Thin-Film-Measurement
Spectroscopic Reflectometer

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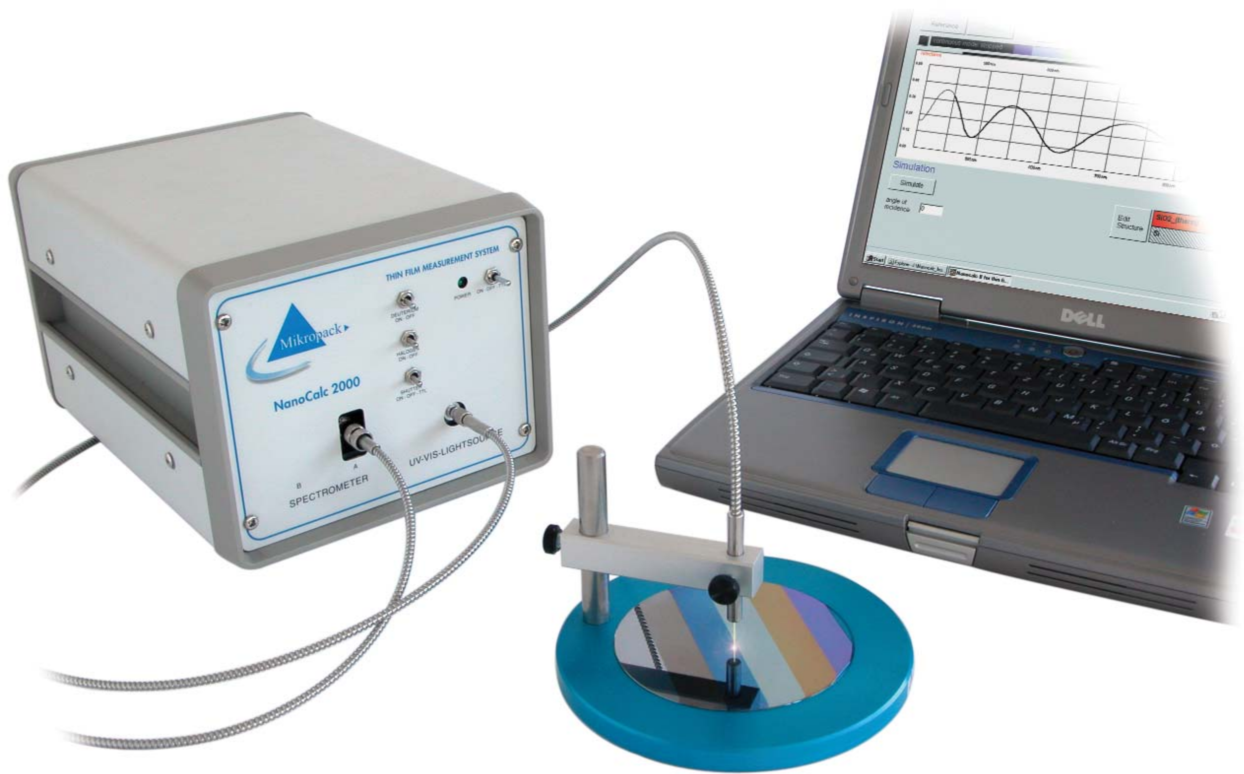


NanoCalc-2000-UV/VIS/NIR

Introduction

Thin films

Very thin layers of different materials that are deposited on the surface of another material (thin films) are extremely important to many technology-based industries. Thin films are widely used, for example, to provide passivation, insulating layers between conductors, diffusion barriers, and hardness coatings for scratch and wear resistance. The fabrication of integrated circuits consists primarily of the deposition and selective removal of a series of thin films.

Films typically used in thin-film applications range from a few atoms to half a millimeter. (< 1 nm = 0.001 µm up to 400 µm). They can be formed by many different processes including spin coating, vacuum evaporation, sputtering, vapor deposition and dip coating.

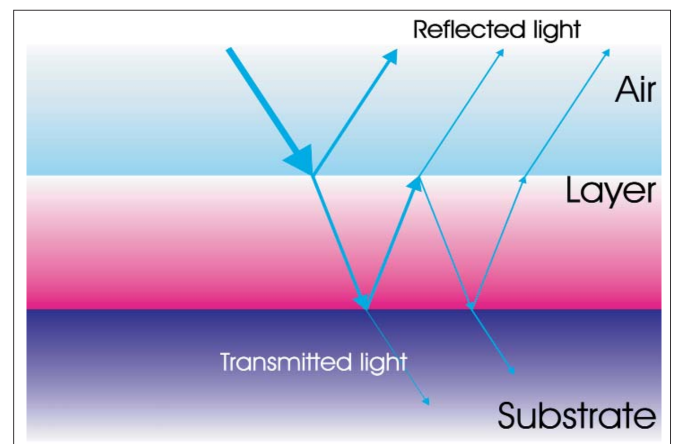
To perform the functions for which they were designed, thin films must have the proper thickness, composition, roughness and other characteristics important to the particular application. These characteristics need to often be measured, both during and after thin-film fabrication. The two ways to measure thickness are optical and stylus based techniques.

