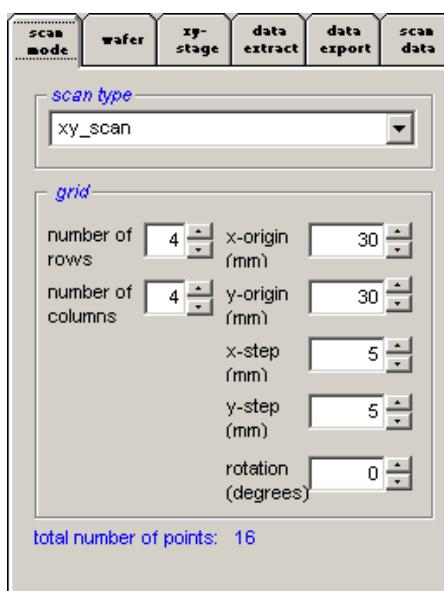
Until the mapping stage is initialized the function start mapping is deactivated.

start mapping

this will start the mapping sequence

cancel

leave mapping mode



scan mode:

a. shape of the wafers:

1. You may use square or round wafers.
2. To use your **own design** as a background you need to edit the file OwnDesign.bmp (this is possible with lots of drawing programs or ask your software supplier for help).

b. wafer size

Wafer size may be changed between 50 mm and 300 mm (= 12").

A grid is shown with a constant grid distance (e.g. 10 mm).

c. scan region

It is possible to change:

- the x and y coordinates of the origin in steps of 0.1 mm
- the number of rows and the number of columns of the scanning grid (from 1 to 100)
- the size of the x and y steps (in multiples of 0.1 mm)

The wafer plot shows what you are doing.

d. rotation

here you can rotate the scan region



e. mapping positions

measuring position:

If you press one of the position buttons (Home, Scan, Center, Reference), the mapping stage will immediately go to this point and a **red circle** is displayed on the screen. Additionally the coordinates of this point are displayed. If option "measure on each click" in Tab2 is activated, a measurement will be performed.

You may reach any point by clicking with the **LEFT** mouse button or by entering the coordinates and pressing the xy-button.

You may move up and down or left and right by pressing the appropriate arrow buttons. If you press the arrow buttons with the **left** mouse button the cursor will move in increments of xSteps. If you press the arrow buttons with the **right** mouse button the cursor will move in smaller increments of xSteps/10

f. position buttons:

1. home position

Usually this is in the right lower corner of the xy-stage. The hardware of the stage will define this point at the beginning of the mapping experiment (and it can be changed manually in the ini-File in section [mapping], HomepositionX/Y=.... The numbers mean the percentage compared to wafersize (0.05 =5% of wafersize)

2. scan position

this is the origin of the scanning coordinate system

3. center position

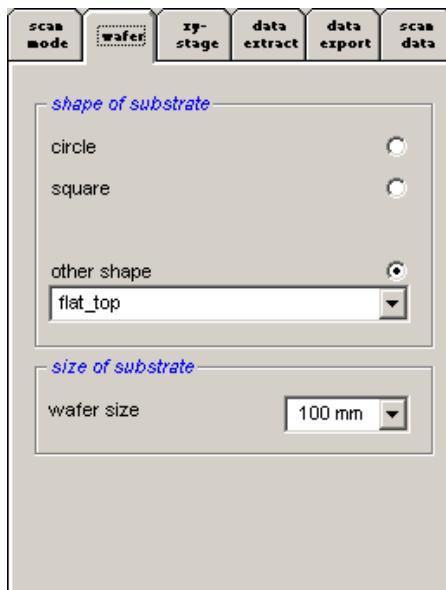
this is the center of the (round) wafer stage

4. reference position

this is the position where the reference measurement has to be done.

this point (=the black circle) may be chosen by clicking with the **RIGHT** mouse button or by changing the numbers

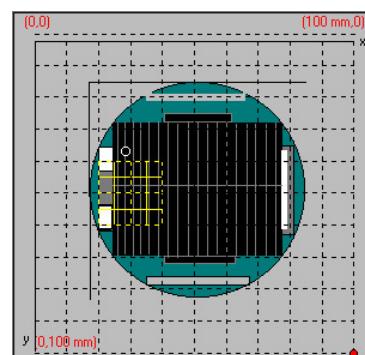
The wafer plot shows what you are doing.



wafer:

The shape of the substrate may be:

- circular (between 50 and 300mm)
- square (between 50 and 300 mm)
- your own design (change file "OwnDesign.bmp" with any drawing software)
example:



Wafer size may be changed between 50 mm (= 2") and 300 mm (= 12").

scan mode	wafer	xy-stage	data extract	data export	scan data
<p>xy reference position</p> <p>xReference • 46.38 (mm) yReference • 16.75 (mm)</p> <p>xy center position</p> <p>xCenter • 50.0 (mm) yCenter • 50.0 (mm) radius • 50.0 (mm)</p> <p>wait interval</p> <p>wait interval after positioning: 60 millisecond</p> <p>scanmode</p> <p>single steps <input type="checkbox"/></p>					

Xy-stage:

Ocean Optics / Mikropack can deliver xy-stages up to 300mm (= 12")

a. xy reference position

with a right mouse button click you may change the position for measuring the reference. You may also enter numbers in this field. There is a possibility to build a wafer-chuck with a special area for a piece of reference-material even outside the defined wafer area. You may enter negative coordinates, but be VERY careful not to damage the stage. When the reference is taken, the stage drives to the set reference position and takes the reference measurement.

b. xy center position:

you may define a round (!) area which means the area of measurements. This area is not necessarily the same as the reserved area for the chuck

c. wait interval:

after each measurement the scanning may be interrupted for a certain interval of time

d. scanmode:

If you activate this option each single measurement is waiting for a trigger signal (a keystroke with ENTER key or an external TTL trigger signal which is applied to the spectrometer. Ask your hardware supplier...)

scan mode	wafer	xy-stage	data extract	data export	scan data									
<p>visibility during map</p> <table border="1"> <tr> <td>d1</td> <td>fitness</td> <td><input checked="" type="checkbox"/></td> </tr> <tr> <td><input checked="" type="checkbox"/></td> <td><input type="checkbox"/></td> <td></td> </tr> <tr> <td></td> <td></td> <td></td> </tr> </table> <p>3D plot <input checked="" type="checkbox"/> 2D plot <input type="checkbox"/> 1D plot <input type="checkbox"/></p> <p>plot simulated curve <input checked="" type="checkbox"/> plot value <input checked="" type="checkbox"/></p> <p>analyzing options</p> <p>analyze thickness on each click <input type="checkbox"/> retry if bad fitness <input type="checkbox"/> fitness limit (e.g.10) <input type="text" value="20"/></p> <p>number of runs</p> <p>single run <input checked="" type="radio"/> continuous <input type="radio"/></p>						d1	fitness	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>				
d1	fitness	<input checked="" type="checkbox"/>												
<input checked="" type="checkbox"/>	<input type="checkbox"/>													

data extract:

a. visibility during map

You have the choice between 1D-plots for line scans, 2D-plots and/or 3D-plots. The 2D-plot and the 3D-plot contain the same data.

A 1D-plot is possible only if you measure along ONE row or column (and not a two-dimensional field.)

Only one variable is allowed to be seen during map.

b. analyzing options

analyze thickness on each left mouse click. This is a very useful feature to make a quick check on thickness distributions on your wafer (do not forget to activate option "plot value").

fitness limit: if your results are completely wrong for some reasons, all measured values with a fitness greater than this fitness limit here will be set to zero. This feature is useful, if dust causes a measurement error during mapping. Without this feature you might get enormous spikes.

c. number of runs

You have the choice between a single run (for real measurement purposes) and a nearly infinite number of runs (=30000) for demonstration purposes.



The screenshot shows a software interface titled "after map". It includes several buttons at the top: "scan mode", "wafer", "xy-stage", "data extract", "data export", and "scan data". Below these are input fields and dropdown menus. The "name of map file" field contains "C:\tmp\test.map". The "Column separator" dropdown is set to ";" and the "NumberFormatter" dropdown is empty. A list box for "insert comments to map-and Excel file" contains "test4" and "user4". A checkbox for "show results window" is checked.

data export:

You may choose the following options during a mapping experiment:

1. plot the simulated curve
 2. plot thickness value

It is more informative to see the analyzed curve and the calculated value of thickness during the simulation, but this is time-consuming. If the mapping takes a longer time it is recommended to switch off these 2 features.

You may choose the following options after a mapping experiment:

1. write data as map-file
 2. insert comments in map or Excel-files
 3. show results window

1. Write data as map-file

All thickness and fitness data together with some coordinate information are written to a ASCII-file in directory "NanoCalc\data\map_files".

examples can be found in the directory "NanoCalc\data\map_Files"

2. insert comments in map or Excel-files

you may enter text like "sample #1, "Paul McCartney" or "myfirsttest". This text will be a header for your map-files and also for all exported Excel files

3. show result window

If you accept this option a results window with possibility for Excel export will open after the mapping process.

scan mode	wafer	xy-stage	data extract	data export	scan data																														
<i>marker data</i>																																			
no	<input checked="" type="radio"/>	marker1	<input type="radio"/>	marker2	<input type="radio"/>																														
marker	x=	20	80																																
	y=	40	60																																
<table border="1"> <thead> <tr> <th></th> <th>x</th> <th>y</th> </tr> </thead> <tbody> <tr><td>1</td><td>30.000</td><td>30.000</td></tr> <tr><td>2</td><td>35.000</td><td>30.000</td></tr> <tr><td>3</td><td>35.000</td><td>35.000</td></tr> <tr><td>4</td><td>30.000</td><td>35.000</td></tr> <tr><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td></tr> </tbody> </table>							x	y	1	30.000	30.000	2	35.000	30.000	3	35.000	35.000	4	30.000	35.000															
	x	y																																	
1	30.000	30.000																																	
2	35.000	30.000																																	
3	35.000	35.000																																	
4	30.000	35.000																																	
<div style="display: flex; justify-content: space-around;"> accept teach-in test single steps </div>																																			

Scan data:

This feature is used in microscope arrangement (e.g. for measuring structured wafers) if you want to hit the xy-positions with higher accuracy. Usually the wafer or sample will be positioned on the chuck with some mechanical adjustments (like pins on 2 sides of the wafer and adjustment to the wafer flat). This will result in a medium accuracy, but not comparable to fine positioning like in semiconductor photolithography.

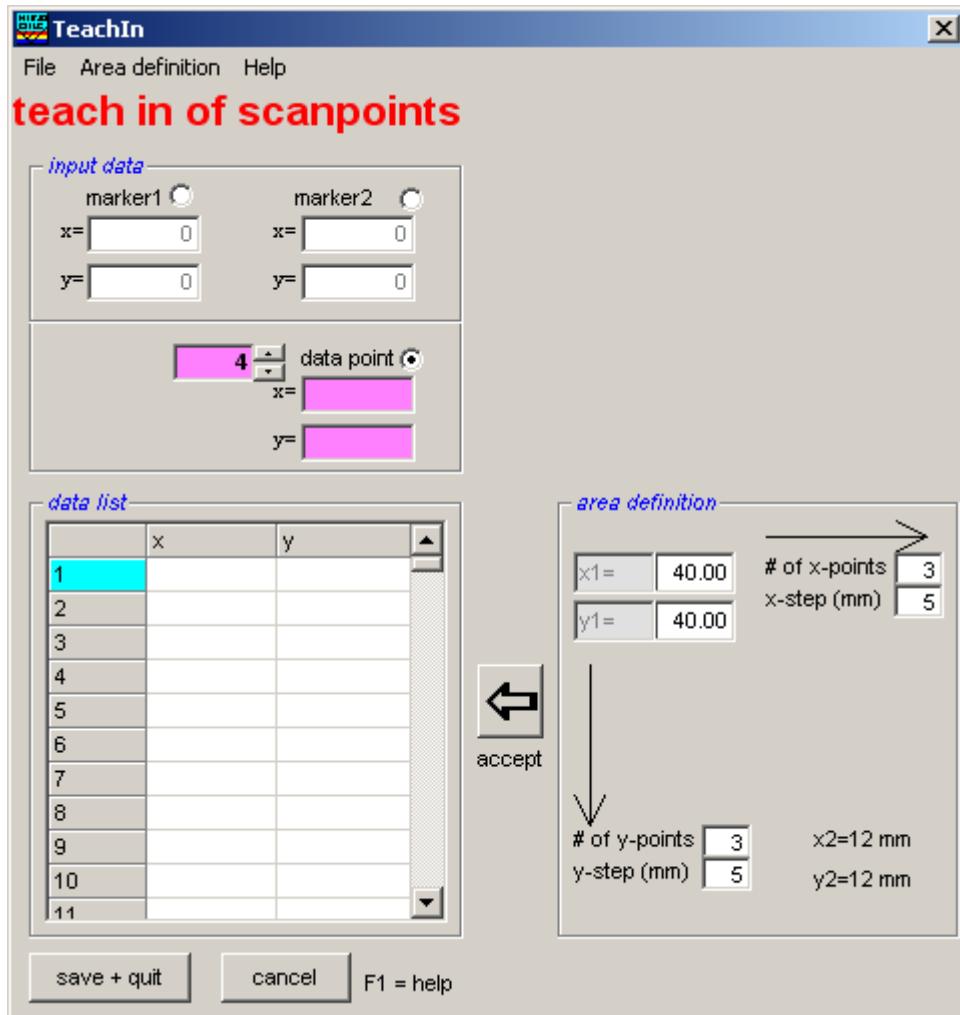
How to get a higher accuracy:

1. click on "marker 1":
The stage will move to this position. If you now look through the microscope you will see a slight deviation between the illuminated spot and the real marker on your wafer.
 2. Correct this deviation by moving the stage (use the keyboard arrows: clicking or pressing once = 10 micrometer, SHIFT + clicking or pressing once = 1 millimeter). The red circle on the screen will move slightly off the marker.
 3. Repeat step 1 and 2 for marker 2
 4. Now the software knows both deviations and is able to calculate what to do: shifting the origin and rotating the scan pattern a little bit. Press the button: "accept teach-in"
 5. Control the values of rotation angle and xy-origin
 6. Start mapping as usual



Teach in:

Teach in is an interactive tool to write new map-recipes without using text editors to edit the map recipe file.



Now the method with teach-in-mode:

1. open the mapping window (main menu “map data”) and then the menu “TeachIn”
2. you will see this window:
3. to set the first marker position, click on “marker 1”, then move the measuring position with the arrow keys on the keyboard
or by clicking somewhere in the wafer area
or by typing values in the text box
4. to set the second marker position, click on “marker 2”, then move the measuring position as before
5. to set the first data point, click on “data”, then move the measuring position as before
6. to set the next data point, click on the up down counter (now it should show the value 2 instead of 1) and then move to the measuring position as before
7. save the new recipe (like test.mrc) with the extension .mrc

7.4.2 Result List

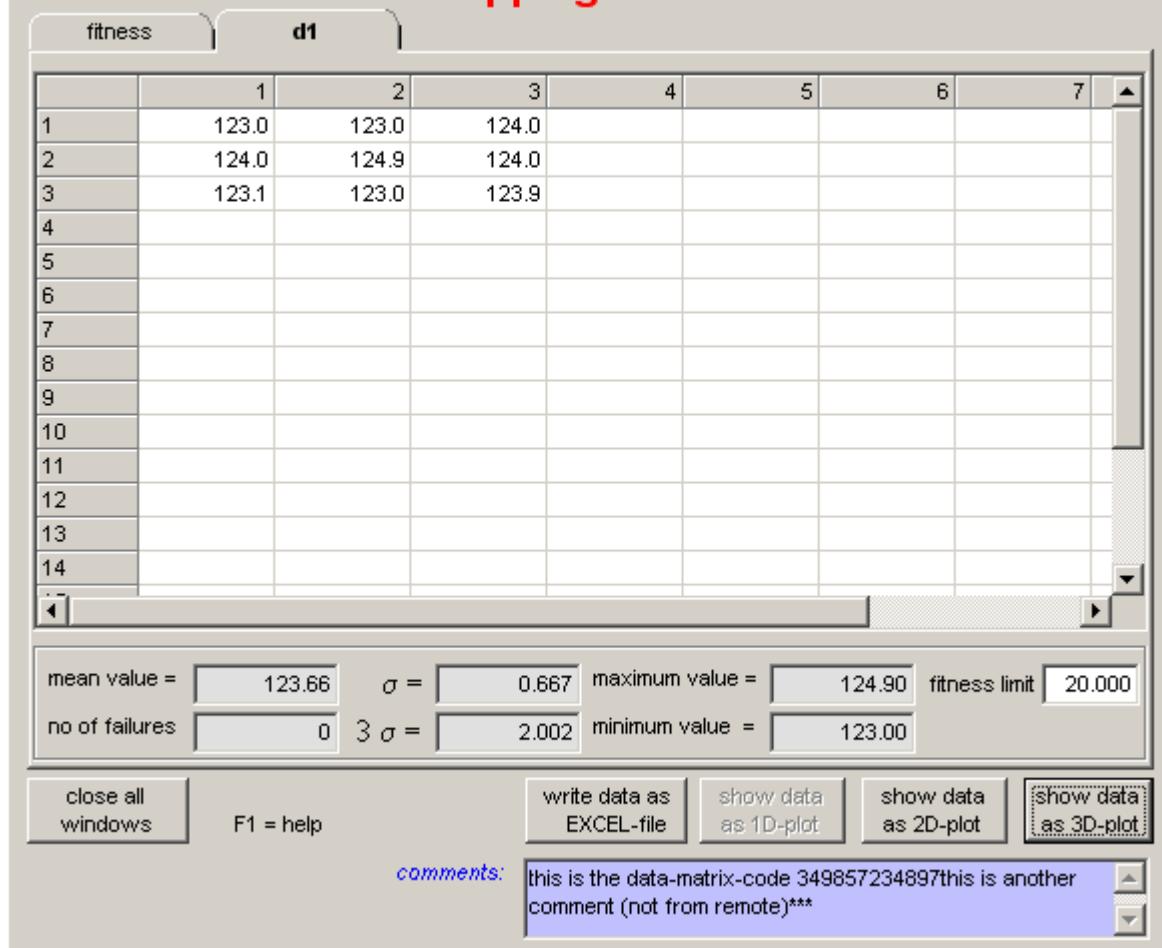
As soon as the mapping is finished you will see a result list:



Results (test_x3y3.map)

File Help

Mapping results



On the first page you see the measured thickness values for each layer. In the picture above there was just one layer and $3 \times 3 = 9$ measured data points. In the last page you can see the associated fitness values for each coordinate. In the text windows below the data window you see mean values, maximum and minimum values and standard deviation σ , the 3σ -value and the number of failures (according to the measured fitness and your fitness limit).

If you did not choose a regular scan pattern, you will see a one-dimensional list.

If you click on the buttons with the numbers in a row or a column you will highlight a certain number of data points (in the picture above column 3 was highlighted). Now you can control these selected values in a one- or two-dimensional plot by pressing the appropriate button in the last row. You may also choose a smaller amount of data by dragging with the mouse (e.g. $2 \times 2 = 4$ points).

If you press "write data to EXCEL-file" EXCEL will be opened (if installed on your PC) and the data will be transferred to a spreadsheet.

With "close all windows" you will return to NanoCalc main window and all mapping windows will be closed.

