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Preparation to view information

FUNDAMENTALS

Operating instructions

QSG 100 film thickness monitor

Version: 0305

1. Introduction

1.1 Operating Instructions

BAL-TEC AG in FL-9496 Balzers is the manufacturer of the QSG 100 film thickness monitor, with which vacuum coating processes can be reproducibly monitored and controlled.

These operating instructions will enable you to use the QSG 100 film thickness monitor correctly and safely.

1.1.1 Area of validity and unit identification

The information in these operating instructions relates to the quartz crystal film thickness and coating rate measurement unit with the following printed type description:

- QSG 100 Quartz Film Thickness Monitor

In the case of queries or correspondence with BAL-TEC AG, you will facilitate and speed up the processing of your query if you can quote the precise unit identification as shown on the unit nameplate. This information completely defines the unit, including any customer-specific modifications.

Note: In the case of diagnosis queries (e.g., following faults) you should also quote the displayed process step and/or the error message shown on the display wherever possible.

1.1.2 Structure of the operating instructions

In the first instance, these operating instructions are intended as a reference work. The information is structured into four parts, in relation to tasks and subjects:

Part 1 Fundamentals

This part provides the basic knowledge that every user should have when working with the QSG 100 film thickness monitor.

- Chapter 1: Introduction
- Chapter 2: Security
- Chapter 3: Structure and Function
- Chapter 4: Theory and Calibration

Part 2 Normal operation

This part contains the information that is necessary for the operation of the QSG 100 film thickness monitor in normal cases. With this information, the user can operate the unit when it is ready for use.

- Chapter 5: Operation
- Chapter 6: Data and Program

Part 3 Special Operations

This part describes all work that is not included under normal operation, such as initial start-up and troubleshooting.

- Chapter 7: Initial start-up
- Chapter 8: Troubleshooting

Part 4 Appendix

The Appendix contains general information that must be available to all users at all times. This includes information regarding the use of the operating instructions (Indexes) and data with regard to the unit itself (technical data).

- Chapter 9: Appendix

1.1.3 Target public and obligation to read

These operating instructions are aimed at authorised users of the QSG 100 film thickness monitor. Authorised users may only be nominated by the system administrator.

The requirements on the users vary depending on the activities that they wish to carry out. We therefore differentiate between various user roles. You can exercise one or more of these user roles if you fulfil the corresponding requirements.

Note: The definition of the user roles with the requirements on the corresponding roles can be found in the Section „Users and their responsibilities“, page 9.

Reading obligation

Regardless of the user role that you take on, you are obliged to read the Chapter „Safety“, page 8.

1.1.4 Access aids

These operating instructions will facilitate rapid access to the desired information with the following access aids:

- Thanks to its task and subject-related structure, you can find the complete information regarding a specific area most easily using the Table of Contents.

Table of contents

Index

- The quickest way to find information regarding a specific activity or on a special subject is to use the Index in the Appendix of these operating instructions.

Marginal notes

- Within the chapters of the operating instructions, you can orient yourself using the marginal notes at the edge of the page.

1.2 Symbol convention

The operating instructions contain abbreviations and symbols for the identification of sections of text or instructions. This section explains the symbol conventions that apply to the whole of these operating instructions.

1.2.1 Warning and utilisation notes

Please note the meanings of the following warning and utilisation notes:



Warning: *Danger or unsafe handling that could result in injury or death.*

Example: Warning of the danger of electric shock by coming into contact with a high voltage line.



Caution: *Danger or unsafe handling that would only lead to minor injuries, but could cause extensive property, financial or environmental damage.*

Example: Danger due to incorrect operation by an inadequately instructed user.

Note: *User information that helps the user with the technically correct and efficient operation of the QSG 100 film thickness monitor or to understand the interconnections and characteristics.*

Example: When setting up the quartz head, it must be ensured that the substrate and the quartz head do not influence one another, for example, by shadowing.

1.2.2 Symbols and abbreviations

The following symbols and abbreviations are used in these operating instructions.

Symbols

Warnings and utilisation instructions are indicated by the symbol shown above.

Abbreviations

Abbreviations are only used in calculation formulae and tables, as well as for dimensional units.

1.2.3 Legends

To ensure the clear identification of parts or elements, the operating instructions include several diagrams. Passages in the text refer to these diagrams by means of legends. Legends consist of lower-case letters, and reference elements in the figures immediately before or alongside the respective text.

1.3 Customer documentation

The operating instructions are an important document, but only represent a part of the customer documentation. This section lists how the complete customer documentation is built up.

1.3.1 Scope of the documentation

The complete documentation for the QSG 100 film thickness monitor comprises the following:

- Operating instructions for the QSG 100 film thickness monitor
- Technical documents (electrical circuit diagram)
- Terminal-Program for the operation of the serial port

Note: The EMC measurement report and other technical documents can be obtained from the manufacturer on request.

1.3.2 Document directory

You will receive the operating instructions:

- printed out in paper form

You will receive the technical documentation:

- printed out in paper form

You will receive the terminal program

- On a floppy disc

You will receive the other documents:

- printed out in paper form

2. Safety



Warning: *When used in accordance with the operating instructions, the QSG 100 film thickness monitor is simple and safe to operate. This system could present danger, however, if the safety instructions are disregarded.*

2.1 Safety concept of BAL-TEC AG

There are only a few possible dangers when using the QSG 100 film thickness monitor, and its operation is simple and safe for the instructed user. Inadequate instruction of the user could, however, lead to damage through incorrect operation, or even cause injury.

A safety concept that should protect the user of the QSG 100 from danger and incorrect operation has been drawn up on the basis of a danger analysis.

In addition to the implementation of protective measures, the core elements of this concept regulate authorisation for the use of the QSG 100 film thickness monitor and the responsibility of the individual users. You can read a summary of these points in the following sections.

2.1.1 Purpose of the QSG 100 film thickness monitor

The correct use of the QSG 100 film thickness monitor is the measurement of film thicknesses and coating rates in thin-film deposition installations. In addition, the automatic process shutdown when reaching the predefined shutdown criteria can be supported.

- The monitoring of defined film thicknesses and coating rates in the generation of carrier films for TEM samples.
- The monitoring of reproducible, electrically conducting thin films on electron-microscopic samples.
- The monitoring of film thicknesses and coating rates for interference films and film systems, for example, for structural analysis.
- The monitoring of reproducible films in the modification of electrical or optical surface characteristics.

Typical areas of use are:

- Dried, frozen or ion-beam thinned samples
- Solid samples, wafers

Any other use without the written approval of the manufacturer will be considered to be improper. The manufacturer will accept no liability of any kind for damage resulting from such use.

EM-samples

Thin films

2.1.2 Users and their responsibilities

All persons who work with or on the QSG 100 film thickness monitor are described as Users. As the requirements on the user vary for the individual activities, different user roles are differentiated. You can take on one or more of these user roles if you fulfil the corresponding requirements:

System administrator

The 'System Administrator' is the contractual partner of the manufacturer and is authorised to sign legally binding contracts.

The 'System Administrator' acquires the QSG 100 film thickness monitor and is responsible for ensuring that it is used for its intended purpose. He also determines who is authorised to use the system.



Caution: *Risk of incorrect operation by inadequately trained users. The system administrator is responsible for ensuring that only users who have received detailed instructions and whom he has specifically authorised are allowed operate the QSG 100 film thickness monitor.*

Machine operator

The 'Machine operator' is an employee who has been instructed in the operation of the QSG 100 film thickness monitor and who is familiar with the special features of quartz crystal film measurement. He operates the unit once it has been made ready for use, and detects and corrects operational faults.

The 'Machine operator' has the responsibility of reporting operational faults that he cannot correct himself and defects on the unit to the technician, so that these can be corrected.



Caution: *Danger of damage to the unit. If work has to be carried out with which the machine operator is not familiar, or that is not described in detail in the Operating Instructions, the machine operator must call in the technician.*

Technician

The 'Technician' is a professional with a mechanical and/or electro-technical basic education. He installs the system, connects it to the energy supply and carries out the commissioning. In addition, he maintains, services and repairs the unit as and when necessary.

The 'Technician' is responsible for the handover of the unit in a technically perfect condition following the installation and after any repair work.

2.1.3 Modes of operation

A differentiation is made between the following modes of operation:

Off

In the operational mode 'Off', the QSG 100 film thickness monitor is switched off and is separated from the energy supply (mains voltage) via the main switch.

Normal operation

We describe 'Normal operation' as the mode when the unit is switched on for normal operation.

Special operation

We describe 'Special operation' as the mode when work is being carried out on the unit that differs from 'Normal operation'. This could include installation, maintenance or repair work.