The latter method uses a stylus in contact with the sample to measure the step height between the coated and the non-coated surface. Optical techniques accurately measure the thickness of thin transparent and semi-transparent layers by analyzing white light interference. This method is non-destructive and does not need any special sample preparation.

Theory

Interference

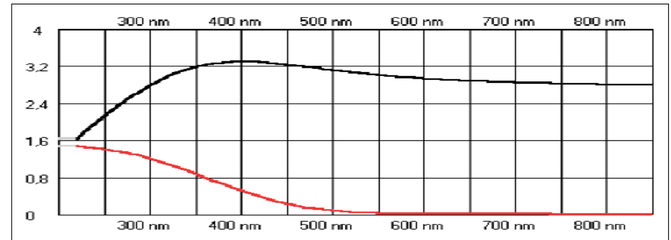
Optical techniques determine thin-film characteristics by measuring how the film interacts with light. Optical techniques can measure the thickness of a film. Optical constants describe how light propagates through and reflects from a material. Optical techniques are usually the preferred method for measuring thin films because they are accurate, non-destructive, and require little or no sample preparation. The two most common optical measurement methodes are spectral reflectance/transmittance and ellipsometry. Spectral reflectance measures the amount of light reflected from a thin film over a range of wavelengths, with the incident light normal (perpendicular) to the sample surface. Ellipsometry is similar, except that it measures reflectance at non-normal incidence and at two different polarizations. In general, spectral reflectance is much simpler and less expensive than ellipsometry, but it is restricted to measuring less complex structures.



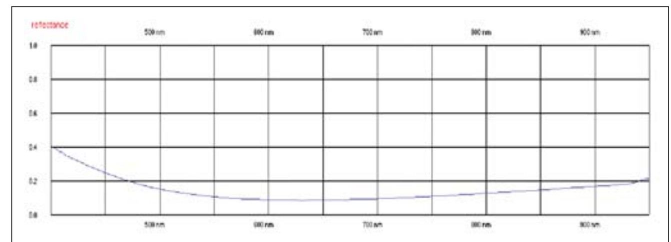
Principle of white light interference

Determining Film Properties from Spectral Reflectance

The amplitude and periodicity of the reflectance of thin films are determined by the films thickness, optical constants and other properties such as interface roughness. In reflectometry it is not possible to solve for film properties in closed form, nor is it possible to solve for n and k at each wavelength individually. In practice, mathematical models are used that describe n and k over a range of wavelengths using only a few adjustable parameters. Film properties are determined by calculating reflectance spectra based on varying trial values of thickness and the n and k model parameters, until the calculated reflectance matches the measured reflectance best (Best-Fit-Algorithm).



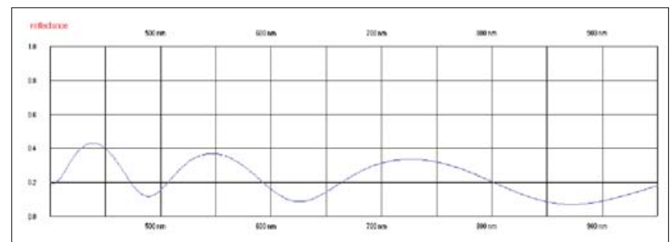
Display of varying n- and k-values of a single material



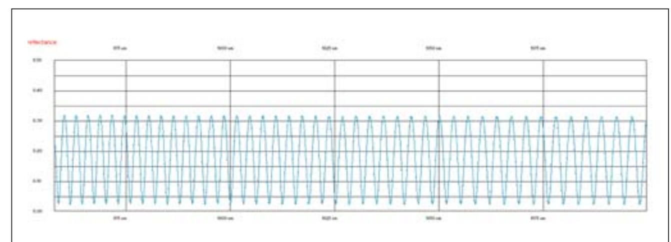
Measurement of a very thin layer (10 nm)

Models for n and k

There are many models for describing n and k as a function of wavelength. When choosing a model for a particular film, it is important that the model is able to accurately describe n and k over the wavelength range of interest using as few parameters as possible. In general, the optical constants of different classes of materials (e.g., dielectrics, semiconductors, metals and amorphous materials) vary quite differently with wavelength and require different models to describe them.



Measurement of a medium thick layer (500 nm)



Measurement of a thick layer (100 µm)

Thin-Film Measurements on your bench top

Thickness of optical layers can be measured quickly and easily with NanoCalc advanced spectrometry systems. The hardware setup is done within a few minutes. The entire system sets up in minutes and measurements can be made by anyone with basic computer skills. The simple hardware and intuitive software provides thin-film capability to a whole new group of users.