If you enter a value for "fitness limit" and press ENTER, the screen will be updated and all cells with a higher fitness than your limit will be plotted in red (cells in grey show that this point was outside the wafer).

7.4.3 Analyze mapped data

You may also analyze your mapped data at a later time, if you saved them to a .map file.



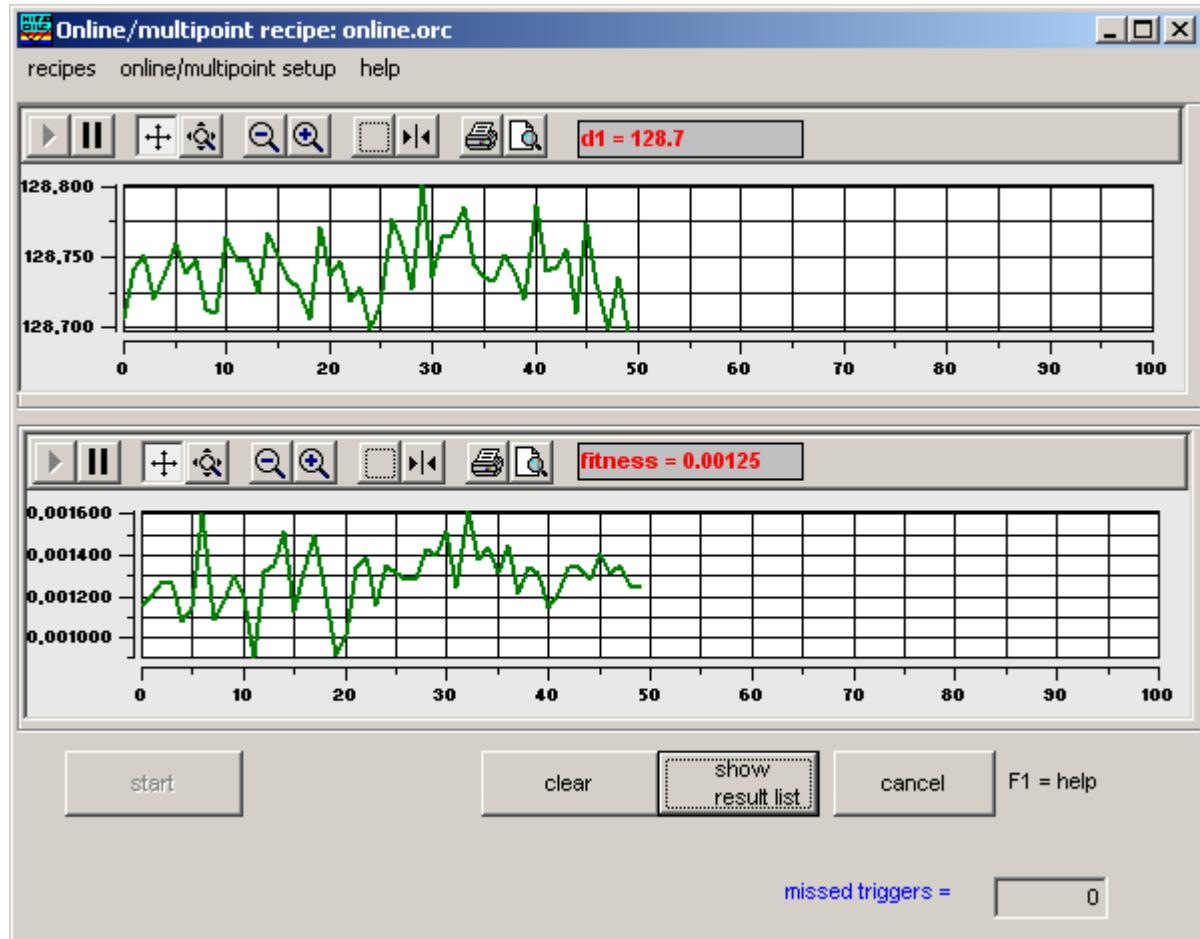
7.4.4 Structure of .map-file

The first 2 lines are comments, the file format is very strict.

```
test4
user4
***
xy-ScanMode
1 Layer(s)
1 Layer(s)ToExtract
2 Row(s)
2 Col(s)
4 total points

5 xStep
5 yStep
***
IndexNo, row, col, x, y, fitness, d1
1, 1, 1, 30.000, 30.000, 0.048, 132.880717
2, 1, 2, 35.000, 30.000, 0.048, 132.806642
3, 2, 1, 35.000, 35.000, 0.048, 132.918102
4, 2, 2, 30.000, 35.000, 0.048, 132.858514
```

7.4.5 Online/multipoint measurements





load online/multipoint recipe:

The online setup window contains lots of input data, so usually you will want to use an online recipe to do that job for you.

You will be asked for a file name (usually in directory "NanoCalc\recipe\online_recipes"). After loading this file nothing happens except new parameters in setup, like different y-axis or other trigger parameters.

save as online/multipoint recipe:

The online setup window contains lots of input data, so usually you will want to use an online recipe to do that job for you.

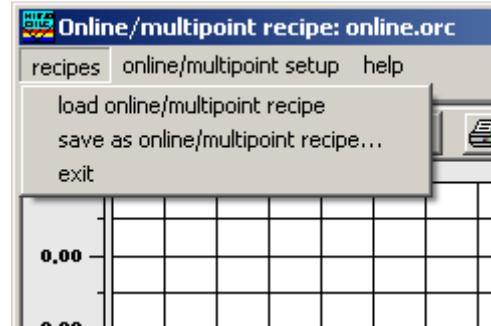
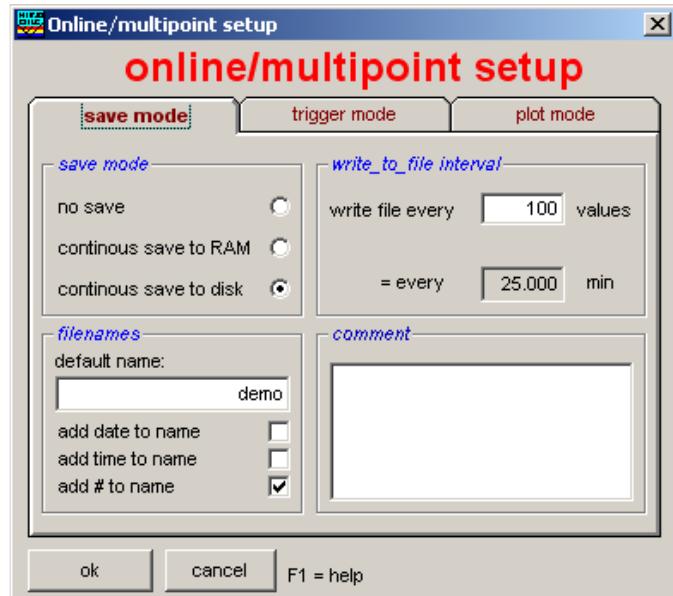
If you changed some setup parameters you can save them as a new online recipe.

You will be asked for a new file name (usually in directory "NanoCalc\recipe\online_recipes").

online/multipoint setup:

Depending on the switch "show setup first" in menu "online\setup" the setup window for online measurements is shown at first or not. If you want to rename your files at the beginning of each measurement cycle it is recommended to open the setup window first.

The setup window contains lots of input data, so usually you will want to use an online recipe to do that job for you.



save mode:

In this first part of online setup you can choose:

a. option "save mode"

1. no save:
all data are lost and only visible on screen
2. continous save to RAM
at the end of the run you may observe and analyze your data in the results window
3. continous save to disk
according to option "write_to_file_interval" all data are written to file in smaller portions with filenames that are determined in option "filenames"

b. option "filenames"

1. choose a name like "series 1" or "test4" or alike
2. choose one or more options "add....."

example: a filename might look like: test156.onl

c. option "trigger interval"

You might want to save the value (not the file !) every trigger, but for some reasons you might want to save only every third trigger.

d. option "write to file interval"

You might want to save the file (not the value !) every trigger, but for some reasons you might want to save only every third trigger.

e. comment

you may add an ASCII-string, which will be added to every online file



Online/multipoint setup

online/multipoint setup

trigger mode

trigger interval	min	<input type="radio"/>
trigger every	15	<input checked="" type="radio"/>
	sec	<input type="radio"/>
	msec	<input type="radio"/>

test recommended time msec

of runs

no of runs 50

infinite no of runs

ok cancel F1 = help

Online/multipoint setup

online/multipoint setup

plot mode

select online/multipoint parameters :

	auto	min value	max value	d1	fitness	
chart 1	<input checked="" type="checkbox"/>	auto	auto	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
chart 2	<input checked="" type="checkbox"/>	auto	auto	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
chart 3	<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	
chart 4	<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	

hints:

- use up to 4 charts
- use as few parameters as possible

ok cancel F1 = help

trigger mode:

In this second part of online setup you can choose:

a. option "trigger modes"

you can trigger continuously by adjusting the appropriate software parameters like trigger interval. You can trigger manually with a keystroke you can trigger externally with a TT-signal to your spectrometer. Please consult your hardware supplier...

b. option "trigger interval"

Here you choose the time interval between two software triggers. Pay attention on the correct unit. You may test the trigger interval empirically with "test recommended time". Add some safety margins.

c. option "number of runs"

You might want to run a certain number of data points only or (nearly) infinitely.

Attention: "infinite" means about 999999 data points.

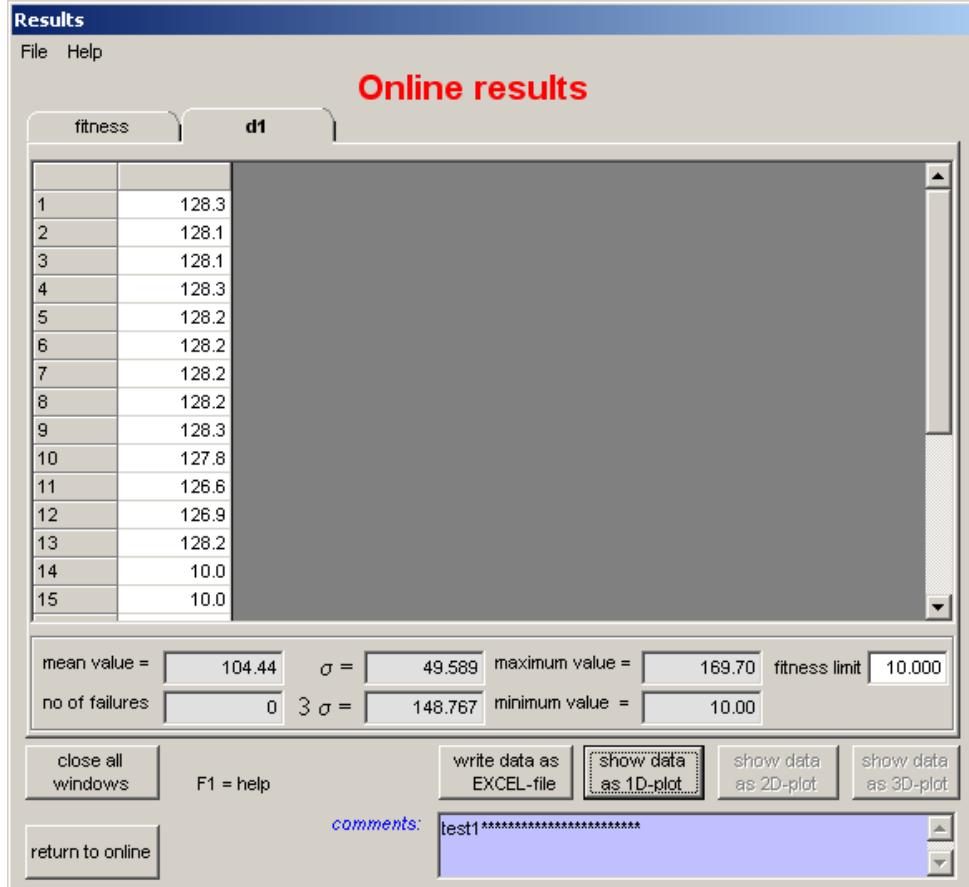
Plots:

In this third part of online setup you can choose plot parameters for up to 4 charts.

Each chart displays a single parameter



Result list for online/multipoint mode



On the first tab you see the fitness for each measurement, on the second tab you see the measured thickness values (for a one-layer system). In the picture above there 25 measured data points.

In the text windows below the data window you see mean values, maximum and minimum values and standard deviation σ , the 3σ -value and the number of failures (according to the measured fitness and your fitness limit).

If you press "write data to EXCEL-file" the data are transferred to an .xls-file (Excel need not be installed on this PC).

If you press this Excel-button together with the SHIFT-key the text will switch to "write data as csv-file" and such a csv-file will be generated instead of an .xls-file.

With "close all windows" you will return to NanoCalc main window and all online windows will be closed.

7.4.6 Analyze online/multipoint data

You may also analyze your online data at a later time, if you saved them to a .onl file.

7.4.7 Structure of .onl-file

The first line is a comment, the file format is very strict.

test1

55 total points

triggercounter, time, fitness, d1

1, 10:35:19, 0.010, 128.3

2, 10:35:19, 0.010, 128.1

3, 10:35:20, 0.014, 128.1

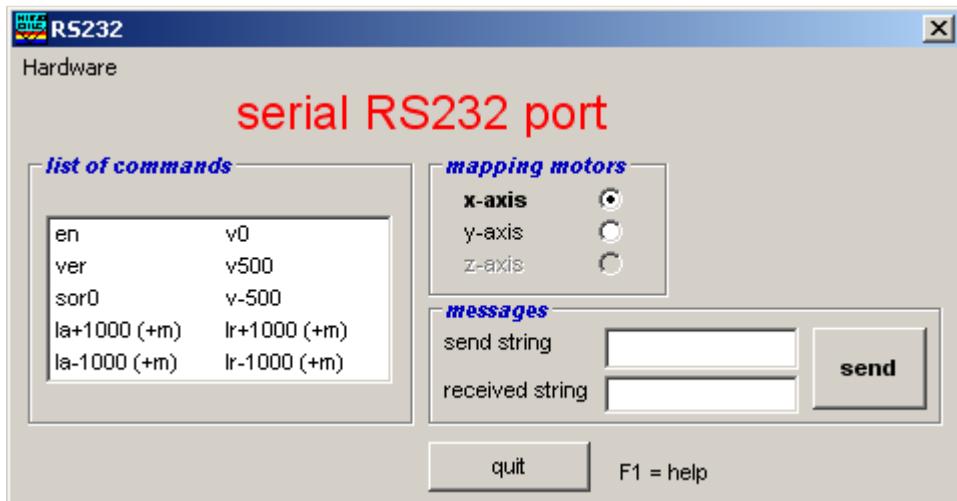
4, 10:35:20, 0.009, 128.3

5, 10:35:21, 0.008, 128.2



7.4.8 RS232

If you own an xy-stage or any other arrangement with Faulhaber motors you may use this menu to drive the motors and to test their behaviour. You find a list of commands on the left side, for more information please consult the motor manuals.

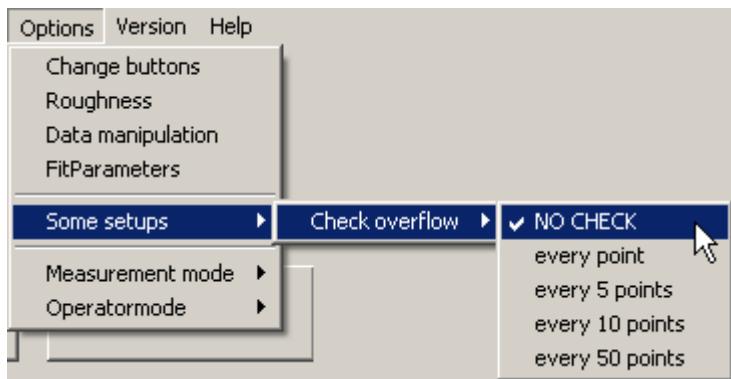


7.4.9 Vision system

If you own a vision system with an IDS uEye-camera you may turn on the camera with this menu



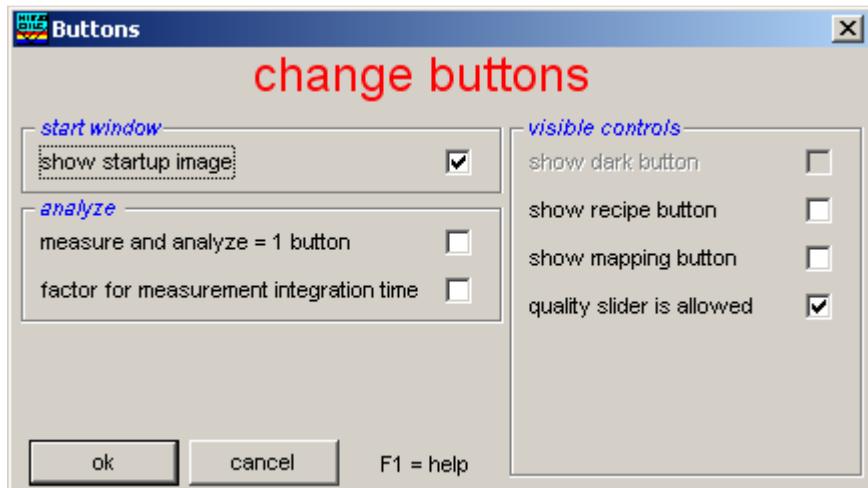
7.5 Main menu “Options”



7.5.1 Change buttons

In this window you can make visible or invisible:

- the startup image:
If you want to start NanoCalc with a nice picture: activate this option !
- the picture will disappear after some seconds or you might “click it away”



- a measure and analyze-button: to combine the functions to the measure and the analyze button

- factor for measuring integration time:
Sometimes the signal intensities from the reference sample and the device under test are extremely different: e.g. the device might have an antireflective coating and does not show a good reflection signal. To avoid signal-to-noise problems, it is possible to switch on the option “factor for measuring integration time” in menu “data extraction”. If you now go to menu “spectrometer data” you will find a new item to change the integration time for the measurement task independently of the reference task.

Example:

Integration time for reference = 100 msec

Integration time for measurement = 1000 msec

Thus there is a factor of 10 between these two experiments. Internally the device signal will first be divided by 10 (maintaining a good S/N-ratio) and then the calculation will be done as usual.

- show dark button: an extra dark button appears if it is necessary to measure any dark current (e.g. in a microscope setup)

- show recipe button: an extra “load recipe” button appears to make it easier to load recipes

- a mapping button: an extra “mapping” button appears to make it easier to use mapping
- a quality slider is allowed

With this feature it is possible to set the speed (or the precision of the fit) for each individual measurement

7.5.2 Roughness

General:

It is quite difficult to measure interference if the substrate or the layers are rough, as the interference patterns get lost.

Roughness is quite common for thick layers like 20 micrometers of photoresist, as the drying process is very critical and the shrinking of the resist does not lead to perfect surfaces.

Roughness is also quite common for technical surfaces like aluminum or brass or steel that are to be covered with protection layers (like DLC = diamond like carbon layers).

Methods:

In NanoCalc an empirical methods is implemented to deal with roughness:

1. no roughness

No roughness is included in the calculation.