2.2 Dangers during use and safety measures

The manufacturer has minimised the scope of dangers arising during use through the design and through protective measures. An inadequately instructed user could nevertheless cause damage to property, or even be injured as a result of incorrect behaviour.

You should therefore pay particular attention to the warnings and safety instructions listed in the descriptions of the various activities, as well as to the general safety regulations listed below.

2.2.1 Danger to persons during use

Note the following dangers during use and the possible counter-measures:



Warning: *There is a danger of electric shock when coming into contact with components that conduct current. Disconnect the system from the electrical mains supply and pull out the plug before starting any work for which the housing will have to be opened.*

2.2.2 Preventative measures

Various constructional measures have been taken to provide protection from the residual dangers of the QSG 100 film thickness monitor. The most obvious measure is the completely closed housing.

In the closed state, the housing covers are securely connected to the housing, and may only be opened by the technician for work in the Special Operation mode.

The Touch-Screen display is low radiation and is CE-tested.

2.2.3 General safety regulations

In general, the following safety conditions apply in connection with the QSG 100 film thickness monitor:

- Each user is responsible for his/her own health.
- Only users who have been instructed and authorised by the system administrator may work on or with the unit.
- It is expressly forbidden to modify or remove any of the protective equipment.
- After every repair, the user (technician) must check the correct functioning of the unit by means of a test run.
- Following repairs, the full functionality of the unit can only be guaranteed if original spare parts are used according to the spare parts list or information from the manufacturer.
- Careful operation of the QSG 100 will reduce the maintenance costs and is a precondition for its reliable operation.
- Greater damage can often be avoided by carrying out regular checks and by correcting even small faults at an early stage.
- Compliance with these operating instructions and all notices placed on the unit is in the interest of your own safety.

3. Structure and Function

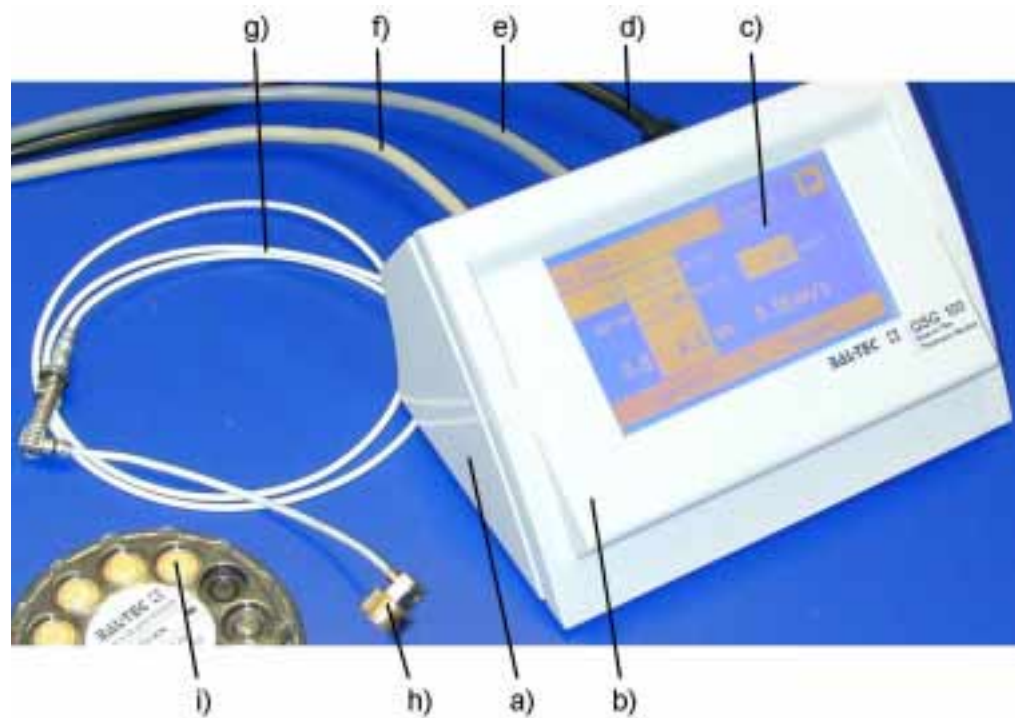
This chapter is intended for all users of the QSG 100 film thickness monitor. It shows the structure, describes its functions and describes all its components.

3.1 Structure of the unit

The QSG 100 is designed as a small compact unit. All the components necessary for the quartz crystal measurement are integrated into the housing, with the exception of the sensor. The connection cable and the vacuum ducts are matched to the respective configuration.

3.1.1 Overall system

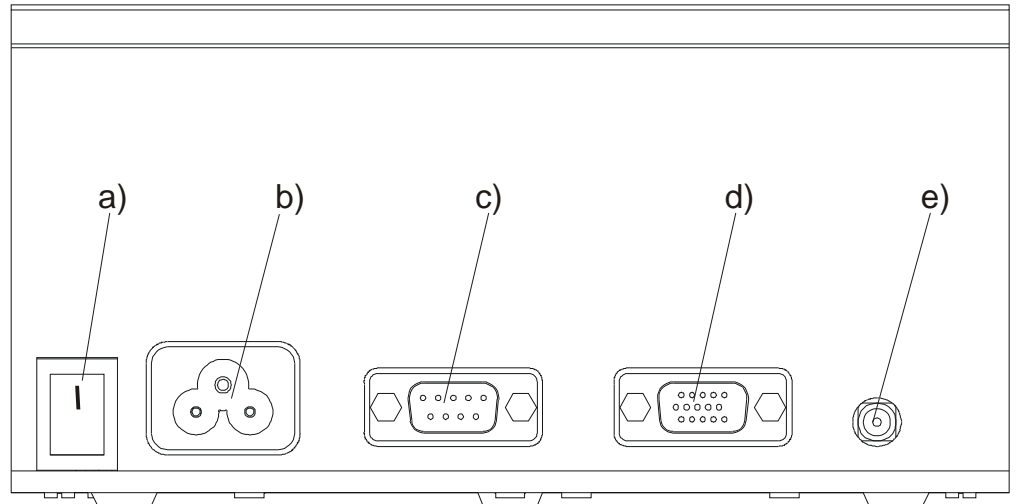
Fig. 3-1, View of the complete unit with its accessories



- a Housing
- b Housing cover
- c Touch-Screen
- d Mains cable
- e Serial interface cable
- f Connection cable for Input / Output module
- g Measurement cable and vacuum duct
- h Quartz head
- i Quartz crystals

3.1.2 Basic unit

Fig. 3-2, Rear view of the basic unit



- a Main switch
- b Mains connection, 90-260V / 50-60Hz, instrument plug according to EN 60320-1C/6
- c Serial interface RS232, 9-pole D-SUB (male)
- d Input / Output module interface, 15-pole D-SUB, high density (male)
- e Connection for measurement cable co-axial, 50 Ohm, snap-plug

3.2 Function

The growth of a layer is measured using a sensor. These signals are transferred to the evaluation electronics through suitable ducts and connection cables. The results are stored and are shown on the display.

3.2.1 Principle of operation

Using an oscillator, a quartz crystal is stimulated to oscillate at its current resonant frequency. The resonant frequency of the quartz crystal changes if material is deposited on the quartz. The change in the resonant frequency is accurately measured to 1Hz within the range of 4-6MHz. On the basis of the specific density of the deposited material, the change in the resonant frequency and the correction factors, the results will be calculated by the evaluation electronics. The change in the film density and the current coating rate are both determined and displayed.

Note: By means of special filter functions, temperature effects, flashovers and other disturbances are suppressed and are taken into account in the calculation of the effective film thickness.

3.2.2 Operation and Display

The complete visualisation and operation of the QSG 100 is carried out via a Touch-Screen display. Commands can be carried out or menu functions can be called up using key fields.