NanoCalc-Software
Version
Ser.No.:
NanoCalc-Software
USB-Interface
Fiber Optic Bundle
Measurement System
ThinFilm Measurement System
NanoCalc-2000
SPECTROMETER
UV-VIS-LIGHTSOURCE
Light IN
Light OUT
Fiber Optic Cable
Stage
Sample
Transmitted and reflected light

NanoCalc-Software

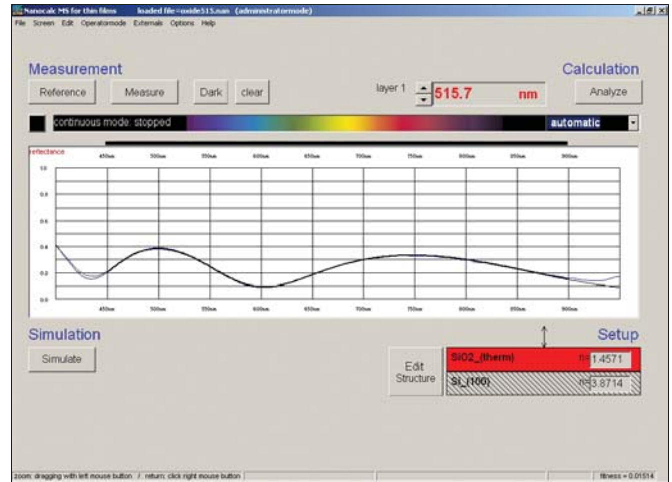
NanoCalc is an easy-to-use production oriented software tool for the acquisition and analysis of spectroscopic data. NanoCalc allows the user to find solutions to a wide range of applications.

NanoCalc enables thickness measurements from 10 nm up to about 250 µm (400 µm). Metallic layers could be determined from 1 nm till they are not any more transparent. The system only needs the knowledge of number and kind of the compound thin films. The refraction index behavior versus wavelength n(λ) and the absorption index behavior k(λ) are given by tabular data or Cauchy coefficients.

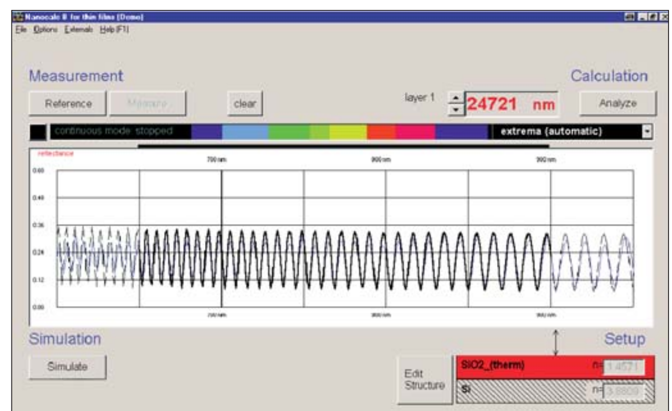
As a result single thickness with a resolution of 0.1 nm can be calculated. To avoid ambiguities in multilayer systems and to reduce the evaluation time it is helpful to work with estimated thickness values. Single layer and multi-layer systems with estimated thickness can be calculated in less than one second. Therefore it is also possible to apply a two-dimensional scanning scheme.

The user mode is specifically designed such for little or no experience in personal computers. In this mode, the user interacts with a single window to open predefined recipes that automatically load all layer settings and instruments parameters. The user only needs to measure the experimental data.

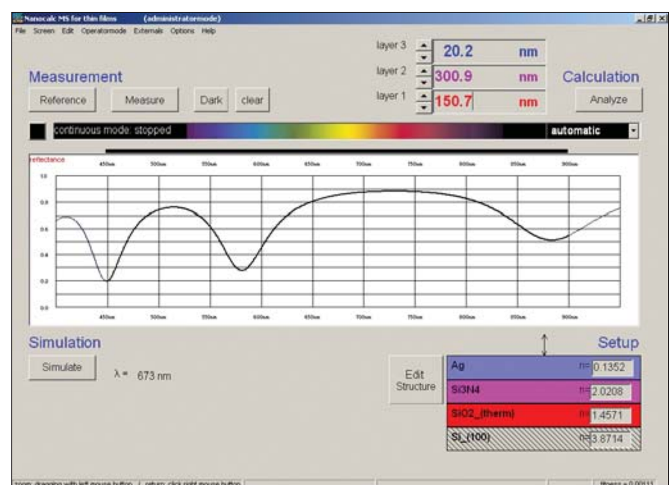
In the administrator mode, the administrator specifies the recipe settings. Each recipe contains the layer and material settings and instrument parameter settings. These recipes can be saved for later use. The administrator mode is protected by a defineable password.