2. constant roughness

You will see some textboxes in the setup area which show "R-factors" for each interface. This value means a **percentage** of light that is regarded as lost at this interface. So there is no real physical roughness model. Such a physical model cannot be given as the typical size of the roughness is absolutely unknown. This means that even the scattering mechanism (Mie scattering, Rayleigh scattering etc) is unknown. There are some formulae in the literature but in our case these are not better than the above mentioned method of light loss via some empirical R-Factors.

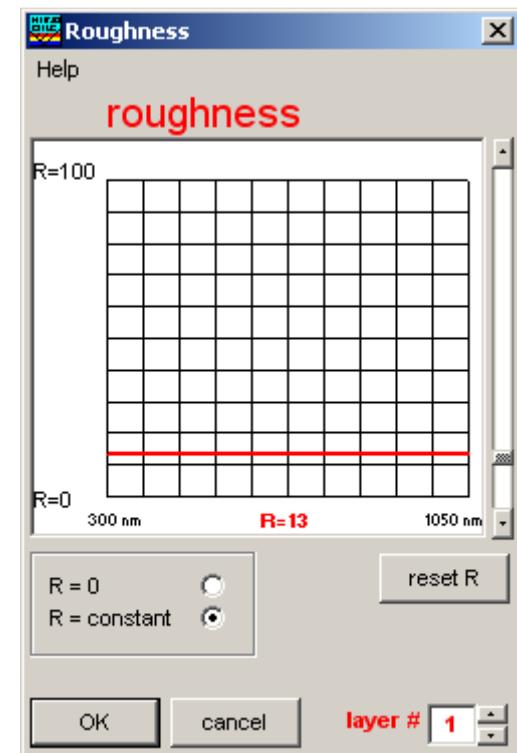
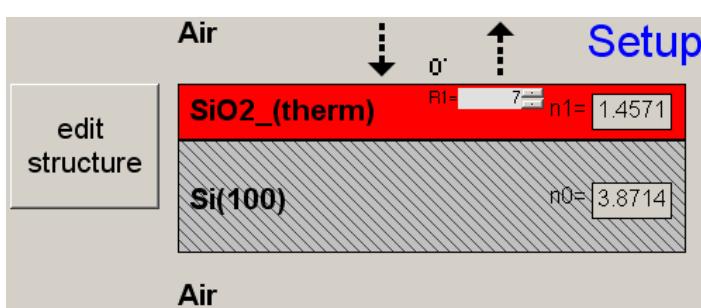
An R-factor of R=0 means a perfect surface = no roughness

An R-factor of R=50 means a loss of 50% light at this interface.

There is no wavelength dependency of these empirical factors.

In the current version there is no wavelength dependency of these empirical factors. Version 3.0 (available in 4/2005?) will remove this restriction.

constant roughness



You may input roughness values in the roughness textboxes or use the slider in the roughness window.
Method:

At each interface a certain amount of light is regarded as lost. This percentage has to be input via roughness textboxes in the setup area. These R-factors are not dependent on wavelength. This algorithm does NOT manipulate measured data, but the measured amplitude might still differ considerably from the simulated amplitudes. This means that the fit procedure might still have problems to find a good solution.
Try menu "Data manipulation" instead.



7.5.3 Data manipulation

Please be aware of the fact that all actions within this menu are real manipulations of your measured data ! You change data to get better results, this maybe risky...

1. apply formula

It is possible to apply many reasonable formulae to the spectrum.

Example:

Spectrum=Spectrum*0.9

(all values ar multiplied with a constant factor 0.9)

You may also try:

Spectrum=Spectrum*(1+lambda/800)

and many others ...

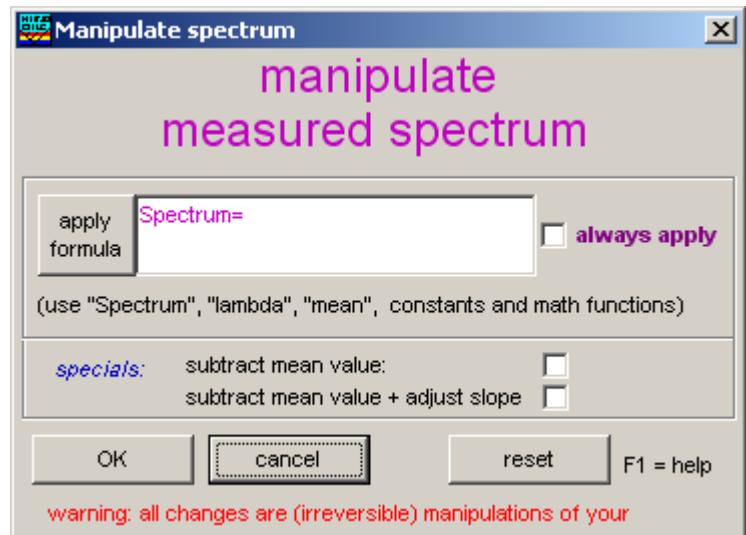
2. subtract mean value

the mean level of the measured signal is adjusted to the level of the simulated signal, but NOT the frequency or the amplitude or the slope of the signal. This option is quite useful if for some reason there is a slight constant offset between signal and simulation.

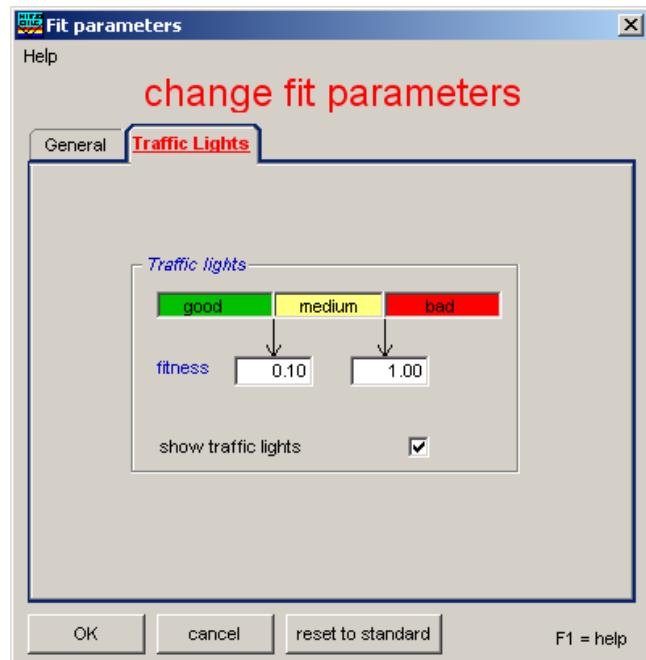
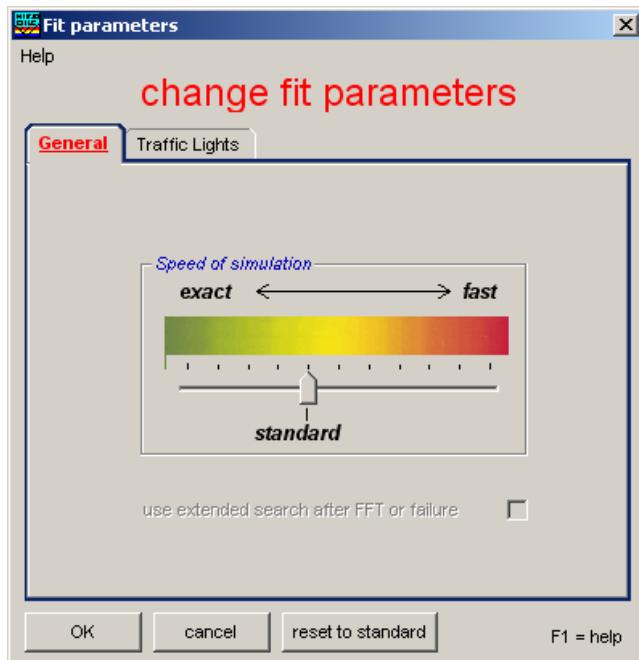
4. subtract mean value and adjust slope

The **level** and the **amplitude** and the **slope** of the measured signal are adjusted to the level of the simulated signal, but NOT the frequency of signal modulation.

Only the frequency of the wiggles remain as information. Think about using the FFT method instead.



7.5.4 Fit parameters



In the file "Thinfilm.ini" you will find 3 entries in section [fit]:

Failure_RedLevel=1

Failure_YellowLevel=0.1



RYG_LevelsAreDisplayed=False

If you change the variable RYG_LevelsAreDisplayed from “False” to “True” (in main menu “Fitparameters”), the usual rainbow pattern on the screen will disappear and a simple color will show up.

- If the fitness is below Failure_YellowLevel=0.1 you will see a GREEN color.
- If the fitness is between Failure_YellowLevel=0.1 and Failure_RedLevel=1 you will see a YELLOW color.
- If the fitness is above Failure_RedLevel=0.1 you will see a RED color

Attention:

If you measure very thick resists (with a good correlation between maxima positions, but bad correlation between signal heights) you may end up with high values of fitness, but nevertheless the thickness results may be o.k.

7.5.5 Some setups

Overflow during a measurement may arise if you use a relatively high level for the reference measurements and then a sample that is reflecting much better than your reference.

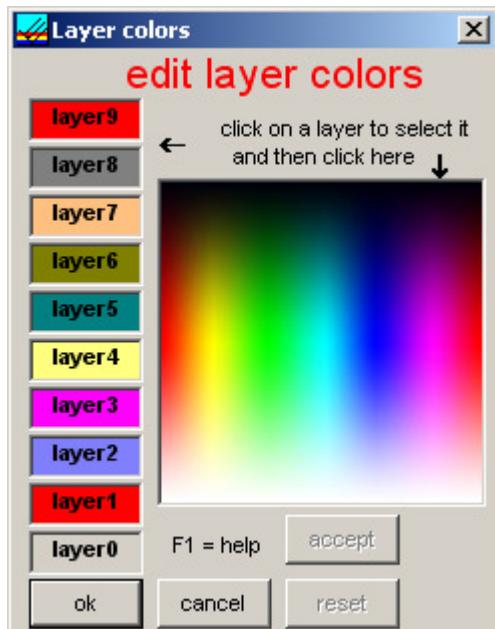
If you suspect that this might be possible: turn on “check overflow” (otherwise not, it is faster!)

Overflow=0:

There is no check for overflow

Overflow=n:

Every n-th pixel is checked for overflow (then: warning)



Change colors: Here you may change the colors of the layers. First click on the layer area on the left side. Then move the mouse over the large coloured area and click if the colour pleases you. Then press OK

7.5.6 Measurement mode

NanoCalc can be used in reflection or transmission setup.

7.5.7 Operator mode

NanoCalc can be used in administrator or operator mode.



7.5.7.1 Internal mode

Password

(for internal purposes only)

please enter a password

click OK or change password:

F1 = help

For internal purposes only (password necessary).

7.5.7.2 User mode

In user mode certain restrictions apply: e.g. the user is not allowed to edit the structure or to change the parameters of the spectrometer.

The default password to come back to administrator mode is: "**admin**". This password can be changed arbitrarily, there are no severe restrictions concerning passwords. Please use letters and numbers only.

7.5.7.3 Administrator mode

In administrator mode no restrictions apply.

This mode is reserved for the administrator of the system.

The default password to come back to administrator mode is: "**admin**". This password can be changed arbitrarily, there are no severe restrictions concerning passwords. Please use letters and numbers only.

The administrator may define the options that will work for a standard user. To get this Rights of User - window just click on "administrator mode".

7.5.7.4 Rights of user

The administrator may set the rights for the user for nearly every single feature of the software.

Rights of user

set rights of user

File Help

main mapping online

Main File Screen Data Editor Play ground Externals Options Version Help Function Keys

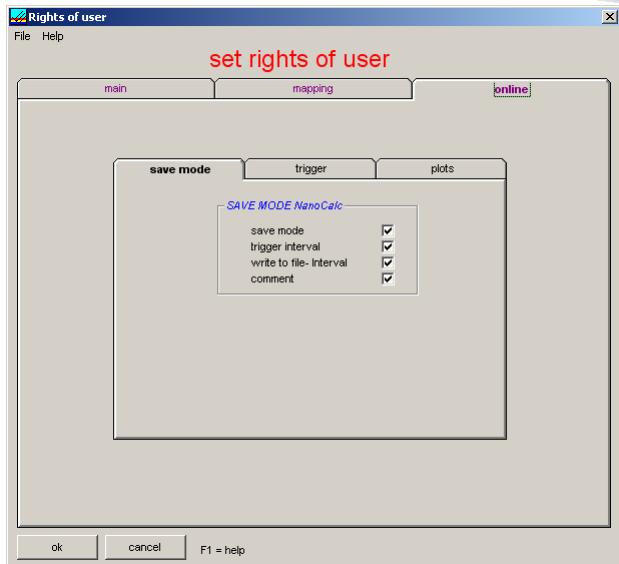
MAIN menus NanoCalc

File menu	<input checked="" type="checkbox"/>	reference button	<input checked="" type="checkbox"/>	load SCOUT recipe button	<input checked="" type="checkbox"/>
Screen menu	<input checked="" type="checkbox"/>	simulate button	<input checked="" type="checkbox"/>	load thinfilm recipe button	<input checked="" type="checkbox"/>
DataEditor menu	<input type="checkbox"/>	dark button	<input checked="" type="checkbox"/>	load mapping button	<input checked="" type="checkbox"/>
Externals menu	<input checked="" type="checkbox"/>	measure button	<input checked="" type="checkbox"/>		
Options	<input checked="" type="checkbox"/>	clear button	<input checked="" type="checkbox"/>		
Version	<input checked="" type="checkbox"/>	analyze button	<input checked="" type="checkbox"/>		
Help menu	<input checked="" type="checkbox"/>	continuous button	<input checked="" type="checkbox"/>		
		method combo box	<input checked="" type="checkbox"/>		
		edit structure button	<input checked="" type="checkbox"/>		

SCAN MODE NanoCalc

scan mode	wafer	stage	data extract	data export	scan data
scan type	<input checked="" type="checkbox"/>	x step	<input checked="" type="checkbox"/>		
number of rows	<input checked="" type="checkbox"/>	y step	<input checked="" type="checkbox"/>		
number of columns	<input checked="" type="checkbox"/>	rotation	<input checked="" type="checkbox"/>		
x origin	<input checked="" type="checkbox"/>	distance	<input checked="" type="checkbox"/>		
y origin	<input checked="" type="checkbox"/>				

ok cancel F1 = help

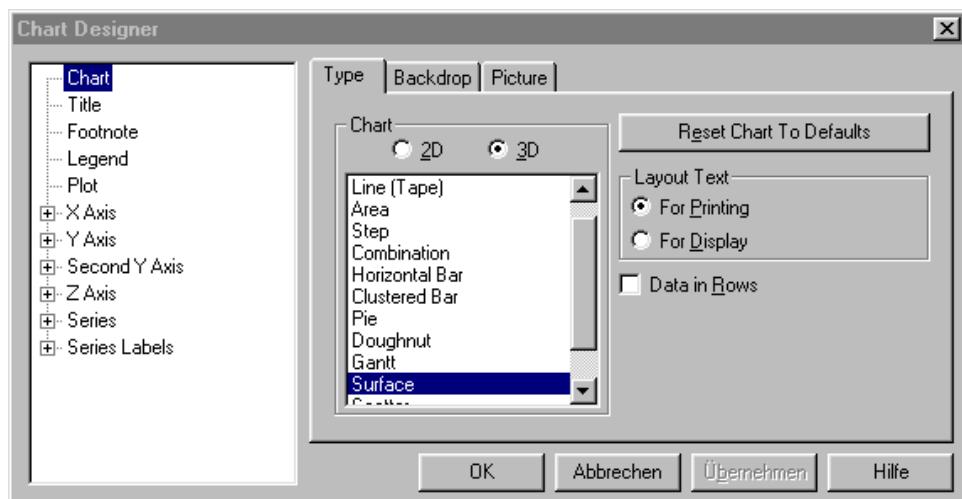


7.5.8 Change colours

7.6 Main menu “Version”

This menu is visible only if you own a “combiversion” = a combined version of NanoCalc and ElliCalc. You may switch to the other application

7.7 Chart and chartdesigner



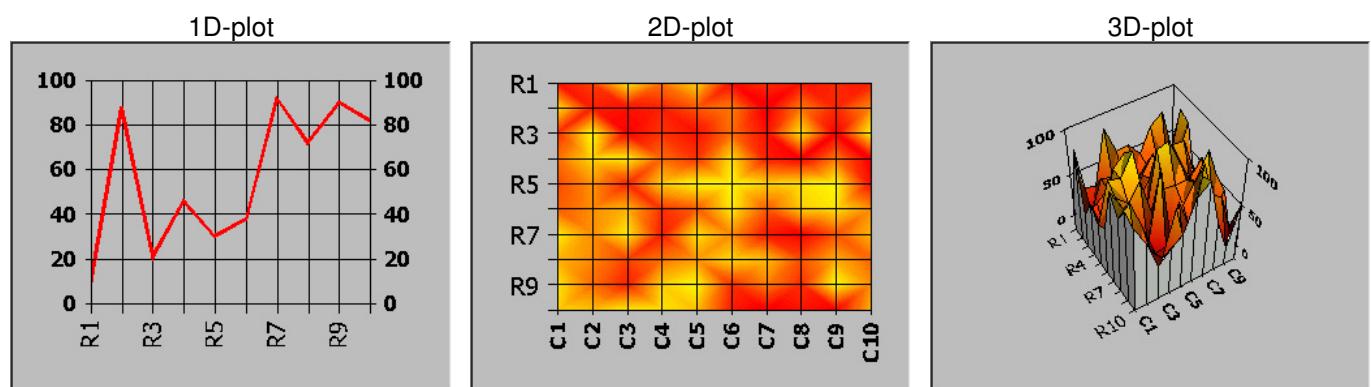
If you produced a 1D-plot or 2Dplot or 3Dplot you may change nearly ALL parameters of the plot by clicking with the RIGHT mouse button

Hint:

To change the view position : keep CTRL button pressed and move the mouse at the same time.

For further information see VCFI5.hlp in the help directory of your NanoCalc installation.

7.7.1 Plot



During mapping it is possible to produce 1D-plots, 2D-plots and 3D-plots.

These plot types can be changed interactively after the mapping was finished. Click with right mouse button on the plot to get access to the "chart designer".



8 Special features for “SCOUT mode”

8.1 Main menu “File”

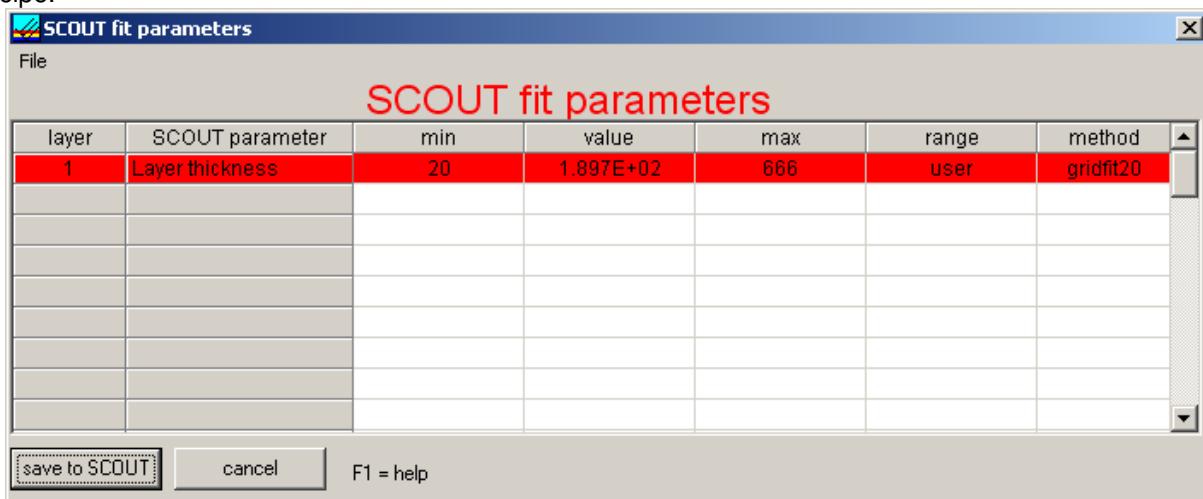
8.1.1 Change layer recipe

if you load a (.irc)-recipe containing a link to a SCOUT .sc2-recipe and measure your sample, SCOUT will analyze in the background and the results will be displayed in the graphical user interface of NanoCalc.