Fig. 3-3, Operation with the Touch-Screen



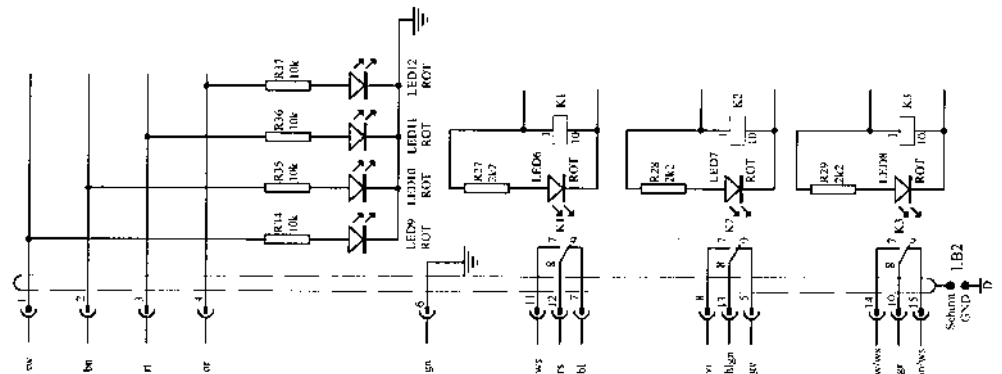
3.2.3 Input / Output module

Different interconnections with external components can be realised with the input/output module. External signals can be read into the unit controller via four digital inputs (DI). Three digital outputs (DO) are available to drive external functions. Each output consists of three pins, Earth (gnd), a closing contact (NO) and an opening contact (NC). All inputs and outputs are potential-free contacts that are galvanically insulated from the unit.

	Pin	Colour	Function	Example
DI gnd	6	green		
DI1	1	black	ext. measurement	Shutter opened
DI2	2	brown		
DI3	3	red		
DI4	4	orange		
DO1 (no)	11	white	shutter	open
DO1	12	pink	shutter	
DO1 (nc)	7	blue	shutter	close
DO2 (no)	8	violet	Stop	

	Pin	Colour	Function	Example
DO2	13	light-green	Stop	
DO2 (nc)	5	yellow	Stop	Process shutdown
DO3 (no)	14	black/white		
DO3	10	grey		
DO3 (nc)	15	brown/white		
free	9			

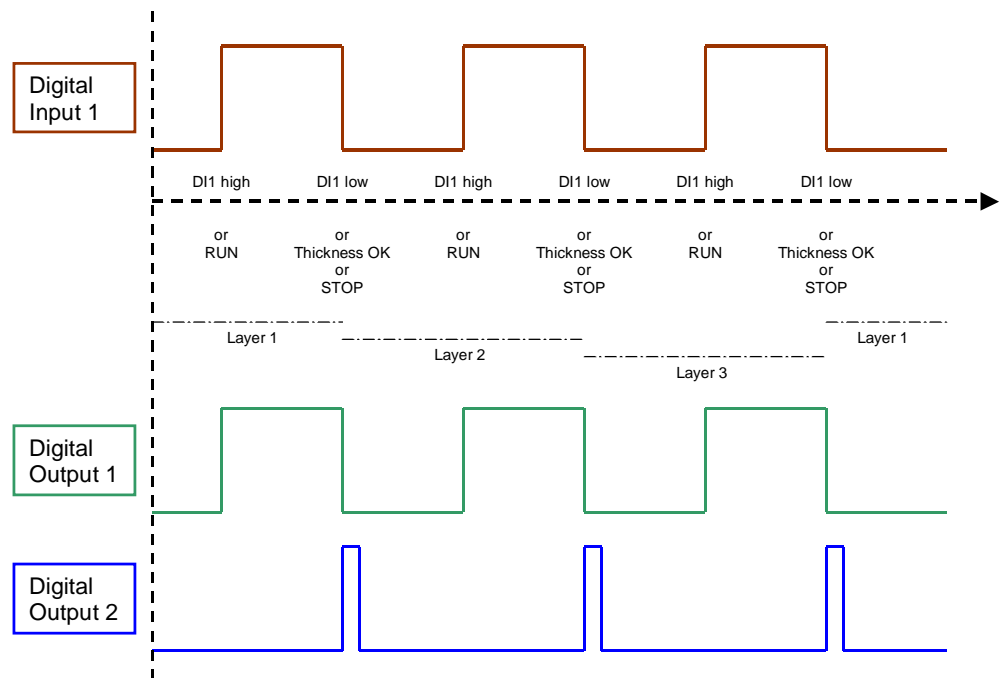
Fig. 3-4, Circuit diagram of the Input / Output logic



3.2.4 Process automation stages

With the input/output functions of the QSG 100 film thickness monitor, coating processes can be safeguarded and automated in various ways.

Fig. 3-5, Input / Output logic



3.2.4.1 Manual

- The input/output module is not used.
- The process is started manually on the coating unit.
- The measurement cycle is started manually on the QSG 100.
- If a shutter is present, it will be opened manually.
- The shutter position is not monitored by the QSG 100.
- When the selected switch-off criteria are reached, the shutter must be closed manually and the coating process is stopped manually.

Note: The operation of the film and coating thickness measurement are completely separated. The machine operator must coordinate the correct procedure.

3.2.4.2 Automatic shutter

- The digital output DO1 is connected to the shutter logic of the coating unit. Ground (Pin 12, pink), open shutter (Pin 11, white) and close shutter (Pin 7, blue) are thereby used. If the shutter should stay closed, Pin 12 is connected to Pin 7, while if the shutter should be open, Pin 12 is connected to Pin 11.
- The process is started manually from the coating unit.
- The measurement cycle is started manually at the QSG 100.
- The shutter is automatically opened at the start of the measurement cycle.
- When the selected shut-off criteria are reached, the shutter is automatically closed.
- The coating process must be switched off manually by the machine operator.

Note: With this operation, the automatic shutter ensures that the substrate is coated to the desired thickness.

3.2.4.3 Shutter operation

- The digital input DI1 is connected to the 'shutter opened' limit switch. In addition, Pin 6 (green) is connected with the earth of the external unit. 24VDC is conducted via Pin 1 (black) of the 'shutter opened' limit contact. When the contact is open, the QSG 100 film thickness monitor remains in the Standby Mode. If the contact is closed, the measurement cycle is started, and will be stopped again when the contact is opened.
- The process is started manually from the coating unit.

- The shutter is opened manually, thereby automatically starting the measurement cycle.
- When the desired coating depth is reached, the shutter must be closed manually, and the coating process be switched off. The measurement cycle is ended automatically by the closing of the shutter.

Note: The external Run function allows the machine operator to concentrate exclusively on the process parameters at the start of the process. The film thickness measurement is automatically started at the correct time by opening the shutter.

3.2.4.4 Shutting down process

- The digital output DO2 is linked to the process shutdown of the coating unit. The two pins 13 (light green) and 5 (yellow) are used for this. The contact is opened for 10 seconds on reaching the shut-off criteria and is then closed again.
- The process is started manually at the coating unit.
- The coating process is automatically ended when the selected shut-off criteria are reached.

Note: This function can be used in combination with all the above-mentioned automation stages.

3.3 Accessories and options

3.3.1 Interfaces

Connection cables and software are available for the data transfer via the RS 232 serial interface. Suitable plugs, connecting cables and power supplies are also available for the input/output module. Please contact your local BAL-TEC AG sales partner, or contact BAL-TEC AG Liechtenstein directly.

3.3.2 Installation kit

Complete installation kits are available for BAL-TEC AG coating systems. These consist of the basic unit (stand-alone or OEM), all necessary connecting cables, vacuum ducts, a quartz head and a set of quartz crystals (6MHz). On request, BAL-TEC AG will be pleased to put together sets for other coating systems. Please contact your local BAL-TEC AG sales partner, or contact BAL-TEC AG Liechtenstein directly.

3.3.3 Connecting cable

Various connecting cables are available with different connectors (snap and screw plugs, straight and angled) and cable lengths (15cm to 1m), matching all current and earlier BAL-TEC AG film thickness measurement units (QSG 201 / 301 / 050 / 060 / 070).

3.3.4 Vacuum ducts

As standard, a high vacuum instrument socket is used with connections for snap plugs on both sides. This is suitable for fitting into a drilled hole with a diameter of 7.1mm. High vacuum ducts are also available for DN 10 ISO-KF, DN 16 ISO-KF, DN 20mm and DN 32mm. BAL-TEC AG will be happy to work out a solution for you for other mounting requirements. Please contact your local BAL-TEC AG sales partner, or contact BAL-TEC AG Liechtenstein directly.

3.3.5 Quartz head

The QSK 060 quartz head is used as standard. Detailed clarifications will be necessary for the use of the QSG 100 together with other quartz heads. Please contact BAL-TEC AG Liechtenstein directly.

3.3.6 Quartz crystals

Quartz crystals of the QS 060 type are normally used. The basic frequency of these quartzes is 6MHz. The crystal itself is a plano-convex disk, 14mm in diameter and 0.4mm thick. Thanks to its plano-convex shape, the stimulated crystal mainly oscillates in the central area. It can therefore be clamped at the edges, which is very convenient for the cooling of the quartz.

Note: The basic frequency at the QSG 100 film thickness monitor must be re-programmed for the use of 5MHz quartz crystals. Please contact BAL-TEC AG Liechtenstein.