Measurement of a medium thick layer



Measurement of a thick layer



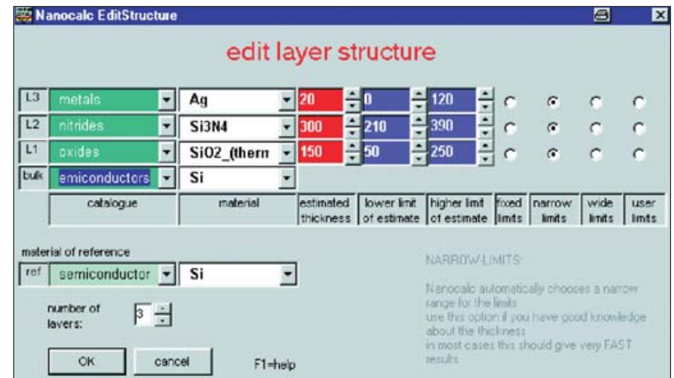
Measurement of a triple layer

Edit Layer Structure

Up to three layers can be specified in the film stack. The various films and substrate materials may be metallic, dielectric, amorphous or crystalline semiconductors. NanoCalc incorporates a large library of n- and k-values for the more widely used materials, which the user can edit and expand. Material types can also be defined by equation/dispersion formulas. The user simply specifies the appropriate coefficients and the program calculates the correct indices.

NanoCalc materials data base

In the data base of NanoCalc a large number of materials are already included. This makes the immediate measurement of standard materials fast and simple. Additionally it is very easy to create new customized materials or catalogs of materials.



Edit layer structure

semi-conductors
Si
a_Si
a_Si_1
a_Si_2
a_Si_3
AlGaAs19
AlGaAs31
AlGaAs41
AlGaAs49
AlGaAs59
AlGaAs70
AlGaAs80
GaAs
GaAs_(100)
GaAs_(111)
Ge
Ge_(100)
Si_(100)
Si_(110)
Si_(111)
Si_poly_1
Si_poly_2
Si_poly_10
Si_poly_20
Si_poly_30
Si_poly_40
Si_poly_50
Si_poly_60
Si_poly_70
Si_poly_80
Si_poly_90
Si_porous
PoSi1
PoSi2

oxides
SiO2_(therm)
Al2O3
CeO2
CuO
Fe2O3
HfO2
ITO
ITO1
ITO2
ITO3
MgO
Nb2O5
PO
SiO
SiO2_(CVD)
SnO2(F)
Ta2O3
Ta2O5
TiO2
TiO2_a
WO3
Y2O3
Y2O3a
ZrO2

polymers
pmma
pmma_495
pmma_950
copolymer_resists

polyimides
Hitachi_PIQ

glasses
BK7
7059
Borofloat40
LASF9
SF11
SodaLime

nitrides
Si3N4
AlN
GaN
SiN1
SiN2
SiN3
SiON_00
SiON_20
SiON_40
SiON_60
SiON_80
TiN

metals
Ag
Al
Au
Co
Co_2
Cr
Cu
Fe
Ir
Li
Mo
Ni
Ni50Cr50
Os
Pd
Pt
Rh
steel
Ta
Ti
V
W

carbides
SiC
SiC_1

fluorides
BaF2
CaF2
LiF
MgF2
SrF2
ThF2

selenides
ZnSe

silicides
CoSi2_4
TaSi2_A
TaSi2_B
TaSi_A
VSi2_A
VSi2_B
WSi2_A
WSi2_B

sulfides
CdS
PbS
ZnS

resists_Clariant
AZ6212
AQUATAR
AZ_EL_2015
AZ_NOVA_2071
AZ_OFPR_800
AZ111_exp
AZ111_non_exp
AZ1350H_exp
AZ1350J_exp
AZ1350J_non_exp
AZ1518
AZ1518_SFD
AZ1518HS_WI
AZ4500
AZ6210B
AZ7209
AZ7510
AZ7700
AZ8100a
AZ8112
BARLI
DX46

resists_Shipley
SPR500
SPR955
UV5
UV6

resists_MRT
SU8
ARU400
ma-N400
ma-P100

resists_Arch(Olin)
APII
ARCH2
ARCH5000series
BPRS-100
ex-KTI_NegRes
HiPR 6512
HiPR 6512GH_025
HiPR 6514HC_17HC
HiPR 6517
HiPR 6517GH_050
HiPR 6517GH_070
HPR 200_500
OCG 825
OCG 895
OCG 896-10i
OCG NegRes
OFR 6800
OiR 32
OiR 32HD
OiR 32MD
OiR 5503
OiR 620
OiR 622
OiR 64
OiR 643
OiR 644
OiR 670
OiR 672
OiR 897
OiR 897_12MK
OiR 906
OiR 907
OiR 908