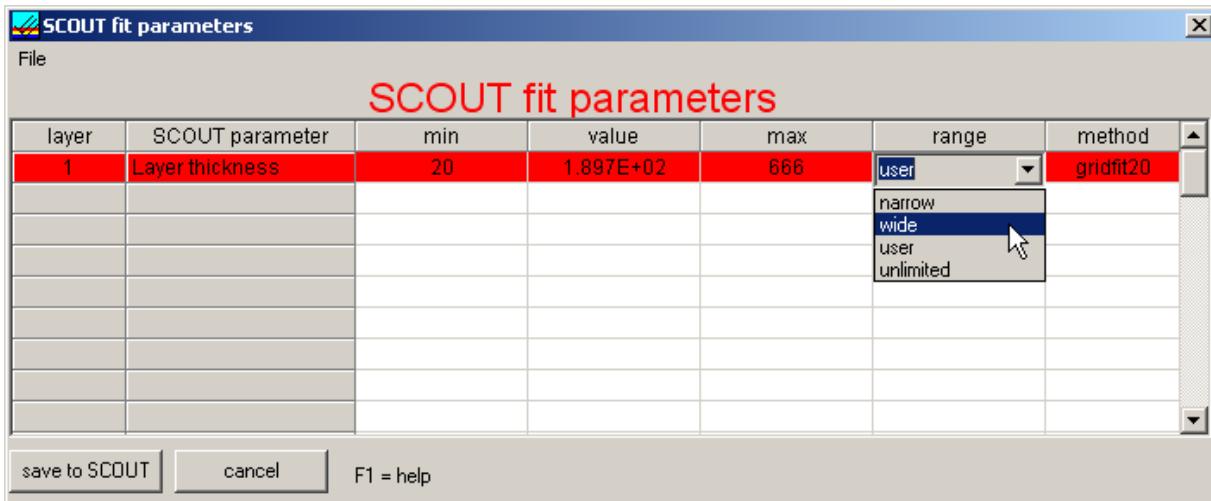
The layer stack and all layer parameters are defined within SCOUT and are extracted by SCOUT. NanoCalc is only a user interface. There are lots of data in NanoCalc's internal .irc-recipe, but most of them are not important in this context: SCOUT is the "master".

With "change layer recipe" you may change some of the layer and fit parameters of SCOUT (but not all). Your changes are NOT permanently saved to the SCOUT recipe on the harddisk, only to the running SCOUT instance. If you are convinced that your changes are good enough you may also save them permanently (at the moment only via Scout itself).

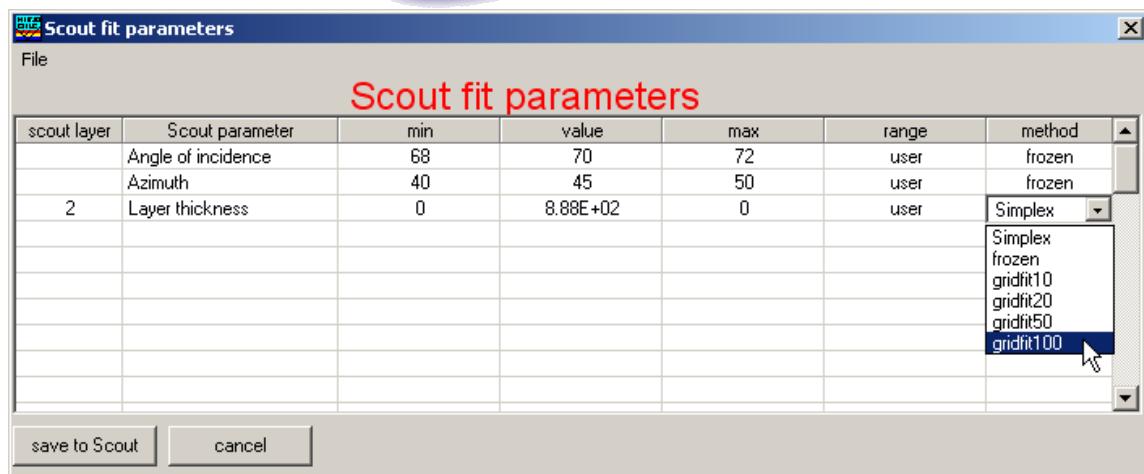
To switch to a completely new recipe you have to load another .irc-recipe with a different SCOUT .sc2-recipe (do NOT use SCOUT directly!). With "change layer recipe" it is not possible to change the layer structure, only values of the recipe.



SCOUT fit parameters: Changing a value



SCOUT fit parameters: Changing a range for parameters



SCOUT fit parameters: Changing an extraction method

8.2 Main menu “Screen”

8.3 Main menu “Options”

8.3.1 Fit parameters

8.3.2 Some setups

8.3.2.1 SCOUT setups



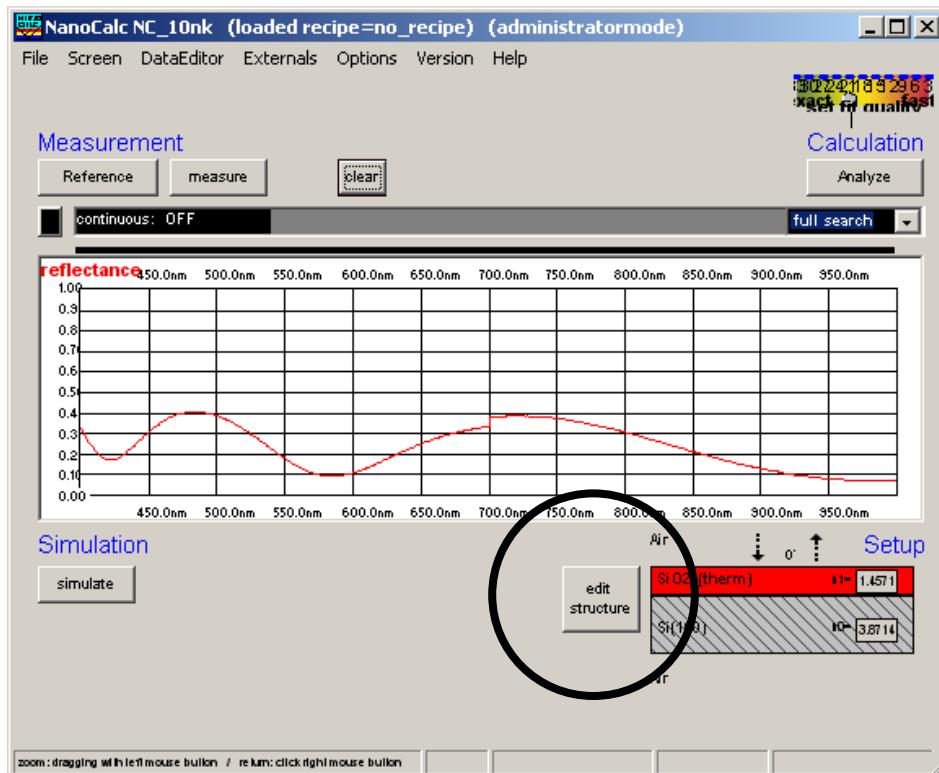
9 Special features for “internal mode”

This internal mode can only extract thicknesses in layer stacks, so this is much more restricted than “SCOUT mode”. You do not need the SCOUT software and it may be faster than SCOUT in simple cases.

To reach this mode you have to use a lrc-recipe without an internal link to a SCOUT .sc2-recipe. There are different possibilities to do do this:

- Press SHIFT+CTRL+F12
 - Or: load a special .lrc-recipe, called “no_recipe.lrc”
 - Or: edit any .lrc-recipe manually: just remove the name of the .sc2-recipe after “Scout_FileName_NC=name.sc2” in section [Scout]. Be careful with this manual editing, make a safety copy!
- Finally the line should read: “Scout_FileName_NC=”

After this change, you will see a new button “Edit Structure”, which allows you to edit your own layer stack.



9.1 Edit structure button

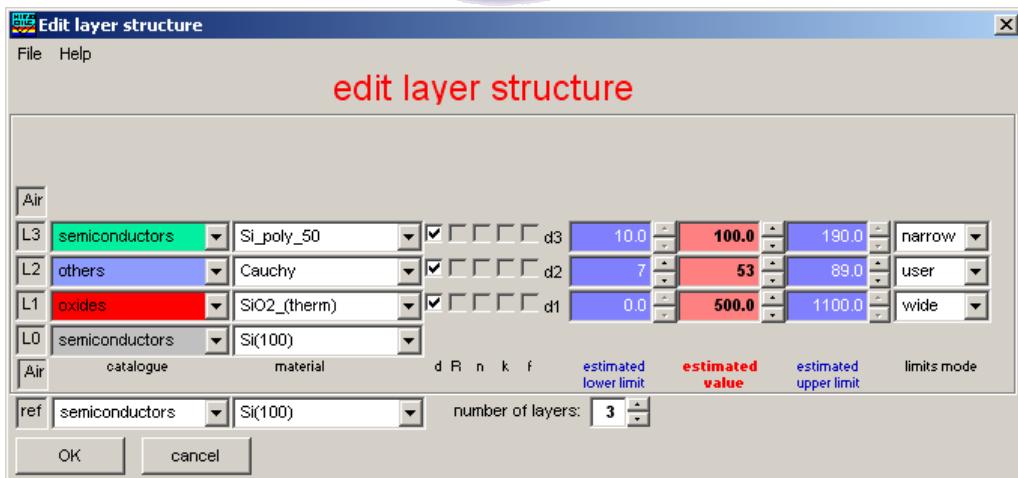
You will see this button and this window only if you do not use a SCOUT recipe= if you use NanoCalc’s internal mode (not yet fully supported). You could get good results, but only for the extraction of thicknesses (not dispersion)

In this menu “edit layer structure” you have to define your own layer structure

9.1.1 General

The full menu EditStructure is only available if you do not use SCOUT. If you use SCOUT only the reference material may be changed.

In the menu Edit Structure you may enter:



1. The type of catalogue like:
oxides
nitrides
semiconductors
.....
2. The type of material within one specified catalogue, like „oxides“:
 SiO_2
 CuO
 TiO_2
.....
3. The number of layers (in the present version: 1 to 10)
4. The thickness of all layers in nanometers. This value is regarded as an EXACT value for simulations and as a GUESS for analyzing measured spectra. Whether this guess is used (or not) will depend on the measurement mode.
5. A lower and an upper limit of the thickness. These values are NOT used in simulations. Whether these limits are used for measuring purposes (or not) will depend on the measurement mode.
6. An option „fixed“:
If you press this option, the lower and upper limits are fixed to the value of the thickness of the layer. Such a layer is regarded as „well known“. Restriction to NanoCalc_1: If you have two layers and one of them is fixed (= „well-known“), NanoCalc is able to determine the thickness of the second layer unambiguously. It is not important whether this layer is the upper or the lower one. The same applies to three layers: two of them have to be fixed, the third will be calculated. Of course it does not make sense to use three fixed layers, there is nothing left to analyze.
This restriction will not apply to NanoCalc_10nk. This multilayer version is able to calculate several layers (Attention: in most cases you need moderate information, otherwise there are several nearly equivalent solutions to the problem)
7. An option „narrow limits“
If you press this option the lower and higher limits are set to about 80-100 nm below and above the value of the thickness. This is equivalent to having a FAIRLY GOOD KNOWLEDGE of the thickness.
8. An option „wide limits“
If you press this option the lower and upper limits are set to a wider range. This range depends on the settings of the menu EditStructureSetup and may be set to:
-- well defined values like: lower limit=200 nm and upper limit=800 nm (with any thickness value between 200 and 800 nm)
-- constant range like lower limit = thickness - 100 nm and upper limit = thickness + 100 nm



Thus the search region is restricted to a rather wide, but more or less "reasonable" range. Of course you may also set the limits very narrow, even to a search range of zero.

9. An option „user limits“

If you press this option you may set the lower and upper limit to any value between 0 and 300000 nanometers. These values are equivalent to having absolutely NO KNOWLEDGE of any thickness.

9.1.2 Catalogues

In the menu Edit Structure you find a row "catalogues" for each layer. You may choose the **TYPE** of material like: glasses, semiconductors, metals etc. In the next row "materials" you may choose the actual material of your layer. There are different catalogues for photoresists (for different companies like Clariant, Arch, Shipley, MRT and others).

You may add a new catalogue manually or use the menu Edit Refraction Index.

9.1.3 Materials

In the menu Edit Structure you find a row "materials" for each layer. You may choose the material itself: Si, GaAs, Ge etc.

In the previous row "catalogues" you first have to choose the TYPE of material of your layer (like "semiconductors"). There are different catalogues for photoresists (for different companies like Clariant, Arch, Shipley, MRT and others).

You may add a new material manually or use the menu Edit Refraction Index.

9.1.4 Thickness

NanoCalc uses values for the thickness between 0 and 300000 nm (=300 micrometers). In the present version only thicknesses may be fitted (otherwise you need SCOUT)

9.1.5 Estimates

NanoCalc uses a maximum value for the estimates of 300000 nm (=300 micrometers).

In automatic mode it is **NOT** necessary to add values for the upper and lower estimate.

You should give reasonable values for these limits in fitting mode as this influences the time for calculation considerably.

9.1.6 Fixed limits

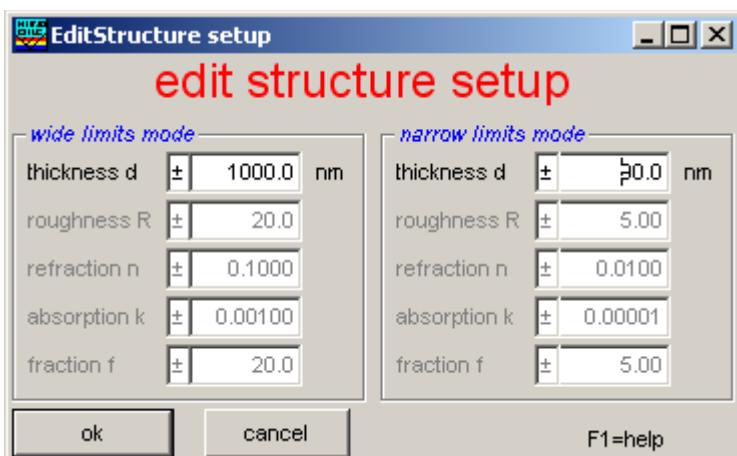
If you fix a layer you force the upper and lower limit to have the same value as the thickness value. This means that the thickness of a fixed layer is regarded to be "well-known" = exact.

Example: thickness = 500 nm
upper limit = 500 nm
lower limit = 500 nm

NanoCalc_1 is able to analyze even 3 layers if **two** of them are "well-known" = fixed.

The same applies to 2 layers: **one** of them has to be fixed and the other may be analyzed. It is of no importance **which** layer is to be analyzed.

NanoCalc_10nk can extract 2 or 3 layers simultaneously. Of course this takes some time...



9.1.7 Narrow Limits

If you click "narrow limits", NanoCalc uses rather narrow low and high limits range of about 100 nm above and below your thickness estimate (depending on the material of the layer)

Example1: thickness = 500 nm
upper limit = 600 nm



lower limit = 400 nm

Example2: thickness = 3500 nm

upper limit = 3600 nm

lower limit = 3400 nm

If you need a larger range of limits you have to choose the options WideLimits or UserLimits (up to 300000 nm).

9.1.8 Wide Limits

To use this option you should consult the menu EditStructure \ Setup first:

You have the choice between relative and absolute wide limits

If you choose “wide limits mode” (e.g. ± 1000 nm and a thickness of 4000 nm), NanoCalc will search between 3000 nm and 5000 nm.

9.1.9 User limits

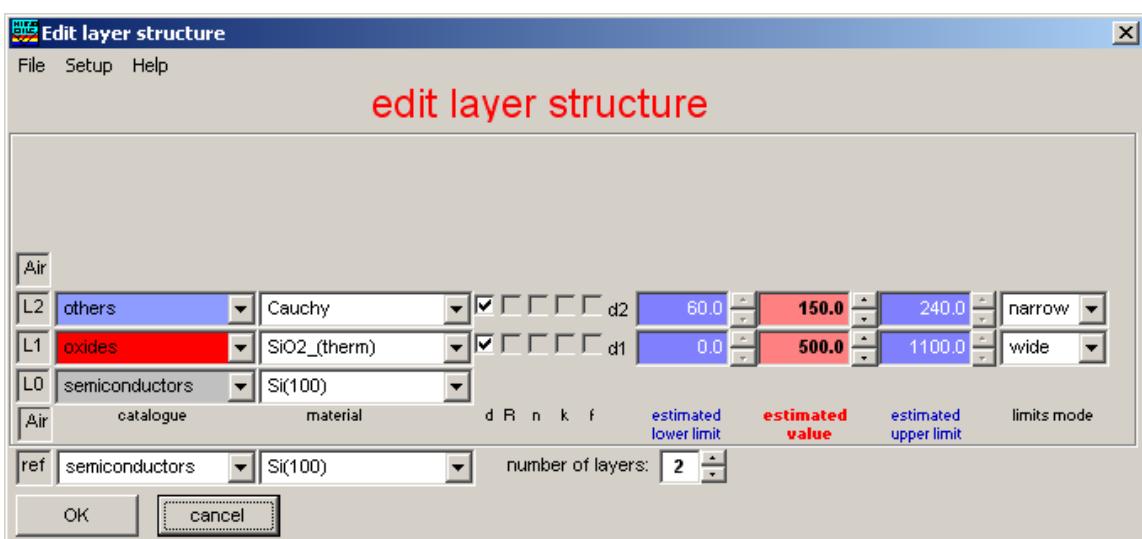
If you click “user limits”, NanoCalc accepts your values for lower and upper limits (up to 300000 nm = 300 micrometers).

9.1.10 Number of layers

NanoCalc_1 is doing all simulations with a maximum of 4 layers (extraction: 1 layer)

NanoCalc_10nk can extract data from up to 10 layers simultaneously.