4. Theory and calibration

This chapter helps the user to understand the special features of quartz crystal measurement. The detection of errors and their causes will thereby be facilitated.

4.1 Theory of quartz crystal measurement

The sensor element in quartz crystal measurement is a quartz crystal that is stimulated to thickness shear vibrations by an oscillator. The oscillation slows down with increasing coating of the quartz crystal.

The coated quartz can be represented as a one-dimensional compound oscillator consisting of the quartz and the coating material. The acoustic analysis then results in the following equation for the calculation of the coating thickness.

Equation 1)

$$t_F = N_Q * \frac{D_Q}{D_F} * T_F * \frac{Z_F}{3.14 * Z_Q * \tan^{-1} \left(\frac{Z_Q}{Z_F * \tan \left(3.14 * \left(1 - \frac{T_Q}{T_F} \right) \right)} \right)}$$

Var.	Description	Units
t_F	Current coating thickness	cm
N_Q	Quartz crystal constant in the thickness-shear-oscill. mode	cm/s
D_F	Specific weight of the coating material	g/cm ³
D_Q	Specific weight of the quartz crystal	g/cm ³
T_F	Current periodic time for the coated quartz	s
T_Q	Periodic time for the quartz before the current coating	s
Z_F	Acoustic impedance of the coating material	g/cm ² /s
Z_Q	Acoustic impedance of the quartz crystal	g/cm ² /s

Equation 1 takes into account the acoustic impedance of the coating material and of the quartz crystal. For all practical applications in thin film technology, however, the following applies:

Equation 2)

$$Z_Q = Z_F = 8.8 * 10^5$$

Equation 1 can thereby be simplified to:

Equation 3)

$$t_F = N_Q * \frac{D_Q}{D_F} * (T_F - T_Q)$$

The frequency constant of the quartz crystal in the thickness shear vibration mode and the specific density of the quartz crystal are known. The periodic time of the quartz before the current coating will be measured before the start of the process. From the specific densities of the coating material selected by the machine operator and the current periodic time continually measured during the process, the film thickness and the coating rate can be continually calculated during the coating.

4.2 Specific weight of the coating material

The specific weight of the coating material has an important influence on the calculation of the coating thickness from the frequency changes registered on the sensor element using the QSG 100 film thickness monitor.

The density of the coating material is entered by the machine operator. The QSG 100 has a comprehensive library of standard coating materials at its disposal, whose specific densities are already stored. The materials will be identified and selected by means of their chemical abbreviation.

If the desired material is not present in the library, the specific density can also be edited manually via the key field.

Note: The selection of a material other than that actually used for the coating or the incorrect entry of the corresponding specific density can lead to a considerable falsification of the measurement result.

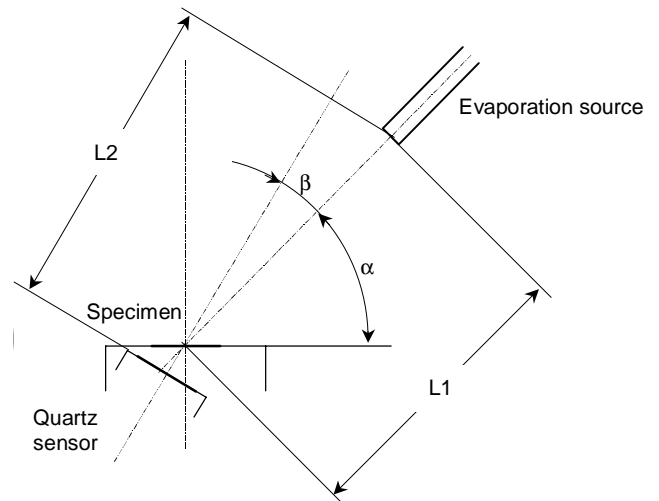
4.3 Tooling factor

The result of the measurement on the quartz crystal can only be directly compared with the result on the substrate if the quartz and the substrate are subject to the same geometrical conditions with regard to the coating source. The geometrical influences can be corrected with different working separations or different coating angles.

The tooling factor is defined as the ratio between the effective film thickness on the substrate and the measured film thickness on the quartz crystal. If the tooling factor is correctly calculated and entered into the QSG 100 film thickness

monitor, the result will correspond to the result of the measurement that is displayed on the QSG 100, the effective film thickness (with regard to the coating rate) on the substrate.

$$T = \frac{t_F}{t_Q} = \frac{\sin(\alpha) * L_2^2}{\cos(\beta) * L_1^2}$$



Var.	Description	Units
T	Tooling factor	
t_F	Effective film thickness on the substrate	cm
t_Q	Measured film thickness on the quartz crystal	cm
alpha	Angle between the source normal and the substrate surface	°
beta	Angle between the source normal and the quartz normal	°
L₁	Distance between the source and the substrate	cm
L₂	Distance between the source and the quartz	cm

Basically, the quartz head should be arranged so that the quartz crystal is subjected to geometrical conditions that are as similar as possible to the substrate (same separation, same coating angle). The tooling factor should thereby be roughly 1.

Note: When arranging the quartz head, ensure that the substrate and the quartz head do not mutually interfere with each other, for example, by shadowing. The quartz crystal should, as far as possible, therefore be arranged approximately at the same separation and under the same angle to the coating source as the substrate.

Note: Very large angles between the source normal and the quartz normal should be avoided. In some circumstances, the edge of the quartz head can shadow the quartz crystal at very flat coating angles.



Preparation to view information



Preparation to view information

NORMAL OPERATION

Operating instructions

QSG 100 film thickness monitor

Version: 0305

5. Operation

This chapter is intended for the machine operator who uses the QSG 100 film thickness monitor in normal operation.

The precondition for this activity is that the machine operator understands the chapter „Theory and calibration“, page 19.

5.1 Principles of the operation

on the rear panel of the housing. During the initialisation, the version number of the installed software will be indicated on the display.

Fig. 5-1, Main switch and initialisation



Main switch



Initialisation



Fig. 5-2, Set-up menu and Layer menu

After the initialisation, the system automatically switches to the Set-up menu. The program index can be called up with the 'Program' key for the selection of a stored, pre-defined coating sequence.

P1	Gold 4.5 nm	Setup	>
Program	Gold 4.5 nm		
Layers	1		
Quartztest	Measure 1		

P1	Gold 4.5 nm	Layer 1	>
Au	19.30	g/cm ³	
00: 00	1	15 min s	tool 1.00
0.0	4.5	nm	0.00 nm/s
Quartztest	Measure 1		

For routine applications, up to ten standard sequences can be programmed into this index. Defined programs are indicated with 'P' (Program). The parameters of these programs are fixed, and cannot be changed. Freely-programmable coating sequences are indicated with 'U' (User). In these programs, all the parameters can be freely selected. The selection of the desired program is carried out by pressing on the corresponding key-field. The active program is indicated in the header bar.

The status of the individual programs can be defined via the serial interface using a terminal program. A freely programmable coating sequence 'U' can thereby be defined as a standard program 'P'. The defined parameters will thereby

be 'frozen' and can no longer be changed. Programs can be identified with a title. You can find a detailed description of this function in the chapter „Freely programmable and fixed programs“, page 33.

Note: When the QSG 100 film thickness monitor is started up, the program that was selected the last time the unit was used will be active. Frequently used standard sequences should be defined as 'P' and variable programs as 'U'.

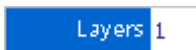
Fig. 5-3, Program index and layers

P1: Gold 4.5nm	Setup
P1: Gold 4.5nm	P6: ZinCselenide 3
P2: ITO 22nm	P7: 4Cr+5Fe
P3: 5ZnO+8Cr	P8: 9Cr2O3+8TiO
U4: User_4	U9: User_9
P5: Gold SEM 2	U0: User_10



Program index

Number of layers



The desired number of coating sequences can be selected by pressing the 'Layers' key. The setting is carried out using the arrow keys. The value set is confirmed by pressing on the Layers display field. In standard programs, the number of layers is also pre-defined and cannot be changed.

5.2 Setting the measurement parameters



The various layers and the Set-up menu can be selected using the arrow keys. The layers will first be displayed sequentially according to the selected number, and the Set-up menu will then be shown again. All parameters will be defined for the current layer that is displayed in the header bar. For pre-defined programs, all the parameters will be displayed, but cannot be changed.

5.2.1 Coating materials from the library



The QSG 100 film thickness monitor has a comprehensive library of standard coating materials at its disposal. The library is called up using the Material key. The materials are listed alphabetically by their chemical abbreviation. You can page through the library using the arrow keys. The material used for the coating of the current layers is selected by pressing on the field with the corresponding chemical abbreviation. Both the selected material and its specific density will be displayed for the respective layer in the Layer menu.