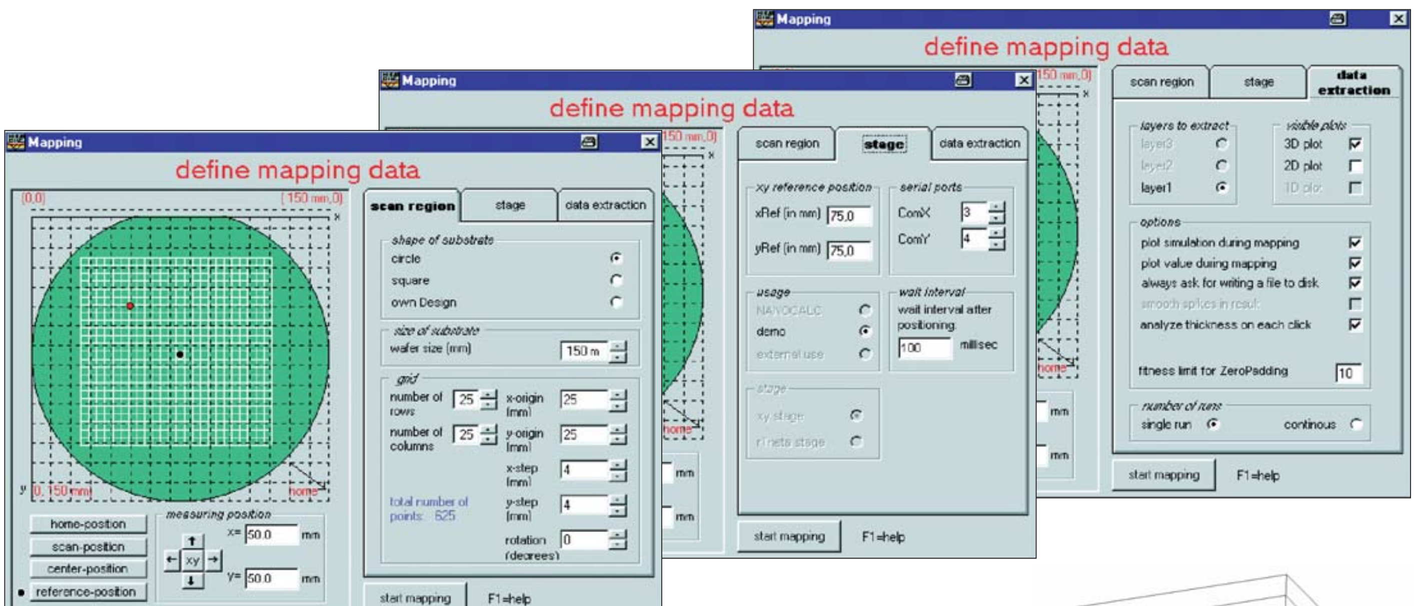
tellurides
HgCdTe0
HgCdTe2
HgCdTe3
PbTe
PZT
ZnCdTe0
ZnCdTe1
ZnCdTe3
ZnCdTe5
ZnCdTe7
ZnCdTe9
ZnCdTe10
ZnSeTe0
ZnSeTe1
ZnSeTe3
ZnSeTe5
ZnSeTe7
ZnSeTe9
ZnSeTe10

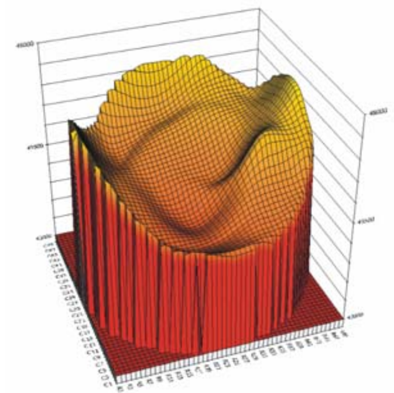
others
a_C
Air
BCB
Diamond
Diaplate132
DLC_a
DLC_b
H20
IRX

Extraction from material data base

Software Options

Software Options

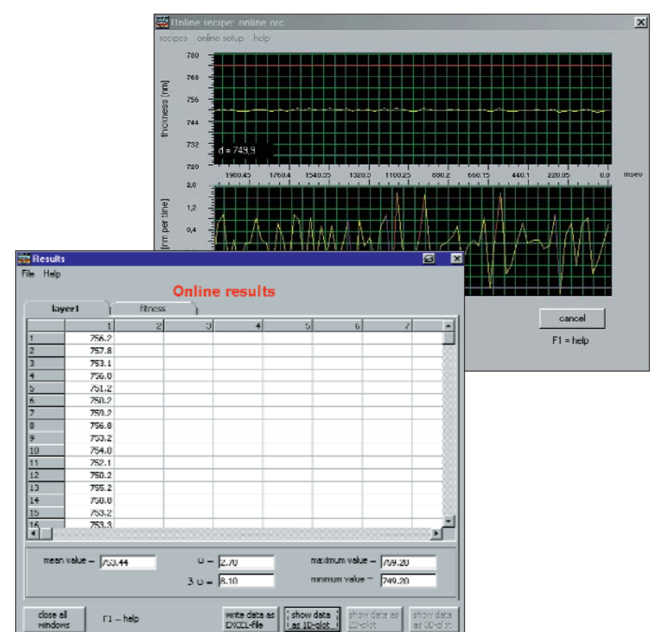




The NanoCalc Mapping module extends NanoCalc to a fully functional mapping software. With this software it is very easy to define the scan region and to measure this region of interest afterwards. The results can be displayed as 2D- or 3D-plot. Additionally they can be stored and printed. All adjustments can be stored in a mapping-recipe, so that the same scan can be repeated later.

NanoCalc Online

NanoCalc Online



The Online-Module can print or show XY-plots and histograms of the layer thickness and removal rate. Terminator point detection and on-line measurement of layer thickness can be readily obtained. The recipes and results can be directly input to MS-Excel to produce process statistics making this software module a genuine production tool. Data reading can be initiated by time, keyboard input or an external TTL-Trigger. These capabilities make this Thin Film Equipment a true professional on-line and in-situ measuring system.