An example of two layers:





9.2 Main menu “File”

9.2.1 Pixel resolution

9.3 Main menu “Options”

9.3.1 Data manipulations

9.3.2 Roughness



10 Experimental setups and problems

10.1 General

10.1.1 Experimental setup

microscope setup:

- if you use a microscope you have the advantage of a high spatial resolution (depending on your lens system), but you should keep in mind:
- the angle of incidence is not well defined and you should repeat your measurement with different lenses to control your results (usually the results are slightly dependent on the magnification factor)
- you have a good chance to measure lots of stray light from your laboratory. Control your measured lamp spectra !
- If you use a fiber for illumination: turn off the usual microscope lamp
- as your spot size is so small: pay attention on particles which may give wrong results
- if film thickness is high: such samples often are inhomogeneous. Try a different spot to measure
- use reference wafers and device under test of the same height

fiber setup:

if you use a simple fiber setup you should keep in mind:

- the spot size corresponds to the area of your fiber core (e.g. 200 micrometers or less)
- try to avoid stray light
- use a distance of at least 3-30 mm (otherwise the results are sensitive to different heights of your reference wafer and the device under test)

10.1.2 Reference spectrum

To measure the thickness of any thin film you have to measure a reference spectrum first. This is necessary to get an information about the incoming amount of light as a function of wavelength.

Insert a blank (silicon?) wafer or your blank substrate in the measuring arrangement and press "reference".

You should get a typical spectrum of a halogen lamp (see chapter 5.1) (or a warning to increase or decrease the intensity of the lamp)

If you want to continue with measuring your thin films:

Do not forget to tell NanoCalc which substrate you used in this step (by pressing Edit Structure and adjusting the correct catalogue)

10.1.3 Maximum intensity

This value describes the maximum intensity in the spectrum of your amp (could be easily checked in Reference mode). This value helps NanoCalc to achieve an automatic adjustment of the reference spectrum within the limits of the screen (=without saturation)

If you use a double spectrometer there are TWO wavelengths corresponding to the sensitivities of the two spectrometers and your light source.

10.1.4 Polarization

In case of oblique incidence polarization plays an important role. In a vertical arrangement (like NanoCalc) the polarization does not play any role.

Attention: in microscope arrangements this condition of vertical incidence may no longer be fulfilled. You should test your results with different magnifications.

10.1.5 Angle of incidence

"angle of incidence" is defined as the angle between the direction of incoming light and an axis vertical to the surface.

In the current version of NanoCalc only vertical incidence is allowed.



10.1.6 Signal to noise ratio

The intensity of your acquired signal depends on:

- the adjustment of the lamp (see light source or NanoCalc-2000 manual)
- the integration time (see menu options)
- the number of averages (see samples to average in menu options)
- the diameter of the fiber
- the distance between fiber and wafer

Do not extend the extraction limits into regions with a high signal-to-noise-ratio !

10.1.7 Stray light

Especially in a microscope setup there is a risk to catch stray light from your laboratory lamps. Try to avoid this as much as possible or use the simple fiber setup. External light sources usually changes and will produce errors.

10.1.8 Fiber

You may use different fibers with core diameters between 8 and 800 micrometers.

There are special fibers (Y-fibers, fibers with 6 outer fibers to illuminate and 1 inner fiber to detect the reflected light, fiber cables for double spectrometers). In most cases it is easily possible to detect more or less light through a different fiber constellation.

Consult your hardware supplier.

10.1.9 Absorbing media

It is not too easy to measure absorbing media like polycrystalline silicon as their refractive and absorption indices usually depend strongly on preparation conditions.

Try to find good values of $n(\lambda)$ and $k(\lambda)$.

10.1.10 Passwords

There are several passwords within NanoCalc:

As a start for user mode and administrator mode there is a password "admin". This password can be changed. To change intercept, first coefficient and second coefficient and third coefficient (to recalibrate your own spectrometer) there is another password corresponding to the serial number of your Ocean Optics / Mikropack spectrometer. This number is displayed on a separate sheet or on the backside of your spectrometer system. If you could not find this serial number ask your hardware supplier...

10.1.11 Function buttons

If you click on the button **F1**, you get access to help functions.

If you click on the buttons **F2 - F7** different spectra or recipes together with their layer data are loaded for demonstration purposes. You should be able to analyze these demonstration spectra by a simple click on the Analyze button.

The button **F8** is not used by the demo version (in full version F8 is used to save the reference spectrum to disk).

F9 is used to load the references spectrum from disk.

If you click on the button **F9** the file "reference.nan" is loaded and may be used as a reference spectrum (to avoid a real measurement with a blank substrate). Of course this is only a very inaccurate method for fast access to measured spectra.

If you click on the button **F11** the last measured file is loaded again (if it was cleared). This file was saved on disk as "LastMeasured_File.nan" in directory \data\Internal_Data.

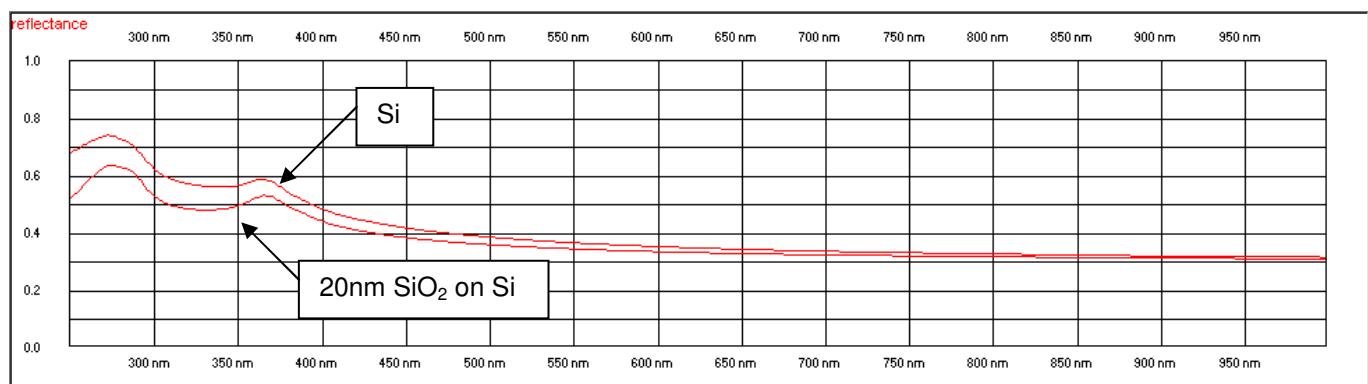
If you click on the button **F12** the last saved file is loaded again (if it was cleared). this file might be a simulated or a measured file.

10.2 How to measure very thin films

It depends very much of the type of layers whether it is difficult to measure very thin films or not. As we have seen in the first section it is necessary to expand the spectral measurement range as wide as it is possible with this system. See chapter 6.2.3 Frequency Limits.

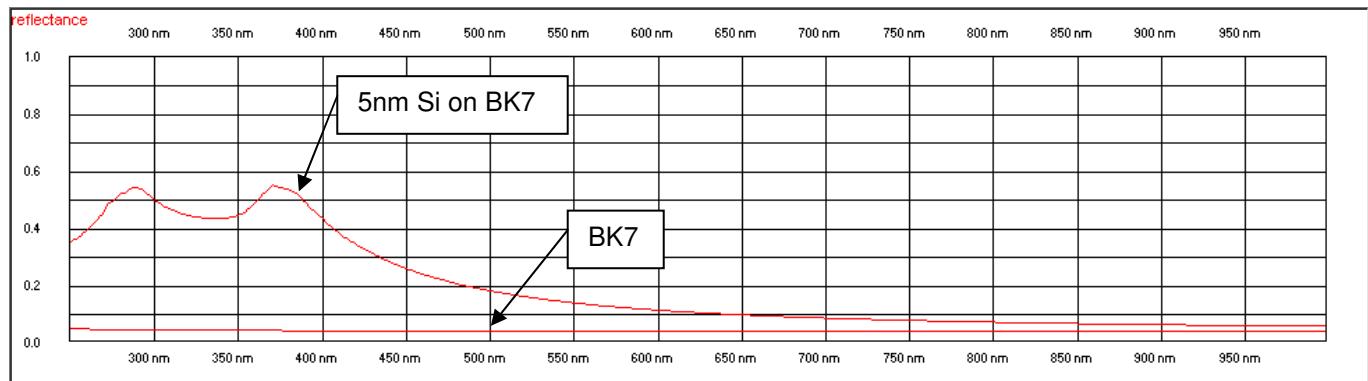
1st example: 20 nm SiO₂ on Si

This is difficult to measure because the intensities and the spectral information of the signals with and without the SiO₂-layer do not differ very much. The problem reduces more or less to an **intensity measurement**.



This means that you should use a light source with a extremely high stability and measure the reference signal immediately before measuring the SiO₂ sample to avoid any drifts. (You should use a UV/VIS/NIR System with a large spectral range (and a suitable lamp as well)).

2nd example: 5 nm Si on BK7-glass

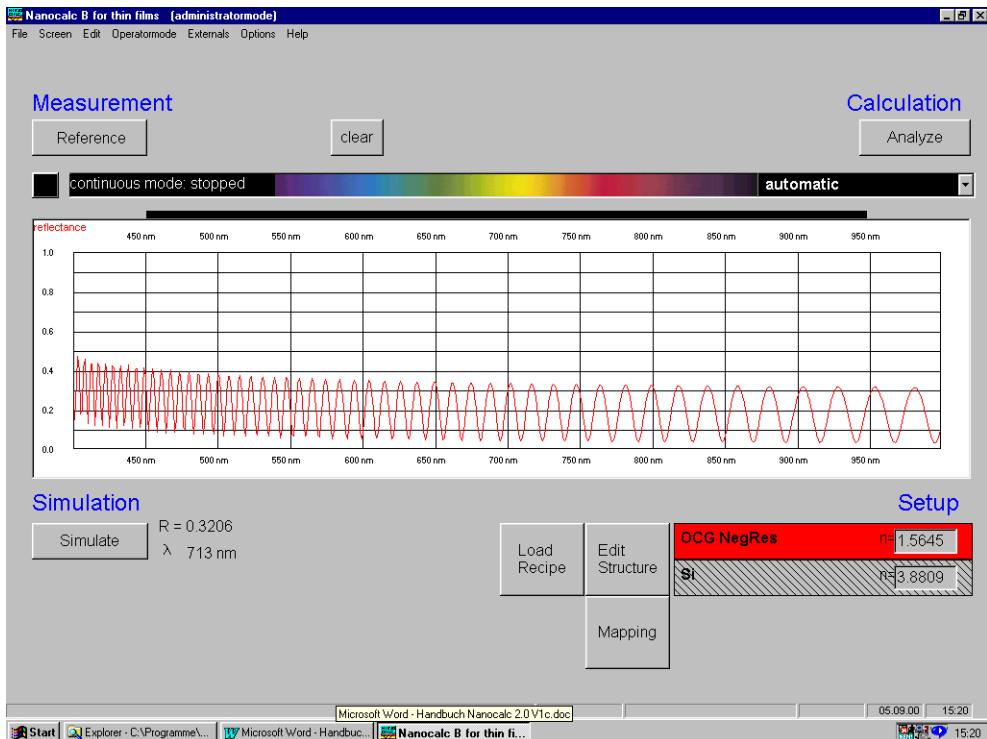


You can see that it is rather easy to measure such a thin film.

10.3 How to measure very thick films

Here you see a (simulated) example of 11 μm resist on silicon

If the film thickness increases above 5 - 10 micrometers it gets more and more difficult to get good results because the numbers of extrema in your spectrum increases. This is in conflict with the spectral resolution of your spectrometer and the thickness of the fiber.



You get the best results (concerning spectral resolution) if you are using a system with a narrow slit. This means that you probably do not get enough intensity. To avoid problems with signal-to-noise-ratio try the following:

- adjust your lamp intensity to maximum
- minimize distance fiber – wafer
- adjust integration time (menu options)
- be careful in your choice of extraction and plot limits
- try manual measurement mode instead of automatic mode

Quite often thick resists are inhomogeneous or have a rough surface. This may destroy the signal completely or reduce the amplitude compared to theory.

10.4 How to measure rough, thick films

If the films or the substrate surfaces are rough it gets more and more difficult to get good results because of scattering effects. Sometimes it is still possible to measure a signal, but usually the amplitude and offsets are drastically different from theory. Nevertheless: if the film thickness is big enough, the spectrum has enough wiggles so that analyzing becomes possible.

In menu “data extraction” you find some options to adjust to roughness problems.

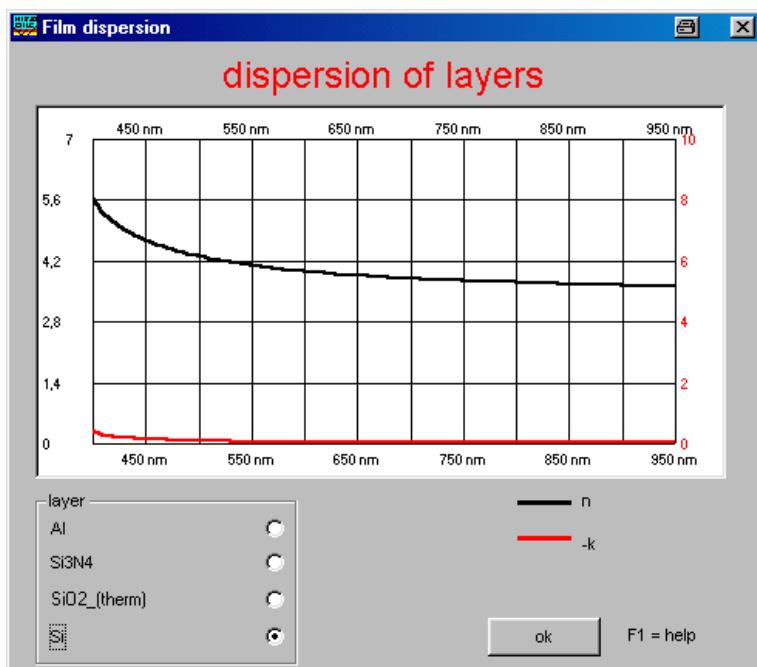
11 Physical explanations

11.1 Refraction index and absorption indices

The **refraction index n** of a substance is defined as

$$n = \frac{c_{vacuum}}{c_{material}}$$

with c = speed of light



The **absorption index k** of a substance describes the absorption behavior of materials. Glasses and photoresists have negligible absorption in the visible range.

n and k are a function of the wavelength lambda: $n = n(\lambda)$. This phenomenon is called „dispersion“. $n(\lambda)$ and $k(\lambda)$ are closely interrelated via the dielectric function $\epsilon(\lambda)$.

11.2 Cauchy coefficients

These coefficients empirically describe the dispersion functions of $n(\lambda)$ and $k(\lambda)$.

In many cases the 6 Cauchy coefficients are sufficient to describe the spectral behavior of resists, glasses etc. Normally NanoCalc uses „nanometers“ as a unit dimension. If you add your own cauchy parameters in a .DAT-file, pay attention on the correct dimension !! It is possible to use other dimensions within the software but not in the .DAT-files.

Structure of a .DAT-file:

SiO2_(therm)	name of the material
# this is my own comment 1	arbitrary comment (beginning with #)
# this is my own comment 2	
633,1.4570,0	lambda, n and k at 633 nm
150,900	measured data between these limits
Table	(or CAUCHY)
150,1.5510,0	n and k at 150 nm
151,1.5504,0	n and k at 151 nm
152,1.5491,0	n and k at 152 nm
153,1.5477,0	n and k at 153 nm
154,1.5464,0	n and k at 154 nm
and so on.....	

The first lines are not used by the software for calculation.

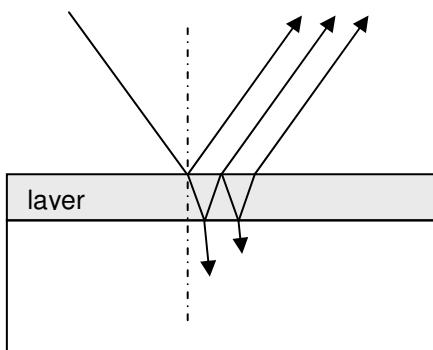
ATTENTION: Do not use any blanks in the name of the file !

The third line (150,900) means that measured data are measured (=available) between these limits (LowerLimit=150 nm and UpperLimit=900 nm) and all extracted and displayed data (drawn in light Grey instead of black) between 900-1100 nm have NO meaning !!

11.3 Interference

The arrangement in the picture below shows the case of an oblique incidence (just to explain „angle of incidence“ in contrast to usual experimental setup of a vertical incidence).

The measurement of reflectivity of thin films is a good example of an interference problem:



The incoming wave splits up in a reflected and a transmitted wave at each external or internal surface. The amplitudes of these partial waves depend on:

- 1.angle of incidence (if this angle is >0 , then polarization plays an important role)
- 2.refraction index and absorption index of all layers

Now the superposition of ALL waves (with different phase relations, amplitudes) has to be done. If the layers are thin and flat you have to add **amplitudes** and not **intensities** (see your physics text book). So you may end up with „destructive and constructive interference“: a positive amplitude and a negative amplitude may add up to zero. This is why your measured intensities usually have maxima and minima.



12 Thinfilm.ini

This *.ini-file has to be located in the working directory of NanoCalc and should **NOT** be changed manually.

In emergency cases (= a corrupt file Thinfilm.ini) you may try to overwrite Thinfilm.ini with the default file Thinfilm.ini (on your CD).

ATTENTION: All files from CD-ROMs are write-protected. Click on the file name in Windows Explorer with your right mouse button and remove the write-protection.

Section [UserEdits]

In the file Thinfilm.ini there is a section [UserEdits] very near to the beginning of the file. You may edit the file Thinfilm.ini with any text editor like notepad.exe or wordpad.exe (do not use Microsoft Word or similar programs).

Attention: be careful in editing this file ! Make a backup before you edit Thinfilm.ini !!

The section [UserEdits] contains some parameters which cannot be changed within the graphical user interface of NanoCalc because only special users need these features.

```
[UserEdits]
WriteTmpFile=False
WriteRefFile=False
MinimumSearch=False
AllowPixels=True
Plot_During_Online=True
Save_During_Mapping=False
CCD_StartCounts=0
WindowShift=175
AdjustRecipes=False
Special_FFTLayer=-1
Plot_After_FFT=False
YScale_FFTLayer=0
CsvExcelExport=xls
CsvExcelSeparator=;
CsvExcelNumberFormatter=.
ExcelMargins_LRTB=2;2;2;1
UseShutter=False
SpecialLambda=-1
UseClipboard=True
HideNanoCalc=False
StopMappingStage=False
SpectrometerSleepTime=30
```

WriteTmpFile:

if this flag is set to TRUE then NanoCalc will write a temporary file after each measurement. In rare cases the PC together with its network connection may be very slow and it is advisable to set the flag to FALSE. Then it will no longer be possible to use the feature "load last file"

WriteRefFile

if this flag is set to TRUE then NanoCalc will write a file after each reference measurement. In rare cases the PC together with its network connection may be very slow and it is advisable to set the flag to FALSE. Then it will no longer be possible to use the feature "load last reference"

MinimumSearch

this is reserved for a special customer (using antireflective coatings)

AllowPixels

If you disable this feature by setting the flag to FALSE it will not be possible to use the pixel mode. You gain some speed as no recalculation for pixels is done with each measurement.

Plot_During_Online

if you set this flag to FALSE then you gain some speed during online measurements as no plots are shown

Save_During_Mapping

allows to save all spectra during mapping (time-consuming !)