Fig. 5-4, Library and manual input of the specific weight

U9		User_9		Layer 1	
Ag	Al	Al2O3	Au	B	
C	CaF2	Cd	CdS	CdSe	
CdTe	CdO2	CeF3	Co	Cr	
Cr2O3	Cu	Fe	GaAs	▲	
Ge	Hf	HfO2	In	▼	

Material library

U9		User_9		Layer 1	
	19.30	g/cm ³			
		min s	tool	▲	
		nm		▼	

Manual entry of the density

5.2.2 Manual entry of the density of the coating material

19.30 g/cm³

In the case of coating materials that are not stored in the QSG 100 film thickness monitor library, the specific density can be entered by the machine operator. The value is set up using the arrow keys and is confirmed by pressing on the Density key. The manual entry of the density will be identified in the Material field with the comment 'USER'.

Note: The correct entry of the specific density of the coating material used has a major influence on the determination of the film thickness. Refer here to the chapter „Specific weight of the coating material“, page 20.

5.2.3 Entering the tooling factor

tool 1.00

Deviations in the geometrical arrangement of the substrate and the quartz crystal are corrected using the Tooling factor. If, for example, the quartz crystal is only coated to half the thickness of the substrate due to a greater separation from or a flatter angle of the coating source, this measured deviation can be corrected with a Tooling factor of 2.

Note: If the quartz crystal is more heavily coated than the substrate as a result of its geometrical arrangement, the correct Tooling factor will have a value of $T < 1$. If the substrate is more heavily coated than the quartz crystal, then $T > 1$.

The separation of the coating source from the substrate and from the quartz crystal must be known for the calculation of the Tooling factor. In addition, the machine operator must also know the angle between the coating direction and the substrate surface and between the coating direction and the quartz normal.

For the calculation of the Tooling factors, please read the paragraph „Tooling factor“, page 20.

Note: Wherever possible, the distances to the coating source from the quartz crystal and from the substrate should not be very different. The angle between the coating direction and the quartz normal should not be greater than 45°.

5.2.4 Desired film thickness



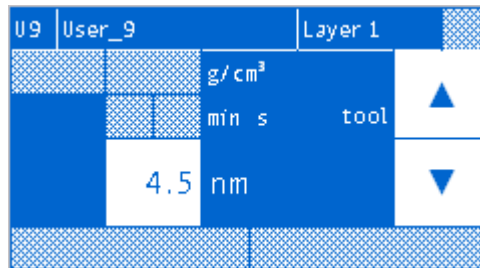
The desired film thickness for the current layer can be entered as a set-value. When the desired film thickness has been reached, the measurement is stopped. For the automatic ending of the coating process, this set-value can be used as a shutdown criterion. To do this, however, an automatic shutter or a process shutdown must be available. Please read the paragraph „Process automation stages“, page 15.

Note: If the machine operator wishes to monitor and end the coating process on the basis of visual or instinctive impressions (for example, colour changes on the substrate or similar effects), a larger film thickness than actually expected should be entered.

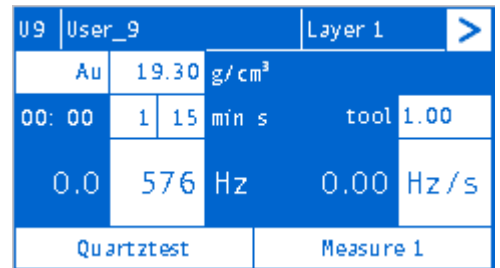


For the display of the film thickness and the coating rate, a choice can be made between the units nm and Hz or nm/s and Hz/s. The display is changed by pressing on the key-field with the Units. The set-value for the film thickness for the selected coating material of the active layer will be directly converted between nm and Hz.

Fig. 5-5, Entry of the desired film thickness and display in nm or Hz



Setting of the film thickness in nm



Display in Hz

5.2.5 Timer



During the film thickness measurement, a timer runs for each layer. This is used as a shutdown criterion. The measurement will be ended as soon as the timer expires. This set-value can be used as a shutdown criterion for the automatic ending of the coating process. To do this, however, an automatic shutter or a process shutdown must be available. Please read the paragraph „Process automation stages“, page 15.

The timer is programmed separately in minutes and seconds.

Note: The measurement will always be terminated by the shutdown criterion that is reached first. If the measurement and the process should be ended by the achievement of a desired film thickness, the running time of the timers must therefore be set to a sufficient length to allow this.

5.3 Quartz test

This paragraph describes how to check the perfect functioning of the measurement system.

With the Test function, the flawless condition of the quartz crystal integrated into the quartz head and the fault-free connection between the quartz head and the base unit are checked. The current resonant frequency is measured by pressing the 'Quartz test' key. The lower limit of the permissible resonant frequency is 5MHz (4MHz). The QSG 100 film thickness monitor indicates whether the quartz crystal is in order or not.

The Test window is closed with the 'ok' key.

If the resonant frequency is not in order, check the cable connection between the quartz head and the base unit and, if necessary, install a new quartz crystal in the quartz head.

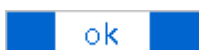
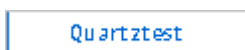
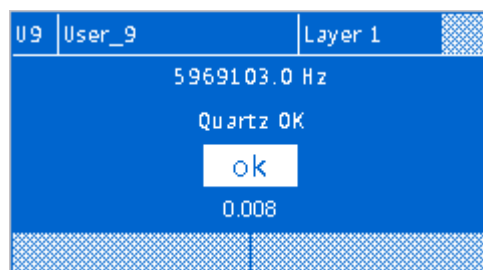
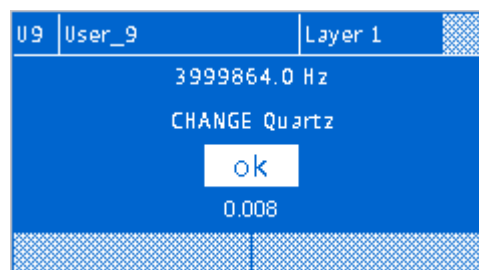


Fig. 5-6, Quartz test, Quartz OK / Not OK



Quartz frequency OK



Quartz frequency to low

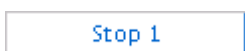
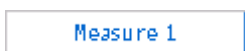
Note: The conversion factor between Hz and nm for the current settings is displayed underneath the 'ok' key.

5.4 Measurement

This paragraph describes the actual measurement cycle.

On the basis of the current parameters, the momentary coating rate will always be displayed in the Layer menu, even when the Measurement cycle has not been started. The measurement is started by pressing the 'Measure' key. From this moment on, the increase in the film thickness will be registered. The Measurement cycle can be stopped at any time using the 'Stop' key. The Measurement cycle will also be stopped on reaching the film thickness that has been defined as the set-value, or if the timer runs down. For the automatic start and stop functions, shutter and process shutdown, please read the paragraph „Process automation stages“, page 15.

For manual operation without shutters, the measurement cycle should be started first, and then the coating. At shutdown, the coating should be ended first, and then the measurement cycle.



When using a shutter, the coating process should be started with the shutter closed. With exposed quartz crystals, the rate will be displayed, even when the film thickness measurement has not yet been activated. Open the shutter when starting the measurement cycle. On reaching the desired film thickness, close the shutter, and end the measurement cycle and the coating process.

Note: *If the shutter covers only the substrate, but not the quartz crystal, the desired coating rate can be set up before coating the sample, and can be monitored with the QSG 100.*

Fig. 5-7, Measurement using the example of a program sequence with two layers

P3	5ZnO+8Cr	Setup	>
Program 5ZnO+8Cr			
Layers 2			
Quartztest		Measure 1	

Measure 1 from the Set-up or Layer 1

P3	5ZnO+8Cr	Layer 1	>
ZnO	5.61	g/cm ³	
0: 15	1	30 min s	tool 0.91
1.2	5.0	nm	0.08 nm/s
Quartztest			Stop 1

Active measurement of Layer 1

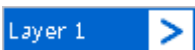
P3	5ZnO+8Cr	Layer 1	>
ZnO	5.61	g/cm ³	
1: 03	1	30 min s	tool 0.91
5.0	5.0	nm	0.00 nm/s
Quartztest		Measure 2	

Layer 1 finished, measurement 2

P3	5ZnO+8Cr	Layer 2	>
Cr	7.20	g/cm ³	
0: 31	1	00 min s	tool 1.13
6.2	8.0	nm	0.20 nm/s
Quartztest			Stop 2

Active measurement of Layer 2

Note: *The measurement of Layer 1 can be started from both the Layer 1 menu and directly from the Set-up menu.*



After a layer has been finished, the values of this layer will be displayed. The measurement of the next layer can now be started, and the settings of the next layer can be called up with the arrow key.