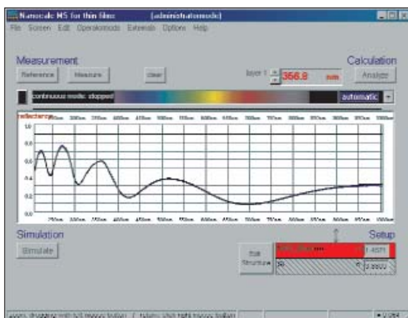
Software Option

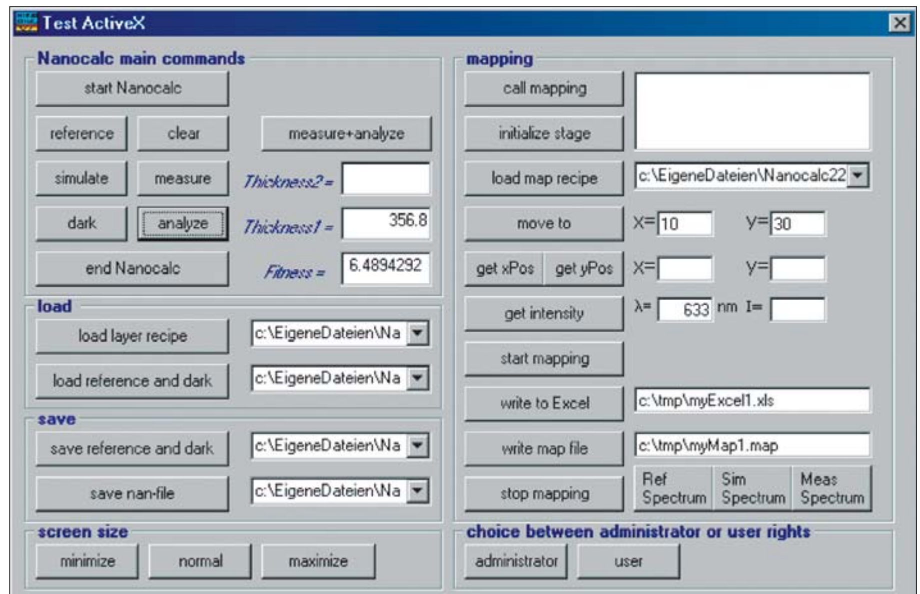
NanoCalc-Remote

This option allows control of the NanoCalc Software by a different software application using ActiveX remote commands.

The TestActiveX sample application shows the functionality of all available commands.

NanoCalc application running as ActiveX component





Sending command
– load recipe – measure – analyze – ...

Receiving results
– Thickness – Fitness

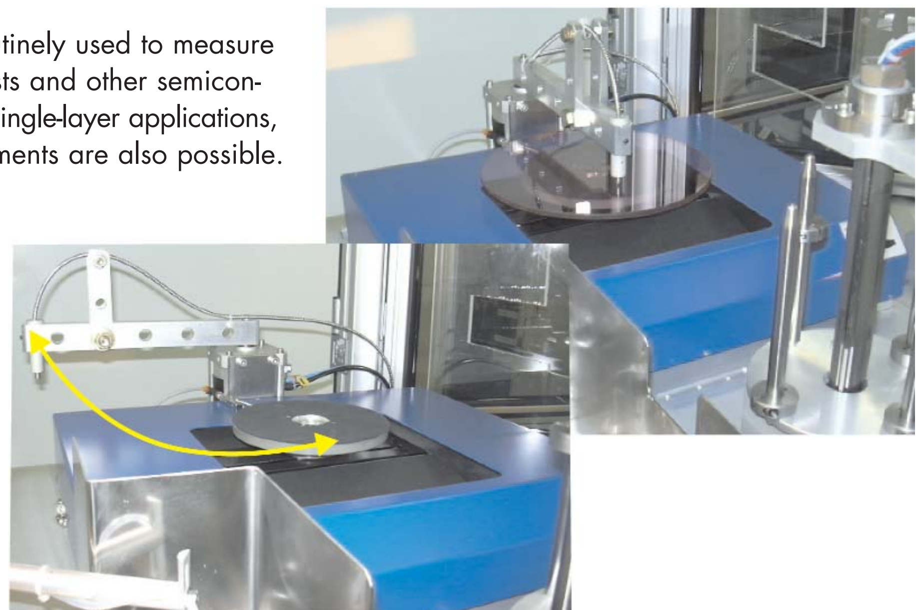
Applications

Semiconductor Process Films

NanoCalc measurement systems are routinely used to measure the thickness of oxides, SiNx, photoresists and other semiconductor process films. In addition to these single-layer applications, many two- and three-layer film measurements are also possible.

In-Situ Measurements

A flexible optical probe assembly makes on-line and in-situ thickness measurements easily possible. All that is required is optical access for normal-incidence reflectance measurements. An example is online-measuring of removal rate in nm per second while removing resist-layers from wafers. Call us for more details about interfacing with your production equipment.