Online_StartCounts

some spectrometers need a certain number of calls to the CCD pixels before they give stable results. If you set this number to any value less than 10 (e.g. Online_StartCounts =5) you will have to wait until 5 dummy measurements have been done. If you use a short integration time it is recommended to use values of 5-10. If you use a longer



integration time and you do not want to wait for some seconds it is recommended to set the value to zero (but be aware that the first 1-5 measurements may not be completely correct)

AdjustRecipes

True: the main menu will contain a possibility to change a certain parameter in ALL recipe or ini-files simultaneously

Special_FFTLayer

if any valid layer number is set to some number <> -1 (=default), the FFT result will be changed to get the thickness result of this special layer and not the total sum of all layers (ask your software supplier for details).

There is also an application to extract the refraction index instead of thickness (ask your software supplier for details).

Plot_After_FFT

If this variable is set to FALSE only the FFT peak wil be plotted and not the extracted (=simulated) curve

YScale_FFTLayer

this number gives a zoom factor for the main FFT peak (it can be changed within the software by pressing the + and – buttons)

csvEXcelExport

you may enter csv oder xls (example: csvEXcelExport=csv). Csv is the well-known “comma separated value” format.

csvEXcelSeparator

here you may enter the separator for the csv-format, like ";" oder "," (example: csvEXcelSeparator=;)

csvExcelNumberFormatter

here you may enter the number formatter for the csv-format, like "," oder ".," (example: csvExcelNumberFormatter =.)

ExcelMargins_LRTB

If you print Excel data LRTB means Left, Top, Right, Bottom as margins for the printout

UseShutter

In case an optical shutter exists this is a flag to use it or not

SpecialLambda

this is reserved for a special customer

UseClipBoard

Setting this value to False: the last measured value is NOT saved to clipboard

HideNanoCalc

Setting this value to True hides NanoCalc in the taskline (for remote)

StopMappingStage

Setting this value to True: after each new position the motors are disabled (to get rid of spurious noisy movements)

SpectrometerSleepTime

If the spectrometer si not used for some time (SpectrometerSleepTime) the first results are not correct. This can be avoided by reading the spectrometer data several times. Within this SpectrometerSleepTime there are no repeated measurements.



13 Appendix A

13.1 Installing and Changing the settings on a A/D converter and Interfaces

This section covers the basic installation instructions for our A/D converters: ADC500¹, ADC1000, DAQ700 and USB2000. Because A/D converter installation goes hand-in-hand with software installation. The A/D converters we offer are:

ADC1000 ISA-BUS A/D CONVERTER is a high-speed, 12-bit, 8-channel, single-ended, half-length card that fits into a slot in a desktop PC and has 1000 kHz sampling frequency.

DAQ-700 PCMCIA A/D CONVERTER from National Instruments is a 12-bit, 16-channel, single-ended card that fits into a credit card-size slot in a notebook PC and has 100 kHz sampling frequency.

USB Interface is a universal Serial Bus Interface for ATX-Pentium Computers with Windows 98 and 2000. The AD/Converter 12 Bit 1 MHz can run with a minimum integration time of 3ms and is integrated in the NanoCalc-2000-System. The Minimum Data Transfer Time from NanoCalc-2000-System to PC is 25ms.

13.1.1 ADC1000 ISA-bus A/D Converter

The **ADC1000 ISA-bus A/D CONVERTER** is a 12-bit, 8-channel, single-ended A/D card that connects our spectrometers to desktop PCs. The AVS-PC2000 has a 2048-element linear CCD-array fiber optic spectrometer mounted onto an ADC1000. This sturdy combination fits easily into a slot in the PC. The following are directions for installing your ADC1000 and PC2000. Because A/D converter installation goes hand-in-hand with software installation, you will find directions for installing NanoCalc Spectrometer Operating Software included in this section as well.

Each device in or connected to your computer is assigned specific settings; it's similar to giving each device its own name so that your computer will know what to call and how to recognize the device. In order for your ADC1000 or AVS-PC2000 to work as a device in your computer, it has to be assigned a Base Address setting and an IRQ setting. The default settings for each are:

Base Address (I/O Range): 768 decimal (300 hexadecimal)

Interrupt Request (IRQ): 07

These default values are set on the A/D converter. There are dip switches on the A/D board and their positions determine the values. These default values are set in the operating software as well. Most of the time, these default settings will work with your computer. However, if you have many devices installed in your computer, you may have a conflict; other devices may be using these settings. If there is a conflict with another device in your computer, you must change the positions of the switches on the A/D board. For the ADC1000 and PC2000, there is only one bank of switches on the A/D board: the Base Address may be changed via the first 6 switches and the IRQ may be changed via the last 3 switches. To first check your computer to see which settings are available, follow the instructions for the Windows system that you use.

¹ Discontinued since August 2000



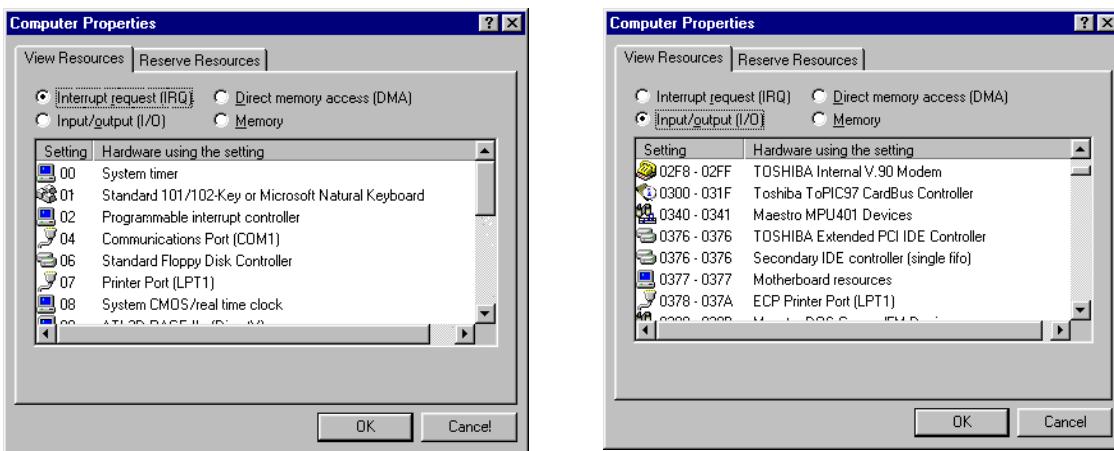
13.1.1.1 ADC-1000 installation

For Windows 95 and Windows 98 Users: Find Available Base Address and IRQ Settings

Go to **Start | Settings | Control Panel** and double-click on the **System** icon.

Choose the **Device Manager** tab and double-click on "Computer" at the top of the list.

Under **View Resources**, find available settings -- numbers unassigned to hardware. Note these available settings for both the Interrupt request (IRQ) and the Input/output (Base Address). When you first run NanoCalc, you must enter these values in the "Setup Hardware" dialog box. (Remember that Input/output settings are expressed in hexadecimal.)



For most computers, the default settings work well. In the picture above left, it appears that the Printer occupies IRQ 07, so the IRQ needs to be changed to 05. All computers have multiple Base Address (Input/output) settings from which to choose.

For Windows NT Users: Find Available Base Address and IRQ Settings

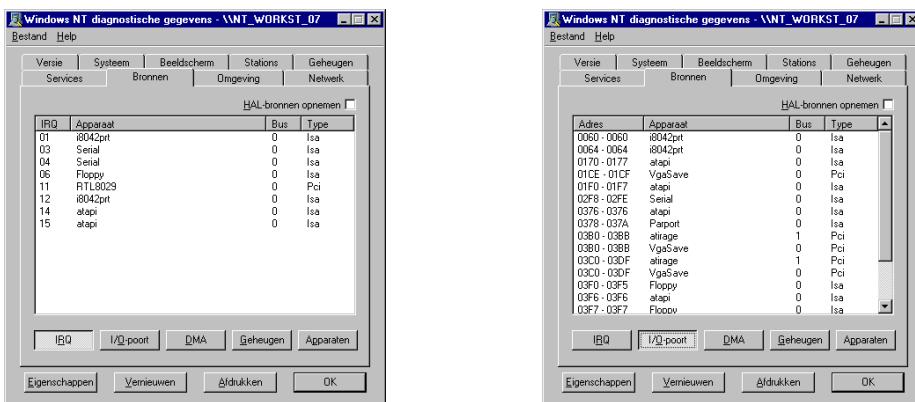
Go to **Start | Programs | Administrative Tools (Common) | Windows NT Diagnostics**.

In the "Windows NT Diagnostics" dialog box, click on the **Resources** tab.

Select the **IRQ** button. Find an available IRQ -- a number unassigned to a device.

Select the **I/O Port** button. Find an available I/O Range (Base Address) -- a number or range of numbers unassigned to a device. (The number is in hexadecimal.)

Note these available settings. When you first run NanoCalc, you must enter these values in the "Setup Hardware" dialog box. With Windows NT, devices cannot share IRQ's; each device must be assigned a unique IRQ.





13.1.1.2 ADC-1000 hardware installation

Installation of the ADC1000 is similar to that of any PC card installation:

Ground yourself to the computer chassis or power supply.

Turn off and unplug the computer. Then take off the computer cover.

Remove the ADC1000 from its static-shielded bag.

If necessary, change the position of the switches on the A/D board. Position the switches to match the available settings you found in the previous section -- numbers not being used by other hardware devices. The Base Address may be changed via the bank of switches labeled SW1 and the IRQ may be changed via the bank of switches labeled SW2.

See Table below for switch setting positions

Find an open ISA-bus slot and remove the slot protector.

Insert the ADC1000 into an available expansion slot on the motherboard connector by *gently* rocking the card into the slot. Make sure the ADC1000 is fully seated in the motherboard before screwing the tab on the ADC1000 to the computer.

Reinstall the cover and reconnect the computer power cord.

For the ADC-1000: Connect the D37 end of the interface cable to the ADC1000 and the D25 end of the interface cable to the spectrometer.

Base Address (SW1)

To change the Base Address settings on the ADC1000 board, see the bank of 6 dip switches labeled SW1.

Switches in the ON position have a value of zero. Switches in the OFF position have the decimal values shown.

The Base Address is the sum of the values of the switches. In the default setting, switches 5 and 6 are added to give a total of 768. A few of the many combinations for Base Address settings are below.

Example: 768 decimal = Hex300 = 0x300 (Default Setting)

Switch #	1	2	3	4	5	6
on	red	red	red	red		
off					red	red

Example: 784 decimal = Hex310 = 0x310

Switch #	1	2	3	4	5	6
on			red	red		
off	red				red	red

Example: 800 decimal = Hex320 = 0x320

Switch #	1	2	3	4	5	6
on	red		red	red		
off		red			red	red

Example: 816 decimal = Hex330 = 0x330

Switch #	1	2	3	4	5	6
on			red	red		
off	red	red			red	red

Switch is in the on-upward position





IRQ Interrupt Request Settings (SW2)

To change the IRQ settings on the ADC1000/AVS-PC200 board, see the bank of 3 dip switches labeled SW2. In the default setting, the IRQ is set to 7. Other combinations for IRQ settings follow.

IRQ 7 (Default Setting)

Switch #	7	8	9
on	red	red	
off			red

IRQ 3

Switch #	7	8	9
on			
off	red	red	red

IRQ 4

Switch #	7	8	9
on	red		
off		red	red

IRQ 5

Switch #	7	8	9
on		red	
off	red		red

IRQ 9

Switch #	7	8	9
on			red
off	red	red	

IRQ 10

Switch #	7	8	9
on	red		red
off		red	

IRQ 11

Switch #	7	8	9
on		red	red
off	red		

Switch is in the on-upward position





Setup Hardware Dialog Box

The first time NanoCalc is started, the hardware needs to be set up correctly. Clicking the menu „screen-spectrometer data-hardware“ can do this. The parameters in this dialog box are usually set only once -- when NanoCalc is first installed and the software first runs.

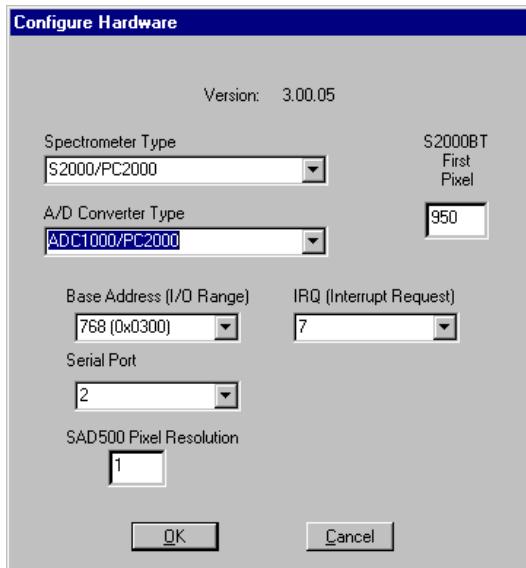
Under **Spectrometer Type**, choose your spectrometer.

Under **A/D Converter Type**, choose ADC-1000/PC2000.

Choose **Base Address** as selected in the previous section.

Choose **IRQ** as selected in the previous section.

For your setup, only these parameters apply to your system.
(Ignore the other settings; they apply to other A/D converters.)
Click **OK**.



13.2 DAQ-700 PCMCIA A/D Converter

The **DAQ-700 PCMCIA A/D CONVERTER** is a 12-bit analog-to-digital converter card that connects our spectrometers to notebook PCs. This 16-channel single-ended, 8-channel differential card -- also known by its National Instruments DAQCard-700 designation -- fits into a credit card-size slot in a notebook PC. It has a 100 kHz sampling frequency.

Before using your spectrometer, you must first configure your computer to properly detect and use the DAQ-700 and then follow several steps to use it as an interface to your Ocean Optics / Mikropack spectrometer. The following are directions for setting up your DAQ-700. Because A/D converter installation goes hand-in-hand with software installation, you will find directions for installing NanoCalc Spectrometer Operating Software included in this section as well.

Install NI-DAQ

Windows 95/98 and NT users must install NI-DAQ Driver Software -- the device driver library necessary for Windows 95/98/NT systems to properly use the DAQ-700.

Insert your NI-DAQ version 6 CD into your CD-ROM drive.

After you insert your CD, a setup program should automatically start. If it does not, run the **Setup.exe** program from the CD.

The installation program has an option called **Install NI-DAQ**. Select that option.

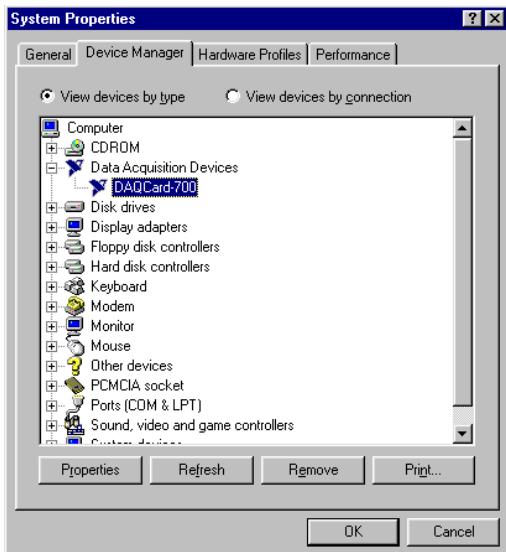
In the “Select Components” dialog box, make sure **NI-DAQ Driver Files (Minimal Install)** is checked. Choose any of the other options you wish to install.

Click **Next>**. Accept the default destination directory and the default Program Group.

In the “Ready to Install” dialog box, click **Next>**. When prompted to do so, restart your computer. **You must restart your computer at this time.**

Install the DAQ-700





After the computer restarts, wait until all disk drive activity stops -- that is, wait until your computer is *completely* restarted. Connect the spectrometer cable between your DAQ-700 and your spectrometer. Insert the DAQ-700 into any available PCMCIA slot.

Windows 95/98 and NT will play a sound consisting of two tones of increasing pitch. If you do not hear this sound, and you do have internal speakers in your notebook computer, try turning the speaker volume up and reinserting the DAQ-700. If you still do not hear the "happy" sound, contact our Technical Support Department.

To find IRQ and Base Address values, follow the instructions for the Windows system that you use. **For Windows 95/98 Users:**

Configure the DAQ-700

If you hear the "happy" sound, click **Start**, and select **Settings | Control Panel**.

Double-click the **System** icon. Select the **Device Manager** tab. In the "Device Manager" dialog box, find the hardware group named **Data Acquisition Devices**. Either double-click the group or select the group and click **Properties**.

Under the Data Acquisition Devices group, find the entry for your DAQ-700. Either double-click **DAQCard-700**, or select the entry and click **Properties**.

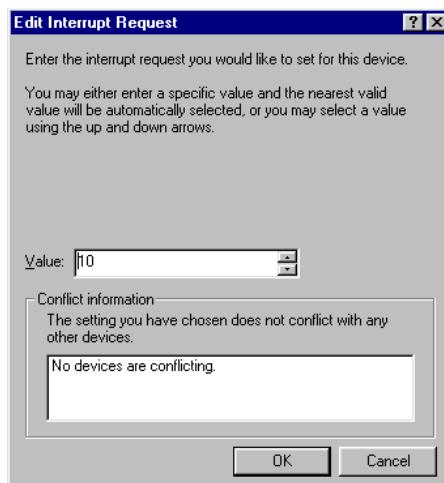
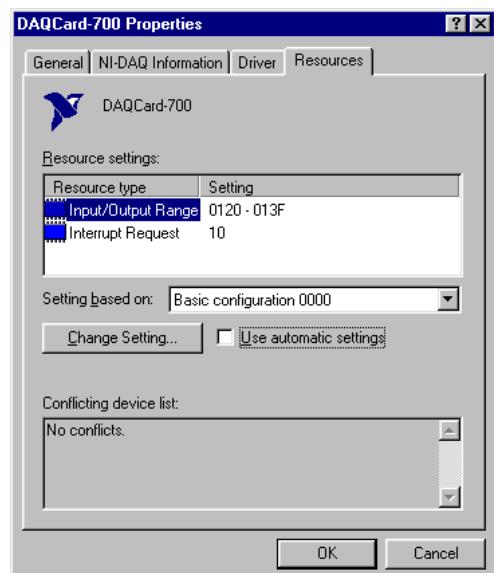
Once you have selected your DAQCard-700 from the Device Manager, click the **Resources** tab. The entries here control the hardware interface to your DAQ-700.

In this dialog box, find the check box next to **Use automatic settings**. Clear that check box (deselect it). We need to know the settings of the hardware before any Ocean Optics /

Mikropack software product starts.

In the same dialog box, you will see entries for input/output Range and Interrupt Request. The input/output Range corresponds to the Base Address, and the Interrupt Request corresponds to the IRQ in our software. By deselecting the **Use automatic settings** box in the previous step, you disabled Plug-and-Play for the DAQ-700. But in order to *fully* disable Plug-and-Play, you must also change the settings for either (or both) the input/output Range or the Interrupt Request. To make this change, double-click either **input/output Range** or **Interrupt Request**. A dialog box giving the current hardware setting appears. On the right side of the **Value** box are two small arrows: one up and one down. You must use these arrows to change the hardware interface parameters of either the input/output Range or the Interrupt Request.

While making this change, notice the **Conflict information** area at the bottom. Make sure you choose a value that says **No devices are conflicting**.



If it shows a conflict, you must select a different value. After selecting values with no conflicts, click **OK**. You will then see the "Creating a Forced Configuration" message box. Click **Yes**.