Fig. 5-8, Starting from different layers

P3	5ZnO+8Cr	Layer 1	>
ZnO	5.61	g/cm ³	
1: 03	1	30 min s	tool 0.91
5.0	5.0	nm	0.00 nm/s
Quartztest		Measure 2	

Measurement 2 direct from Layer 1

P3	5ZnO+8Cr	Layer 2	>
Cr	7.20	g/cm ³	
0: 00	1	00 min s	tool 1.13
0.0	8.0	nm	0.00 nm/s
Quartztest		Measure 2	

Measurement 2 from Layer 2

Note: When changing between the layers with the arrow key, layers can be jumped over, the same layer can be coated several times or any number of layer sequences can be processed.

5.5 Replacement of the quartz crystal

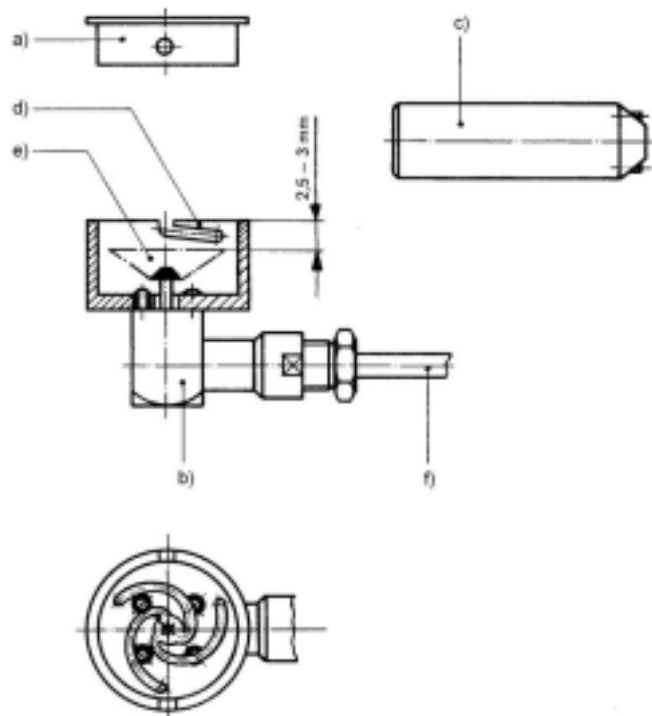
This paragraph describes the correct set up of a standard QS 060 quartz crystal in the QSK 060 quartz head.

With each coating, the mass of the quartz crystal increases. The natural frequency of the quartz also falls with rising mass. As soon as the natural frequency of the quartz crystal falls below a critical value, it must be replaced.

The shutter cover of the quartz head is removed from the quartz head housing. To do this, the bayonet coupling is opened using the special tool. The used quartz crystal is removed using tweezers, and the setting of the contact bracket is checked. The separation to the upper edge of the quartz head housing should be between 2.5 mm and 3.0 mm. The new quartz crystal is held at the edge with the tweezers, and is laid into the quartz head with the electrodes facing downwards. Finally, the shutter cover is positioned and secured with the bayonet coupling.

Fig. 5-9, Changing the quartz crystal

- a Cover
- b Housing
- c Tool
- d Bajonet coupling
- e Contact bracket
- f Connecting cable



6. Data and Program

This chapter is intended for the advanced machine operator who is very familiar with the routine normal operation and with the function of the unit.



Caution: *Via the serial interface, you have access to the software of the QSG 100 film thickness monitor. Actions and commands that differ from those described in this chapter could lead to errors or faults on the unit.*

6.1 Data transfer

Measurement data and parameters can be exported to an external computer via the serial interface. With the use of suitable Terminal programs, the settings on the QSG 100 can be changed.

The external computer must be connected to the serial interface of the QSG 100 via the interface cable and the Terminal program must be started. For PCs, a Terminal program is available that is specially configured for operation with the QSG 100. When using Macs (Mackintosh computers), the Terminal program to be used must be correctly configured.

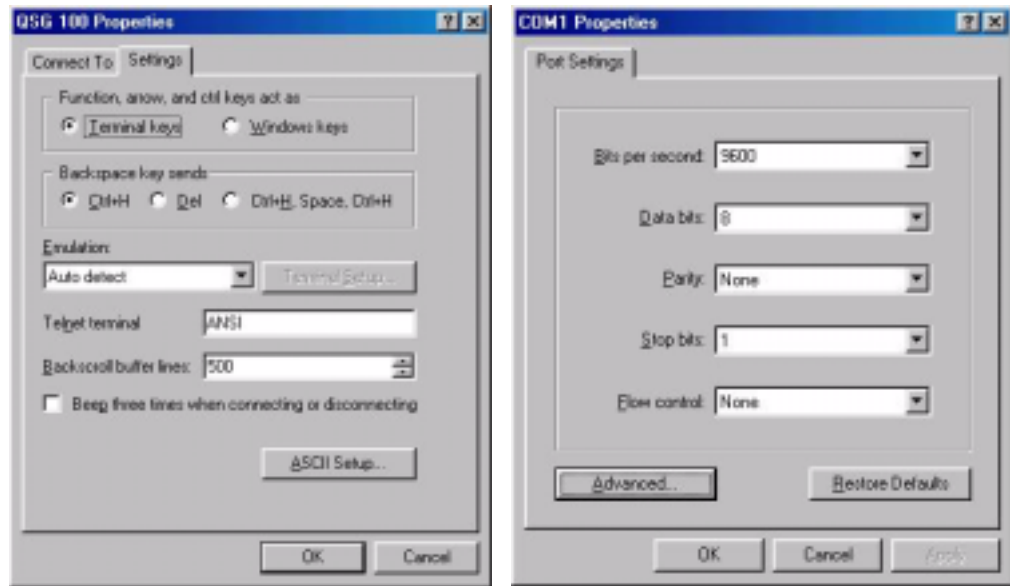
Fig. 6-1, PC-Terminal program



Started QSG 100 - Terminal program TERM.EXE with Help text

Note: *The Help text for the available standard functions can be called up with the Function key 'F1'. The Terminal program is ended with 'F10'.*

Fig. 6-2, Configuration of the connection to the serial interface



Configuration of the Terminals using the Mac as an example

6.2 Exporting data

This paragraph describes the output of parameter lists and measurement results to an external file and the processing of the data with a data processing program, for example MS-Excel.

With the QSG 100 Terminal program, the commands can be carried out using the function keys. 'F2' writes all the current settings of all programs ('U' and 'P') into the file qsg100_a.txt. 'F3' writes all the settings of the active programs ('U' or 'P') into the file qsg100_x.txt, whereby x stands for the program number.

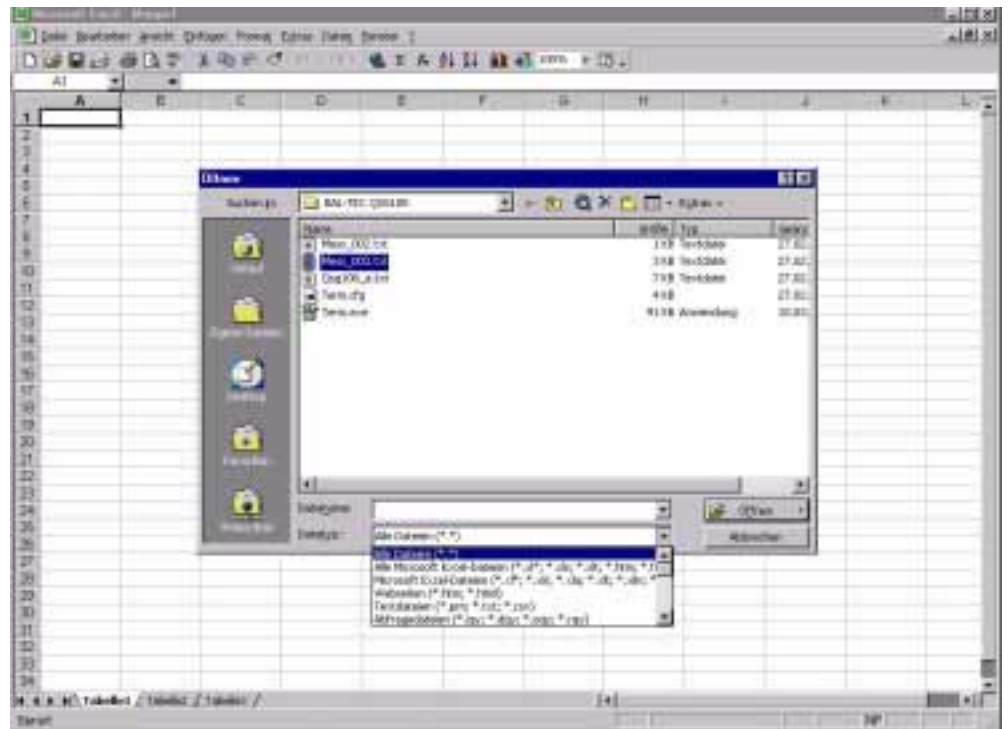
'F5' starts the data logger. The settings of the current programs and the rate and the progress of the film thicknesses of all layers that will be carried out will be stored in mess_xxx.txt. Here, xxx is a control variable that runs from 000 to 999. The data logger is ended with 'F6' and the output file is closed.