Applications

Optical Coatings

Optical Coatings are used for scratch resistance and/or antireflection coatings in many industries. Automotive plastics, eyeglass lenses, and many plastics packaging applications use thin films.
For hardcoats, a primer layer is often applied first for improved film adhesion. Mikropack systems are capable of measuring the thickness of these layers individually or simultaneously.

Coatings on Rough Surfaces

Usually Thin-Film-Mathematics and optical reflectometry are based on perfect smooth surfaces. If for example photoresist layers grow thicker than 20µm, the surface will not be smooth any longer. There is a roughness. In the world of coatings are many Thin-Film-Applications with rough substrates like steel, aluminum, brass, copper, ceramic and plastic. These surfaces can be coated by DLC (Diamond Like Carbon Layers) or other coatings. All these rough surfaces are causing a lack of signal because of stray light loss. NanoCalc is able to measure rough surfaces with three different and very much improved methods, without having prior knowledge about the roughness of the samples. The system measures and compensates simultaneously.

Specifications	NanoCalc-2000-VIS	NanoCalc-2000-NIR	NanoCalc-2000-NIR-HR	NanoCalc-512-NIR	NanoCalc-2000-VIS/NIR	NanoCalc-2000-UV/VIS	NanoCalc-2000-UV/VIS/NIR
Wavelength:	400-850 nm	650-1100 nm	700-978 nm	900-1700 nm	400-1100 nm	250-850nm	250-1100 nm
Thickness Range:	50 nm…20 µm	70 nm…70 µm	1…250 µm	50 nm…200 µm	50 nm…100 µm	10 nm…20µm	10 nm…70 µm
Resolution:	0,1 nm	0,1 nm	0,1 µm	20 nm	0,1 nm	0,1 nm	0,1 nm
Repeatablity:	0,3 nm	0,3 nm	10 nm	10 nm	0,3 nm	0,3 nm	0,3 nm
Abs.Accuracy:				<1% (100 nm…100 µm)			
Measurement Time:				100 ms…..<1 s			
Numbers of Layers:				1…3 (NanoCalc-MS maybe needed)			
Distance with fiber:				1-5 mm			
Distance with optic:				5 mm…100 mm			
Angle of incidence:				90°			
Spotsize:				Standard 400 µm (optional 100/200µm)			
Microspot:				1…20µm with Microscope 10x/20x/50x Magnification and MFA-Adapter			
Fiber cable length:				2 m (other lengthes on request)			
Interface:				USB 1.1 (RS-232)			
Power consumption:		12 VDC@1,2A		24 VDC@1,2A		12 VDC@1,2A	
Power requirements:				90…240 VAC 50/60 Hz			
Size:				180 mm x 152 mm x 263 mm			
Weight:				~ 3,5 kg			

MPM-2000-2 x 8

The Mikropack 16-Channel Multiplexer MPM-2000 allows the measurement from up to 8 individual fixed fiber positions in less than 8 seconds. Using the ActiveX Remote NanoCalc Software in combination with the MPM 2000 it can be easily customized to integrate into most sample transfer systems.

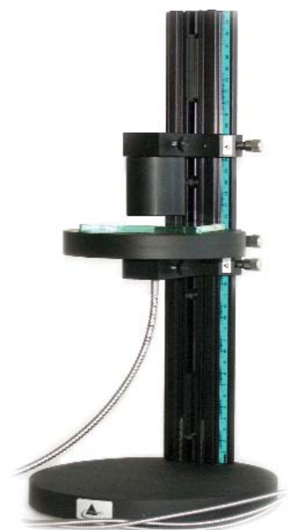
Stage – Single point reflection measurement

Probeholder for simple reflection measurements on optical layers. Base plate for parts with maximal diameter of 150 mm. Height adjustment for standard 6,35 mm fiberprobe.

Stage RTL – (T) Transparent sample measurement

This Stage-System is useful for different kinds of Thin-Film- and Spectroscopy-Measurement-Setups. To measure the reflection from below gives the advantage of constant distance between measuring-fiber and sample surfaces. Therefore the thickness of the sample is not relevant. The setup with a light trap is important to measure transparent materials to avoid background reflections and ambient light. The Stage RTL-T enables the transmission setup. Two extra fiber cables are needed.

Stage RTL-T



Stage RTL

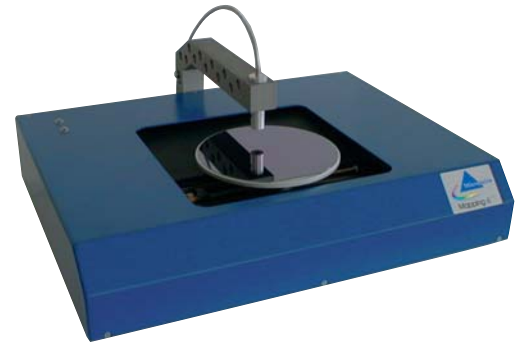
CSH – Probe holder for curved samples

Probeholder for simple reflection measurements on optical parts with curved surfaces. A hard rubber part prevents samples against scratches.