Note your values of both the input/output Range (Base Address) and the Interrupt Request (IRQ). When you first run NanoCalc, you must enter these values in the "Setup Hardware" dialog box.



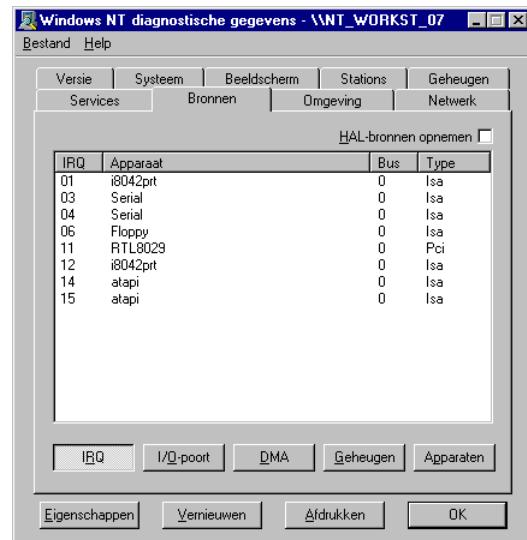
For Windows NT Users: Find the IRQ and I/O Range

If you hear the “happy” sound, go to **Start | Programs | Administrative Tools (Common) | Windows NT Diagnostics.**

In the “Windows NT Diagnostics” dialog box, click on the **Resources** tab.

Select the **IRQ** button. Find the IRQ that your computer assigned to the A/D converter you are using to interface to your spectrometer. *Note this number.*

Select the **I/O Port** button. Find the I/O Range (Base Address) that your computer assigned to the DAQ-700 to interface to your spectrometer. *Note this number.* (This number is in hexadecimal.)



Software Installation

Running the Install program

NanoCalc needs to be installed by executing the file INSTALL.EXE on the CD-ROM. After all files have been installed, Windows needs to be restarted.

Installation Dialogs

The Install program will check the system configuration of the computer. If no problems are detected, the first dialog is the “Welcome” dialog with some general information. In the next dialog, the destination directory for the NanoCalc software can be changed. The default destination directory is C:\Programme\NanoCalc If you want to install the software to a different directory, click the Browse button, select a new directory and click OK. If the specified directory does not exist, it will be created.

In the next dialog, the name for the program manager group can be changed. After this, the “Start Installation” dialog is shown. After clicking the “next” button, the installation program starts installing. After all files have been installed, the “Installation Complete” dialog shows up. After clicking the “Finish” button, the last dialog is shown which contains the following information: “This system must be restarted to complete the installation. Press the OK button to restart the computer. Press Cancel to return to Windows without restarting.

Setup Hardware Dialog Box

The first time NanoCalc is started, the hardware needs to be set up correctly. Clicking the menu „screen-spectrometer data-hardware“ can do this. The parameters in this dialog box are usually set only once -- when NanoCalc is first installed and the software first runs.

Under **Spectrometer Type**, choose your spectrometer.

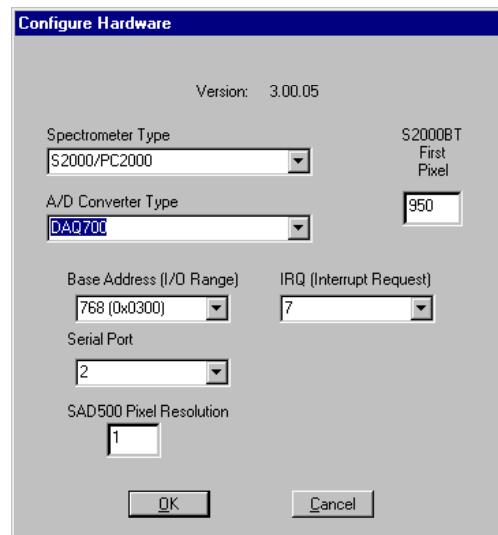
Under **A/D Converter Type**, choose DAQ700.

Choose **Base Address** as selected in the previous section.

Choose **IRQ** as selected in the previous section.

For your setup, only these parameters apply to your system.
(Ignore the other settings; they apply to other A/D converters.)

Click **OK**.



Specifications

Type	PCMCIA Type II
A/D resolution, sampling frequency	12 bit @ 100 kHz
Channels	16-channel single ended, 8-channels differential
Interface cable	50 Pin connector to PCMCIA slot, 25-pin to spectrometer



13.3 NanoCalc-2000 Systems with ADC1000-USB Installation

The NanoCalc-2000 Systems delivered from October 2001 and later have an internal AD-Converter as standard and the communicates between computer and NanoCalc works via USB-Serial Interface. This AD-Converter is called ADC-1000-USB. (AD-Converter, 1MHz, USB Interface)

After installing the NanoCalc Software, connect the ADC1000-USB with the USB cable delivered with the system and insert the cable to your computer's USB port. If you use Windows2000, an error dialog may appear caused by the missing file ezusb.sys. In that case, please refer to the section “Troubleshooting installation ADC1000-USB with Windows2000” on how to solve this problem.

Setup Hardware Dialog Box

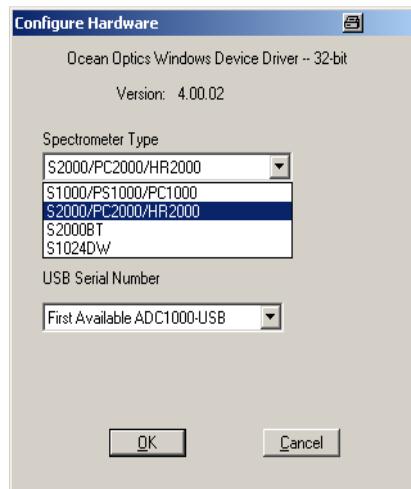
When the NanoCalc Software runs the first time, the hardware needs to be set up correctly. Go to the Setup > Hardware menu. The parameters in this dialog box are usually set by the user only once when the NanoCalc software first runs.

Under Spectrometer Type, choose S2000 (see picture1)

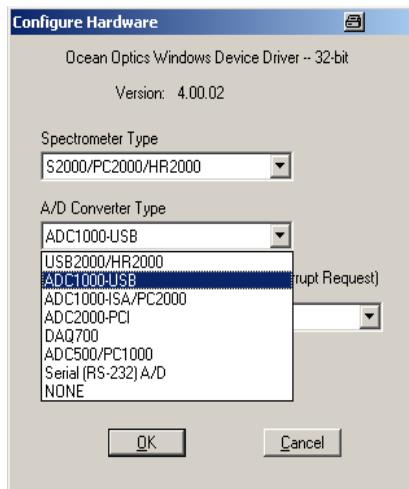
Under A/D Converter Type, choose ADC-1000-USB (see picture2)

Choose the USB Serial Number addressed to the NanoCalc System (see picture3) Click OK.

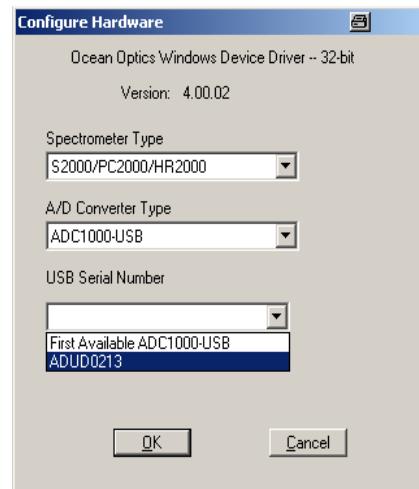
picture1



picture2



picture3



Specifications

Type	USB universal serial Bus
A/D resolution, sampling frequency	12 bit @ 1 MHz integrated in NanoCalc-2000-System
Channels	16-channel single ended, 8-channels differential
Interface cable	USB interface cable (Standard)
Data Transfer rate	Min. 25ms (integration time 3 ms)
Software requirements	WIN 98, WIN 2000
Computer requirements	ATX-IBM compatible with Pentium or better microprocessor, 32 MB RAM and Windows98 or Windows2000



13.3.1 Trouble Shooting with ADC-1000-USB

If you accidentally connected the ADC-1000-USB to your PC before installing the NanoCalc Software, or if you use an older version of the NanoCalc Software, you will get a message that Windows has not installed a driver for the device. To rectify an incorrect installation follow these steps:

Navigate to the Device Manager. If you use Windows98, select Start > Settings > Control Panel. Double-click the System icon. Select the Device Manager tab. For Windows2000 systems, right click My Computer, select Properties, select Hardware tab and click on the Device Manager button.

Scroll down until you see Other devices.

Under Other devices you will see ADC-1000-USB with a large question mark, hit the remove button.

A warning box will appear to ask if it is OK to remove the USB device, click OK.

Unplug the ADC-1000-USB from your PC and reinstall (new version) of the NanoCalc software.

Now you can plug in the ADC-1000-USB again and start the NanoCalc software.

13.3.2 Known problems under Windows95 and Windows2000

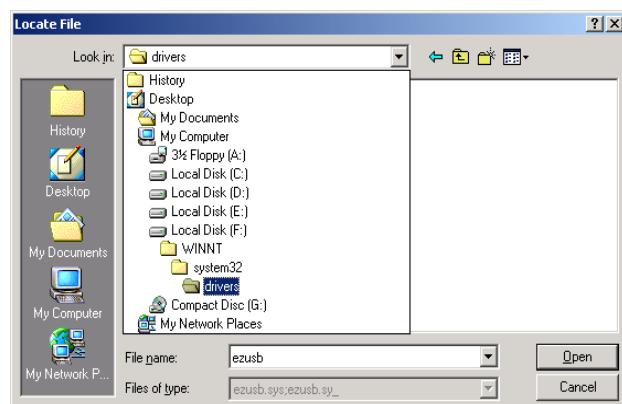
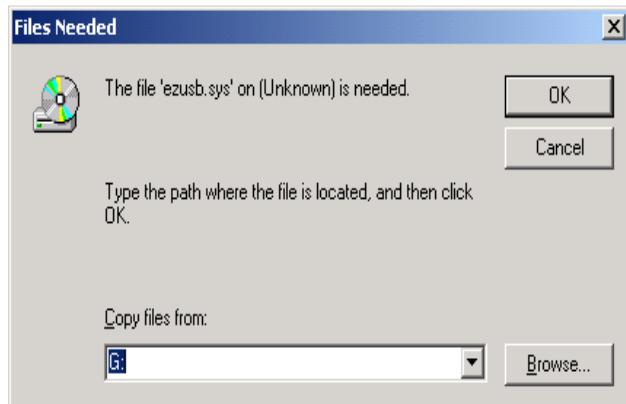
Windows95

On some computers which run under Windows95 the figures on the buttons in the toolbar were not visible. This is a known Windows95 problem for which a utility program (401comupd.exe) can be found on the internet at:
<http://www.microsoft.com/msdownload/ieplatform/ie/comctrl.asp>

Of course we can also send this utility program on request per attached e-mail. After executing 401comupd.exe, the problem is solved.

Windows2000

After installing the NanoCalc Software and connecting the USB cable with the NanoCalc-System and the computer's USB port, Windows2000 shows in some occasions the following dialog.

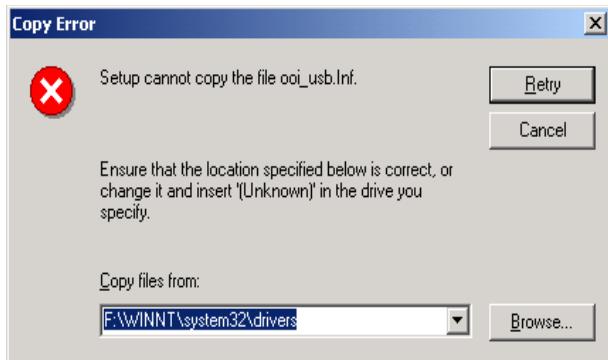


The file ezusb.sys has been installed by the NanoCalc installation program into the directory: winnt\system32\drivers\, on the drive where Windows2000 has been installed (in most cases c:\, but in the following example f:\). Normally, this file will be found automatically by Windows2000 in this directory. If the dialog above is shown, please browse to the directory to tell Windows2000 where it is located. By clicking the open button in the dialog at the right, the problem is solved.

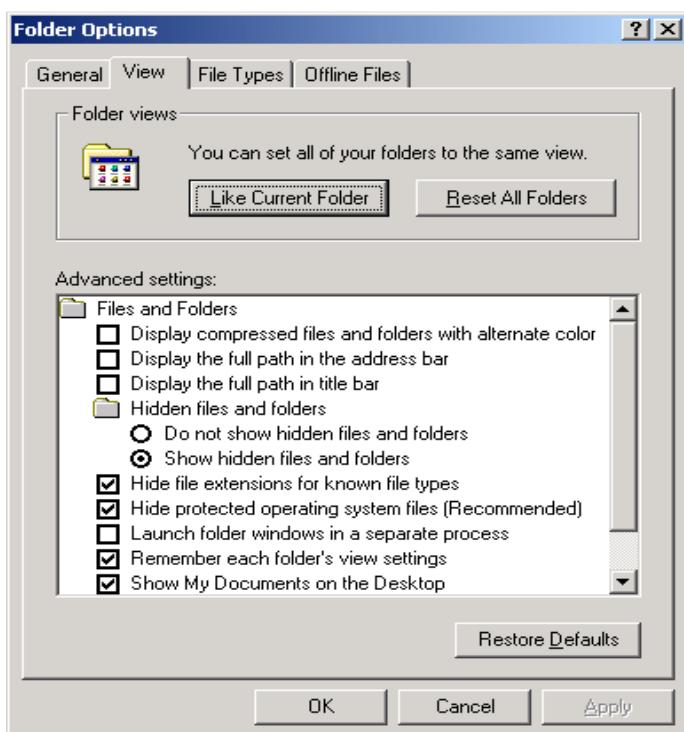


Also the following error message can occur with the file ooi_usb.inf.

This file has been installed by the NanoCalc installation program into the directory WINNT\INF, on the drive where Windows2000 has been installed (in most cases c:\, but in this example f:\). Normally, this file will be found automatically by Windows2000 in this directory. If the dialog above is shown, please browse to the \winnt\inf\ directory to tell Windows2000 where it is located.



Note that the files and folders of the type inf can be hidden, so the browser will not display the files of this type. Then, you need to select under the Windows explorer menu option: Tools/Folder Options (in the View TAB), the "Show hidden files and folders" option, instead of the "Do not show hidden files and folders". See figure below.



After browsing to the file ooi_usb.inf, and clicking the Open button, NanoCalc can be started. The Hardware dialog will be displayed in which you need to set the spectrometer type to S2000 and the A/D converter type to ADC1000-USB (depending on the hardware that is connected). Select the USB Serial number of the attached USB device, instead of the (default) option First Available USB.



14 APPENDIX B

14.1 NanoCalc-Quick-Setup

This Appendix helps you step by step to get a first measurement. This description is using the reference stepwafer from Mikropack, SiO₂-Steps on Si-Wafer.

Install the NanoCalc software and AD-Converter (see Appendix A)

Start the computer and lightsource

Plug-In the USB-Cable (or blue AD-Cable), then install fibercable between the spectrometer and lightsource.

Start the NanoCalc software

Put the reference (Si-Wafer) on the table (Bare Silicon)

Click the "Continuous mode" and “Reference” button

Set the integration time to 3 ms

**Now adjust the fiber distance between wafer and fiber in that way that you get the highest possible signal.
A typical distance is 1-5 mm**

Now adjust the integration time in that way that the Max-Level is around 0.8 on your screen

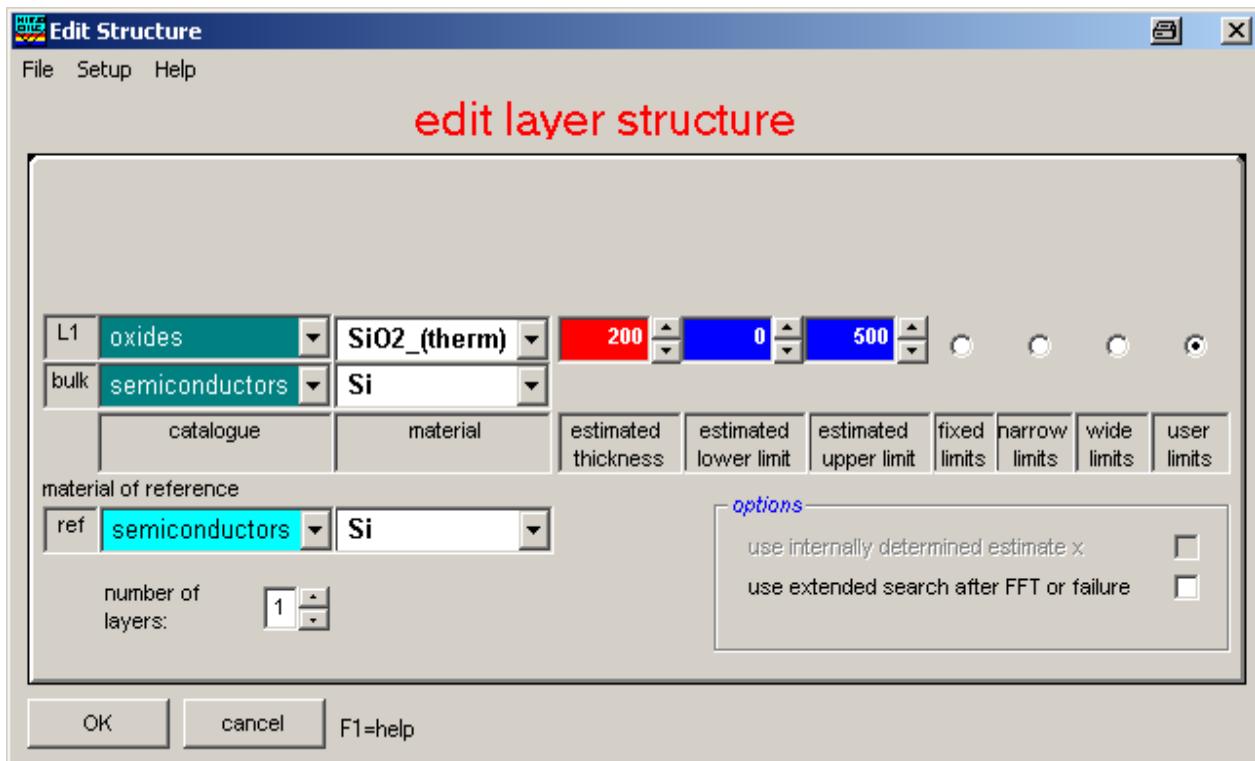
Click again the "Continuous mode" button to stop the measurement

Click the "Reference" button

Now you are ready to work with the NanoCalc System!



Example I: Measure SiO₂ on a Si-Wafer
Go to menu Edit layer structure.