Note: The files will be stored in the directory (folder) from which the TERM.EXE was started.

With other terminal programs, a command text must be entered instead of using the function keys and be confirmed with 'Enter'.

- F2 - @Save settings
- F3 - @Save program
- F5 - @Start measure
- F6 - @Stop measure

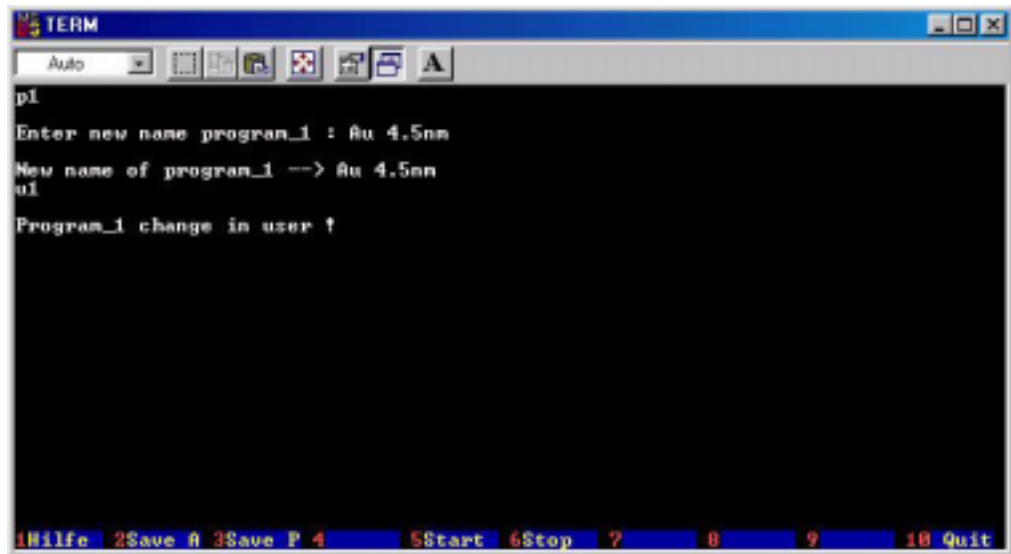
Fig. 6-3, Open the protocol file in Excel



Die Textdatei muss für die Excel Anwendung in Windows konvertiert werden.

6.3 Freely programmable and fixed programs

With the text input px and the subsequent confirmation with 'Enter', a fixed program Px will be defined from the freely programmable program Ux. Here, x stands for the program number of the desired program. A designation can be entered for the program. With the text input ux and subsequent confirmation with 'Enter', a fixed program Px will be released once again as a freely programmable program Ux. The set parameters remain unchanged by this.





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SPECIAL OPERATION

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7. Initial start-up

This chapter is intended for the technician who installs the QSG 100 film thickness monitor and carries out the initial start-up.

The precondition for this work is that the technician has read and understood the chapter „Structure and Function“, page 12.

Note: The relevant industry-specific provisions and accident prevention regulations for the respective installation location must also be complied with.

7.1 Preparatory work

The installation location and the unit must be made ready before the start of the installation.

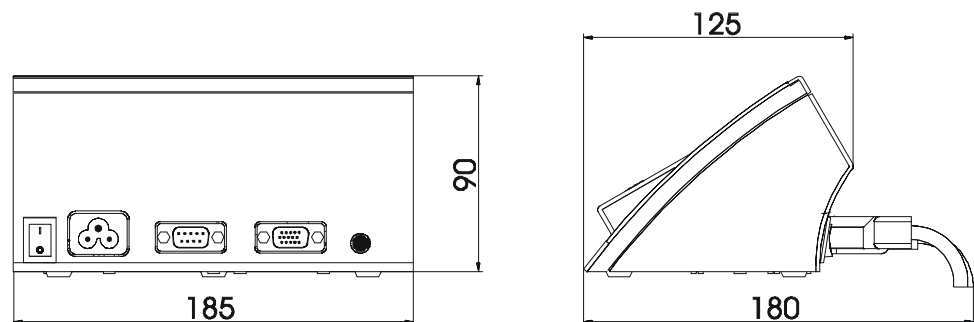
When unpacking the QSG 100 film thickness monitor, pay attention to the transportation symbols and notes on the packaging. Be particularly careful that the unit is not dropped. Store the original packaging in case the unit has to be returned for repair work. Immediately after unpacking, check the items delivered for any damage and check the parts received against the despatch papers. Immediately report any differences and any damage to both the company making the delivery and your local BAL-TEC sales partner.



Caution: *Danger of damage from rough handling. The unit contains sensitive parts.*

The QSG 100 film thickness monitor should be set up on a firm, level base, ideally at table height, ensuring that enough space is allowed behind the unit for the outgoing cables. Also ensure that the Touch-Screen is easily accessible for operation. The contrast of the display should not be impaired by unfavourable lighting conditions.

Abb. 7-1, Space requirement



7.2 Installation

The unit is delivered ready for installation. The installation itself merely consists of the connection of the electrical supply, the measurement cable and the optional interface connections.

Measurement cable

Mount a quartz crystal in the quartz head. To do this, please read the chapter „Replacement of the quartz crystal“, page 30. Mount the quartz head with the installed quartz crystal, vacuum duct and connecting cable according to your system layout. For assistance in doing this, please read the chapter „Accessories and options“, page 17.

Interface

As an option, connect the contacts of the connecting cable of the Input/Output module to your external units according to the layout of your process automation stage. Please refer to the chapter „Process automation stages“, page 15. As a further option, connect the interface cable to the serial interfaces on your PC and on the QSG 100.



Caution: *The mains switch must be at the "Off" position before starting the installation.*

Power connection

The QSG 100 film thickness monitor is equipped for connection to 115V or 230V and 50Hz or 60Hz mains supplies. No internal switchover is necessary. Simply plug in the mains plug, and the unit is now ready for operation.

8. Clearing faults

This chapter is intended for the technician who services and maintains the QSG 100 film thickness monitor.

8.1 Maintenance

The QSG 100 film thickness monitor requires no maintenance.

The only maintenance work for the complete system consists of the changing of the quartz crystals if the latter becomes too heavily coated over time. Refer here to the chapter „Replacement of the quartz crystal“, page 30.

8.2 Faults, their causes and their correction

Fault	Cause	Correction
The display remains dark after switching on the main switch.	The mains cable of the QSG 100 is not connected.	Connect the mains cable to the unit and to the mains supply.
Data transfer does not function via the serial interface.	Interface cable not connected.	Connect the interface cable to the unit and the external computer.
Data transfer does not function via the serial interface.	Terminal on the external PC is incorrectly configured.	Check and correct the configuration.
Communication does not function via the digital I/O.	Logic connection cable not connected.	Connect and check the logic connection cable.

8.3 Error messages

Error message	Correction
NO Quartz	Lay a quartz crystal in the quartz holder and re-make all the connections between the QSG 100 and the quartz head.
CHANGE Quartz	Lay a new quartz crystal in the quartz holder or use a shorter connecting cable or reduce the number of connections between the QSG 100 and quartz holder.
PREDEFINED Value	The parameters of fixed programs cannot be changed. Define the desired fixed program as a freely programmable program via the serial interface.
Measuring TERMINATED	The measurement sequence has been terminated by a manual intervention. Check the shut-off criteria and the coating parameters. Repeat the coating.

8.4 Putting out of service and disposal

The QSG 100 film thickness monitor can be placed in intermediate storage without any problems. It contains no elements that could damage the environment.

The unit should be put out of service if the unit will probably not be used for a period of three months or longer.

If you wish to temporarily store the QSG 100 without using it for a longer period, you should disconnect the unit from the electrical mains supply. The connections to the serial interface, the Input/Output module and the measurement cable should also be disconnected.

Note: In case of storage over longer periods, ensure that the electronics contains a buffer battery for the storage of the data, whose capacity will, however, only be sufficient for approximately two years.