Accessories

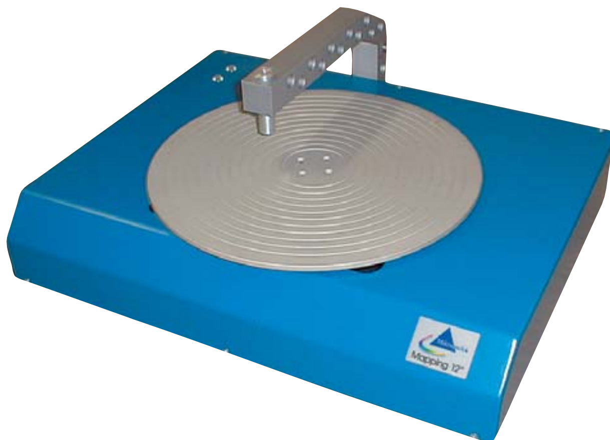
MAPPING 6" and 12"

Are scanning stages with high precision- linear and rotary axes. Travel range is 150 x 150 mm for the 6" and 300 mm for the R-Theta 12" stage. The Mapping 6" and 12" Stages are interfaced by RS 232 and could be powered wide range 110-240 VAC 50-100 Hz. The fiber probe (6,35mm) is placed in a swivel arm, for easy sample change. **Special-Vacuum-Chucks** and holders for other materials are available on request.



Microscope Adapter / Micro-Spot

The MFA-C-Mount adapter allows easy mounting of the fiber probe to the C-mount exit of almost any microscope. Depending on the microscope magnification a measurement spot size between 1 µm and 40µm can be realized. The measurement spot itself can be observed through the eyepieces or an additional CCD-camera for accurate positioning of the sample.



Reference

This special Reference Step Wafer consists of a 4inch Si-wafer with 6 silicon dioxide (SiO_2) steps between 0nm (native Oxide) and 500nm. Each thickness step has a laser marked area for which accurate ellipsometric thickness data are supplied on the corresponding calibration sheet.

Thinfilm Thickness Reflectometer System NanoCalc-2000

NanoCalc-2000-VIS	Wavelength 400-850 nm, Thickness 50 nm....20 µm, (SiO_2 on Si) Spectrometer, A/D-Converter, USB- and RS 232-Interface, Halogen-Lightsource, Reflection Probe, NanoCalc Software
NanoCalc-2000-NIR	Wavelength 650-1100 nm, Thickness 70 nm....70 µm, Spectrometer, A/D-Converter, USB- and RS 232-Interface, Halogen-Lightsource, Reflection Probe, NanoCalc Software
NanoCalc-2000-VIS/NIR	Wavelength 400-1100 nm, Thickness 50 nm....100 µm (optional 1 µm....250 µm). Spectrometer, A/D-Converter, USB- and RS 232-Interface, Halogen-Lightsource, Reflection Probe, NanoCalc Software
NanoCalc-2000-UV/VIS	Wavelength 250-850 nm, Thickness 10 nm....20 µm, Spectrometer, A/D-Converter, USB- and RS 232-Interface, Deuterium-Halogen-Lightsource, Reflection Probe, NanoCalc Software
NanoCalc-2000-UV/VIS/NIR	Wavelength 250-1100 nm, Thickness 10 nm....70 µm, Spectrometer, A/D-Converter, USB- and RS 232-Interface, Deuterium-Halogen-Lightsource, Reflection Probe, NanoCalc Software
NanoCalc-2000-NIR-HR	Wavelength 700-978 nm, Thickness 1 µm....250 µm (400 µm) High Resolution Spectrometer, A/D-Converter, USB- and RS 232-Interface, Halogen-Lightsource, Reflection Probe, NanoCalc Software
NanoCalc-512-NIR	Wavelength 900-1700 nm, Thickness 50 nm....200 µm, InGaAs-512 Element-Array-Spectrometer, A/D-Converter, USB- and RS 232-Interface, High-Power-Halogen-Lightsource, Reflection Probe, NanoCalc- and Scout-Software

Software

NanoCalc	Thin Film Measurement Software for Windows™ Measurement, simulation and analysis of a single-layer systems
NanoCalc MS	Thin Film Measurement Software for Windows Measurement, simulation and analysis of a multi-layer systems
NanoCalc Mapping	Mapping module software (needs NanoCalc or NanoCalc MS) Complete 3D-Mapping-Modul with control-software for Mapping Stage Mapping-6" and Mapping-12"
NanoCalc Online	Online module software (needs NanoCalc or NanoCalc MS). Online display of XY-graphs and histograms of layer thickness and removal rate. End point detection, on-line check of layer thickness. Recipe, result list, statistics with data transfer to Excel®
NanoCalc Remote	Remote module (needs NanoCalc or NanoCalc MS) Active-X functionality allows to control most of the NanoCalc functions from any other software. Comes with a example program (MS Visual Basic).

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