Settings:

L1 (layer1) oxides SiO₂_(therm)
bulk (substrate) semiconductors Si
ref (reference) semiconductors Si
user limits 0 nm - 500 nm
estimated thickness 200 nm

Go to menu Screen > Frequency limits

adjust the plot limits and the extraction range to:

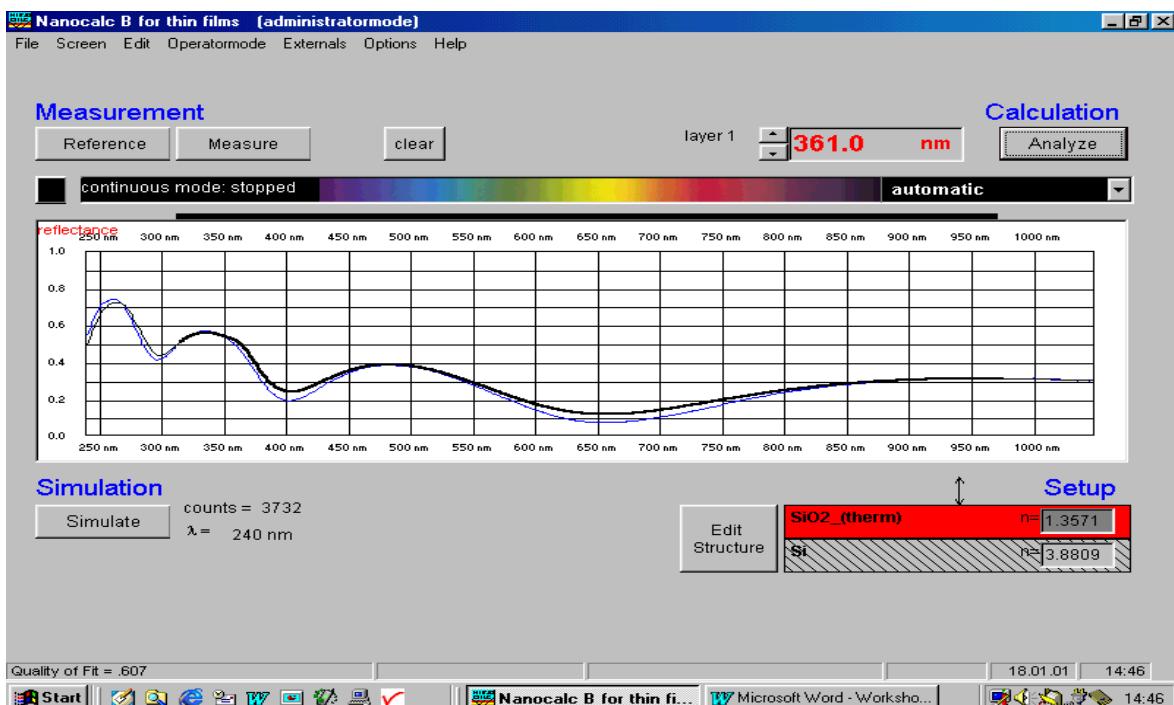
System	max. plot limits [nm]	max. extraction range [nm]
UV/VIS	250 – 850	300 – 800
VIS	350 – 900	400 – 850
NIR	650 – 1100	700 – 1050
VIS / NIR	400 – 1050	450 – 1000
UV / VIS / NIR	250 – 1100	300 - 1050

For thin materials choose a bigger range, for thicker materials (NIR) choose a smaller range and set the smoothing factor 1.



Measure the reference again

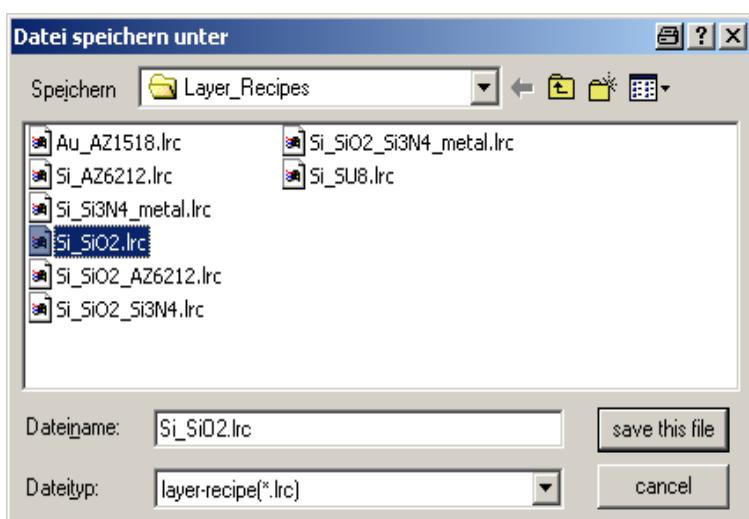
Then put the first step of the wafer under the fiber and push the button "Measure" than "Analyze".



The two curves from measure and analyze should be nearly the same. How good they fit can you see in the left lower corner as Quality of Fit.

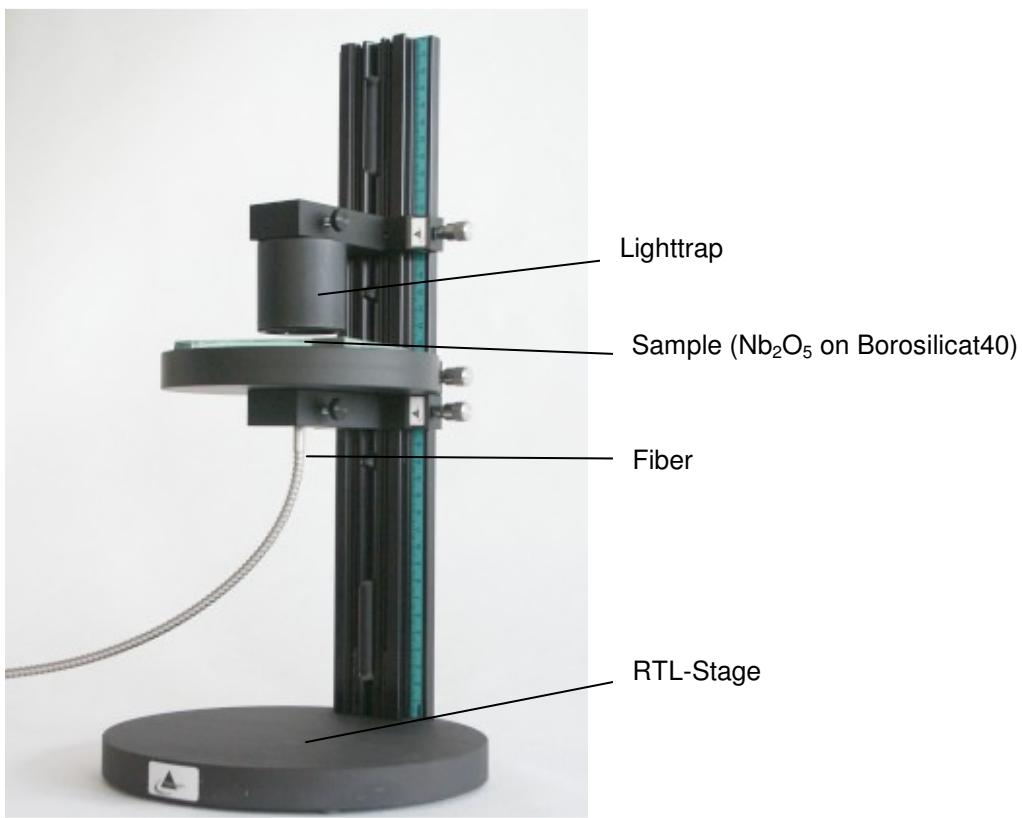
Please try the other steps on the wafer.

Save these settings as a recipe in menu "File" and "Save as recipe" under the name "Si_SiO2.lrc".



**Example II: Transparent Samples
Nb₂O₅ on Glass (Borosilicat 40)**

a.) RTL-Stage (Reflectance mode)



Please accept that Nb₂O₅ has a higher reflectivity than glass without coating, therefore we have to adjust the integration time with the substrat plus layer first and take the reference from the substrate without any changes.

Put the Nb₂O₅ glass onto the RTL-Stage. We need a light trap (black absorber material) behind the glass material, to prevent reflections or ambient light.

Click on the "Continuous mode" reference button.

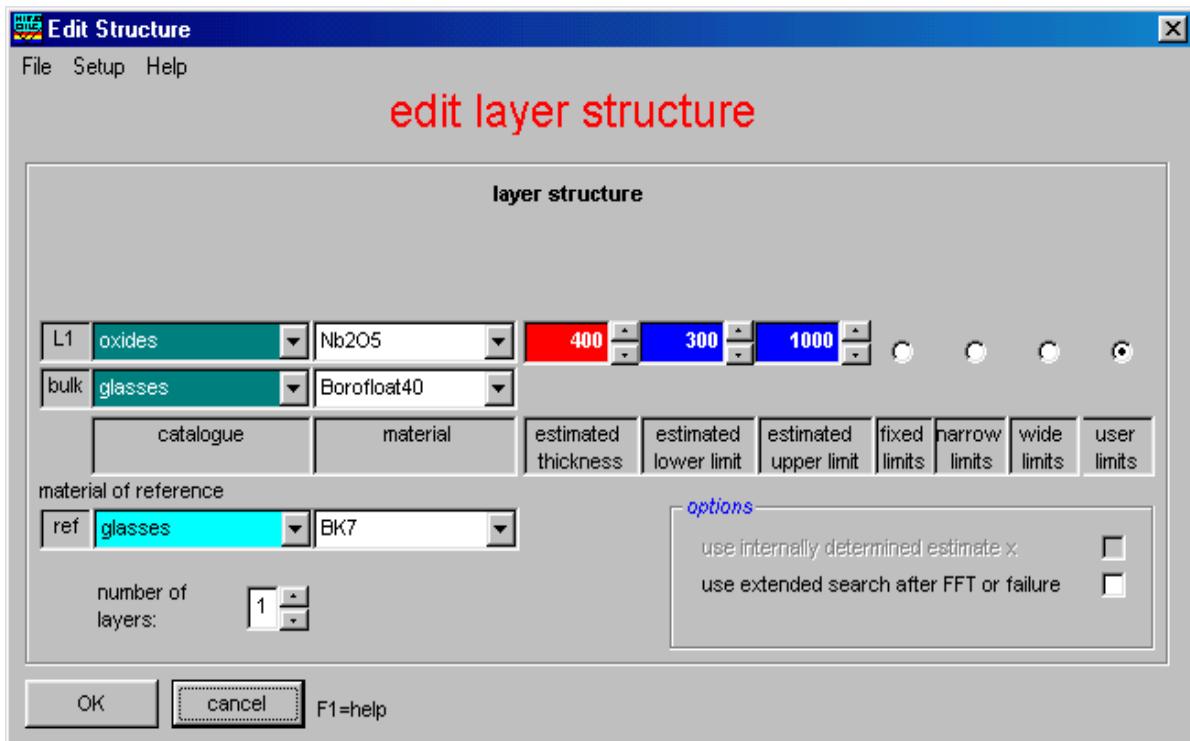
Adjust the fiber distance between sample and fiber in that way that you get the highest possible signal. A typical distance is 1-5 mm

Now adjust the integration time in that way that the Max-Level is around 0.8

Now put the reference glass (BK7) on the table.

Click the button "Reference".

Now you are ready to measure, but as every time we have to go to the menu Edit layer structure first.



Settings:

L1 (layer1) oxides Nb₂O₅
bulk (substrate) glasses Borofloat40
ref (reference) glasses BK7
user limits 100 nm - 800 nm
estimated thickness 400 nm

Go to menu Screen > frequency limits
adjust the plot limits and the extraction range to:

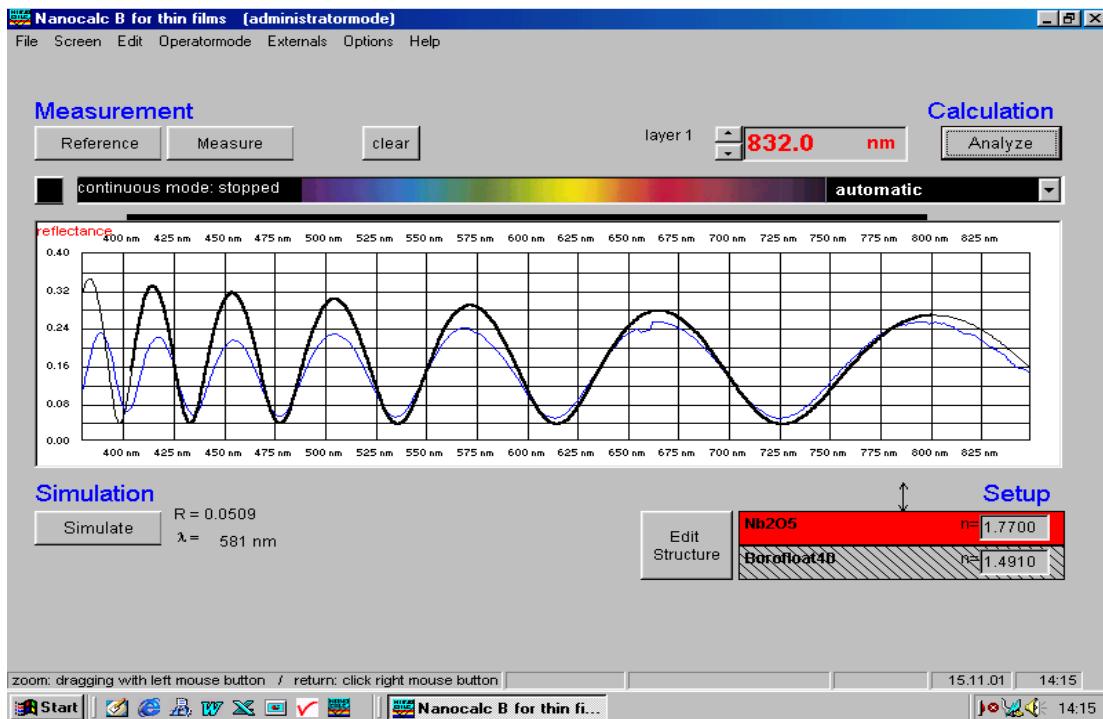
max. plot limits [nm]	max. extraction range [nm]
350 - 1050	400 - 1000

Please make again a reference measurement.

Now put the test-glass under the fiber and push the button "Measure" than "Analyze".

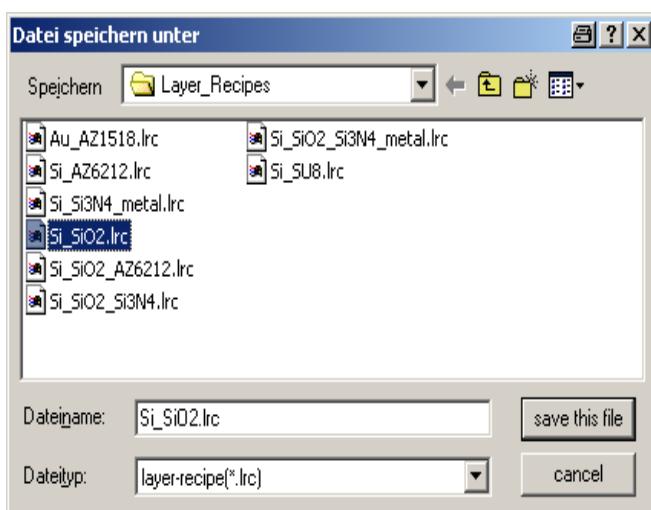


The two curves from measure and analyze should be nearly the same. How good they fit can you see in the left lower corner as Quality of Fit. The difference in amplitude comes from the "wrong" reference BK7 instead of Borosilicat 40 and the inexact values for the $n(\lambda)$ and $k(\lambda)$ from glass and layer. This does not effect the thickness value in this case.

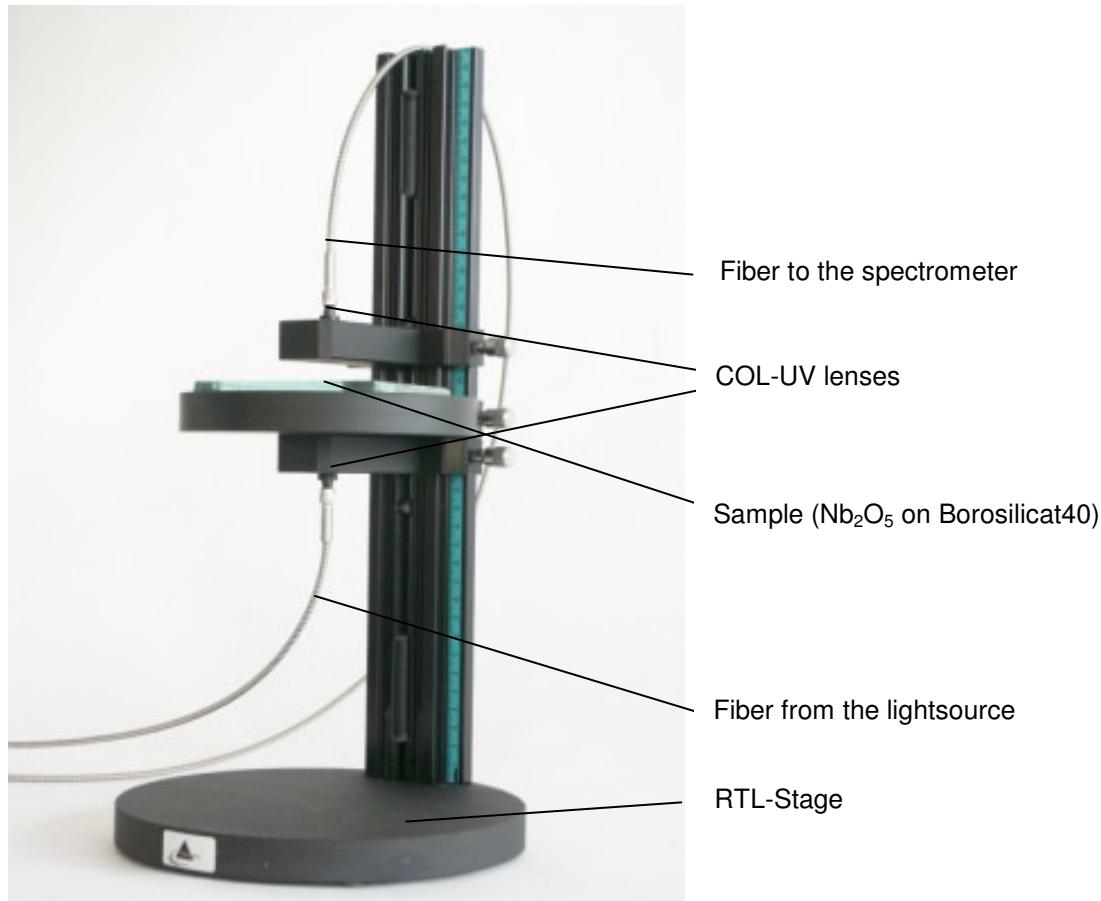


Please try different points on the wafer. Activate the continuous mode and analyze, and move the wafer by tweezers.

Save these settings as a recipe in menu "File" and "Save as recipe" under the name Nb2O5_Boro40.lrc".



RTL-Stage with 2 COL-UV lenses (Transmission mode)



Change to Transmission mode and go to menu Screen > Operationmode > Measurementmode > Transmission mode.

Please accept that Nb_2O_5 has a higher reflectivity than glass without coating, therefore we have to adjust the integration time with the substrat plus layer first and take the reference from the substrate without any changes.

Put the Nb_2O_5 glass on the RTL-Stage.

Click on the "Continuous mode" button.

Adjust the fiber distance between wafer and fiber in that way that you get the highest signal. A typical distance is 1-5 mm.

Now adjust the integration time in that way that the Max-Level is around 0.8.

Now put the reference glass (BK7) on the table.

Click the "Reference" button.

Now you are ready to measure.