Over time, some parts of the system will have to be disposed of. Separate the materials as far as possible, and dispose of them in an environmentally friendly manner. Note that the electronics should not be disposed of with normal waste, but must be sent to specialist companies for disposal.

Note: In case of doubt, please contact the manufacturer, who will be pleased to assist you with the disposal.



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Preparation to view information

APPENDIX

Operating manual

QSG 100 film thickness monitor

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9. Appendix

This chapter is intended for all users of the QSG 100 film thickness monitor.

9.1 Technical data

Weights	
Net weight of the basic unit	1640g
Total weight of the packaged system	2500g
Dimensions	
Width	185mm
Height	90mm
Depth	125mm
Depth with plugs and outgoing cables	180mm
Elektrical Data	
Voltage	90-260VAC
Frequency	50Hz / 60Hz
Power consumption	10VA
Main connection	in accordance with local regulations
Ambient conditions	
Ambient temperature	10-40°C
Air humidity	30-80% (non condensing)

9.2 Accessories and spare parts

	Installation kits	
	QSG 100 kit for the MED 020	LZ 03428 VN
	QSG 100 kit for the SCD 050	LZ 03429 VN
	QSG 100 kit for the SCD 005 / CED 030	LZ 03533 VN
	Accessories	
	Basic unit with CH mains cable	LE 03349 VN
	EU mains cable	LE 03534 KN
	US mains cable	LE 03535 KN
	Cable for cut-off (MED 020 / SCD 050)	LZ 03447 VN
<i>Connecting cable</i>	Connecting cable 25cm, snap plugs at both ends (s/s)	BU 005 122 -T
	Connecting cable 30cm, snap plugs at both ends (s/s)	BU 005 226 -T
	Connecting cable 40cm, snap plugs at both ends (s/s)	BU 005 273 -T
	Connecting cable 50cm, snap plugs at both ends (s/s)	LZ 03445 VN
	Connecting cable 75cm, snap plugs at both ends (s/a)	LZ 03446 VN
	Connecting cable 80cm, snap plugs at both ends (s/s)	BU 014 931 -T
<i>G-Receptacle</i>	G-Receptacle for housing, snap connections at both ends	LE 03449 KN
<i>Vacuum duct</i>	Measurement duct, DN7mm, snap connections at both ends	LE 00571 LN
	Measurement duct, DN20mm, snap connections at both ends	BU 007 304 -T
	Measurement duct, DN10KF, snap connections at both ends	BU 008 526 -T
	Measurement duct, DN16KF, snap connections at both ends	BU 008 529 -T
<i>Extension QSK 060</i>	Extension cable 12cm, coupling, angled plug (a)	BU 005 138 -T
	Extension cable 12cm, coupling, straight plug (s)	BU 008 806 -T
	Extension cable 25cm, coupling, straight plug (s)	BU 005 249 -T
<i>Quartz head QSK 060</i>	Quartz head QSK 060 with 15cm cable, angled plug (a)	LZ 03441 VN
	Quartz head QSK 060 with 25cm cable, angled plug (a)	BU 007 217 -T
	Quartz head QSK 060 with 40cm cable, straight plug (s)	LZ 03440 VN
<i>Quartz head holder</i>	Quartz head holder, height-adjustable(for MED)	LZ 03442 VN
	Quartz head holder DN22 (for SCD 050)	LZ 03443 VN
	Quartz head holder (for SCD 005)	LZ 03444 VN
	Quartz head holder, angled (for MED)	BU 017 985 -T
	Consumables	
	Quartz crystals QS 060	LZ 02321 KN
	Spare parts	
	Snap plug straight (s)	LE 00730 LN
	Snap plug angled (a)	LE 03450 KN
	Snap connection	B 8010 086 85

9.3 Technical coating data

This chapter contains the important vacuum evaporation and atomisation data for the most common coating materials.

Substance	Weight at 20°C [g/cm ³]	Melting point [°C]	Boiling point [°C]	Sputtering Rel. rate DC (Al=1)	E-Gun	Res. Evap. source
Ag	10.49	961	2212	DC 2.8	good	W, Mo
Al	2.70	660	2467	DC 1.0	good	(W)
Al ₂ O ₃	3.97	2046	2980	RFR	good	
Au	19.30	1063	2966	DC 2.3	good	W, (Mo)
B	2.34	2300	2550	RF	possible	
C	2.25	3500	4827	DC	good	
CaF ₂	3.18	1360	2500			W, Mo, Ta
Cd	8.64	321	765			W, Mo, Ta
CdS	4.83	1750	1405			W, Mo, Ta
CdSe	5.81	1350			possible	Mo, Ta
CdTe	5.85	1042				Mo, Ta
CeF ₃	6.18	1460	1987		possible	Mo, Ta
CdO ₂	7.13	2150			good	W
Co	8.90	1495	2870	DC	good	(W)
Cr	7.20	1857	2672	DC 1.1	good	W
Cr ₂ O ₃	5.21	2345	4000	RFR	possible	(W)
Cu	8.96	1083	2567	DC 1.9	good	W
Fe	7.86	1535	2750	DC	good	(W)
GaAs	5.31	1238				W
Ge	5.32	937	2830	DC 0.9	good	(W)
Hf	13.20	2150	5400	DC	possible	
HfO ₂	9.63	2812	5400	RFR	possible	
In	7.31	157	2000	DC 0.5	good	W, Mo
In ₂ O ₃	7.18	2200		RF	possible	Pt, (W)
In ₂ O ₃ SnO ₂ (ITO)	7.1	2000		RF	good	(W)
Ir	22.42	2410	4527	DC	possible	
LaF ₃	5.94	1495	2400			Mo, Ta
La ₂ O ₃	6.51	2260	4200	RFR	good	(W, Ta)
LiF	2.64	842	1676			Mo, Ta

Substance	Weight at 20°C [g/cm ³]	Melting point [°C]	Boiling point [°C]	Sputtering Rel. rate DC (Al=1)	E-Gun	Res. Evap. Source
Mg	1.74	639	1090	DC	possible	W, Mo, Ta
MgF ₂	3.00	1266	2239		good	Mo, Ta
MgO	3.58	2640	3600	RFR	good	(W)
Mn	7.43	1245	1962	DC	good	(W), Mo, Ta
MnS	3.99	1615			possible	(W, Mo)
Mo	10.20	2617	4612	DC 0.8	good	
Na ₃ AlF ₆	2.90	1000				Mo, Ta
Nb	8.57	2468	4927	DC 0.5	good	(W)
Nb ₂ O ₅	4.47	1512		RFR	good	(W)
NdF ₃	6.51	1377	2400			Mo, Ta
Nd ₂ O ₃	7.24	2240		RFR	good	(W)
Ni	8.91	1453	2732	DC 0.6	good	(W)
Pb	11.34	327	1740	DC	possible	W, Mo, Ta
Pd	12.02	1552	2927	DC 1.9	good	(W)
Pt	21.45	1772	3827	DC 1.4	good	(W)
Pt/C	19.45				good	
Re	21.04	3180	5627	DC	good	
Rh	12.41	1966	3727	DC	good	
Sb	6.68	630	1750	DC		W, Mo, Ta
Se	4.79	217	685			(W, Mo, Ta)
Si	2.33	1410	2355	DC	good	(W)
SiO	2.13	1705	1880		possible	Mo, Ta
SiO ₂	2.20	1713	2230	RF	good	
Sn	7.30	232	2270	DC	possible	W, Ta
Ta	16.60	2996	5425	DC 0.5	good	
Ta ₂ O ₅	8.20	1880		RFR	good	(W)
Te	6.24	450	990	DC		W, Mo, Ta
ThF ₄	6.32	1100	1680		good	Mo, Ta
Ti	4.50	1660	3287	DC 0.5	good	(W)
TiO ₂	4.26	1775	2700	RFR	good	(W)
V	5.96	1890	3380	DC	good	(W, Mo)
W	19.30	3410	5660	DC 0.5	good	
Y	4.47	1523	3337		good	W
Y ₂ O ₃	5.01	2410	4300	RFR	possible	
Zn	7.14	420	907	DC		W, Mo, Ta

Substance	Weight at 20°C [g/cm ³]	Melting point [°C]	Boiling point [°C]	Sputtering Rel. rate DC (Al=1)	E-Gun	Res. Evap. Source
ZnO	5.61	1975		RFR	possible	
ZnS	4.09		1665		possible	Mo, Ta
ZnSe	5.26					W, Mo, Ta
Zr	6.51	1852	4377	DC 0.5	good	(W)
ZrO ₂	5.60	2700	4300	RFR	good	(W)

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