

## Realtime Measurement of crystal growth

### Description

#### 5 Field of the Invention

The disclosure is related to Realtime measurement of crystal growth and such a system.

### Background and Summary of the invention

10 In particular in electronics, wafers (also called a slice or substrate) play a major role as a basis for semiconductors for any range of use, such as microelectronics, solar wafers, processor dies and so on. But also in other technical fields crystals are grown by means of different growth methods. One of the most known and widely used processes is the Czochralski method. When growing crystals some of the parameters to be optimized may include to obtain a high purity, a low defect rate, especially for monocrystals, and/or to increase cost-effectiveness of the process chain.

15 A major issue with modern crystal growth systems refers to the typically extreme process conditions. For example in the case of silicon crystals a specific atmosphere is provided to the seed chamber and process temperatures can easily rise to more than 2000 °C. Typically, such a chamber is sealed and surrounded by a special housing and insulation making it hard to obtain any information from inside the hot chamber. Additionally, or alternatively, any such measurement has a high potential to disturb the process, because materials involved may outgas, react with the process gasses, or may involve electrical or magnetic fields that change, e.g., crystal growth behaviour. Typical measurement  
20 carriers such as electrical current/voltage or optical signals cannot propagate through the housing or through the atmosphere inside the housing or are altered such that the obtained information is unreadable. Next to this, the extreme conditions make it impossible to connect to or arrange any electronics to or inside the hot chamber housing.

At present, at least for the reasons as mentioned before, crystal growth processes are started and eventually left alone without a possibility of observation until a defined end, where only after opening of the chamber housing it is  
25 possible to see whether crystal growth went as planned and in the quality or speed as intended. In other words, at present no signals or insufficient information is obtained from a crystal growth system, resulting in an often to be seen outcome that the whole process, including expensive materials and process time and huge amounts of energy consumed, is eventually wasted.

Although there is a high demand for any working measurement system, so far there hasn't been found any  
30 solution that could be able to provide the required or desired information from the crystal growth process. If such information was available, for example deviations from the intended process state could be observed and process conditions could be changed accordingly and/or the process could be terminated without the need to wait until the very end of the process schedule. In particular, information obtained from a running process could also be used in order to feed back information to the process control, such as process temperature, chamber pressure, gas composition and so  
35 on. As a result, an improved growth rate and/or a higher level of crystal purity could be obtained, or simply process time for a process "going wild" could be spared.

Therefore, and to summarize, it is an object of the invention to provide improvements to the state of the art regarding information to be obtained from a crystal growth system while the same is operative.

In an aspect of the object of the invention, a measurement system is to be designed capable of performing such a method. In another aspect of the invention, related or unrelated to the other aspects of the object of the invention, the sensitivity or measurement resolution of such a measurement system is significantly to be improved.

5 The object of the invention is achieved by subject matter of the independent claims. Preferred embodiments of the invention are subject of dependent claims.

#### First embodiments

The method according to the invention for obtaining information in realtime from a crystal growth process or crystal growth system in a high temperature environment, such as for growing a silicon carbide crystal, comprises the  
10 following steps. Arranging a crystal or crystal seed in a hot zone of said crystal growth system, that corresponds to preparing the hot zone for later crystal growth. After preparation of the hot zone said hot zone is hermetically sealed, that is, sealed against the environment, because there may still be a gas flow into or out of the hot zone. In fact, in some processes it may be preferred that a gas flow through the hot zone is established or maintained. The hot zone may be arranged in a hot zone housing or hot chamber. Next, in the hot zone during crystal growth a significantly high  
15 temperature is imposed on the crystal and/or, inside the hot chamber. For example, the hot zone persists whenever a temperature of more than e.g. 1000 °C is present in the hot chamber. In the method according to the invention a probing signal is provided by means of an active element such as a signal generator. Said probing signal is directed onto a first surface of said crystal inside said hot zone. The signal response is analysed and at least one process status or process development information is retrieved therefrom. The active element or signal generator is arranged outside said hot zone  
20 in order to prevent melt up or destruction of or damage to said signal generator.

The signal generator preferably extends into the hot zone from an outside. Due to this, parts of the signal generator, e.g. containing electronics, can be arranged outside the hot zone in order to protect them from high temperature. As the case may be, the method may comprise at least one of the additional steps of coupling a coupling rod to said signal generator, transporting said probing signal by means of said coupling rod into said hot zone, and/or  
25 positioning said coupling rod such that it is in direct contact with said first surface of said crystal. In other words, a coupling rod may be used in order to transport the probing signal into the hot zone. The signal from the signal generator is preferably coupled with high transmittance to the coupling rod, so that low signal losses result. The coupling rod may be part of the signal generator or may be a separate part, and could be glued to the signal generator.

Further, there may be comprised the additional step of arranging the signal generator spaced apart from said  
30 first surface of said crystal, in particular outside of said hot zone. Said probing signal may be directly coupled from the signal generator into said coupling rod and transported into the hot zone and onto said crystal by means of said coupling rod. Alternatively or additionally said probing signal may be coupled, for example directly coupled, into the first surface of said crystal. Directly coupling means that no further item is arranged in between, in this example, the coupling rod and the first surface of said crystal. For example, as the case may be, an adhesive or another coupling fluid may be arranged  
35 between the coupling rod and the first surface and/or to the outer side of the coupling rod and the signal generator, however the thickness of the coupling fluid or adhesive being very small against the length of the coupling rod. For example, the thickness of the coupling fluid or adhesive may be as thin as technically possible, or may be 10 µm or less, or may be 25 µm or less, or may be 50 µm or less.

The method may further be comprising an ultrasound transducer as the active element. The method therefore comprises arranging an ultrasound transducer at an outside end of said coupling rod. In other words, the signal generator may comprise an ultrasound transducer at an outside end of the coupling rod, where the coupling rod extends from said ultrasound transducer into said hot zone or hot chamber. Said probing signal may be generated by means of  
5 at least one ultrasound transducer arranged outside the hot zone.

The crystal may initially be provided as a seed crystal. It can be composed or is to be composed of silicon carbide during the crystal growth process. The crystal may be a monocrystal or monocrystalline crystal.

Crystal growth can be performed at high temperatures and in harsh environments like necessary for a PECVD (plasma enhanced chemical vapor deposition) process, a hot temperature HTCVD, in sputtering deposition, epitaxial  
10 growth processes, and other crystal growth processes. Besides high temperatures, layout deposition processes are most typically performed in chemically and/or electrically reactive environments, where conventional optical or electrical measurements are difficult to operate, to say the least. But additionally, immersion of electrical components in high-temperature process zones could pollute the system due to, e.g., thermionic emission, reactive or ion sputtering.

It is most preferred that the method is performed as a non-disturbing measurement. In order to not disturb the  
15 crystal growth process, materials used are preferably selected to not emit any particles, because in such high-temperature environment lots of materials tend to outgas surface material. Further, the measurement setup is selected to disturb electrical or mechanical field structure in and around the hot chamber only in a low extend or not at all. Finally, whenever a connection from the inside of the hot chamber to the outside is to be introduced, this connection opening is preferably sealed to a high degree. The method may further be including heating up the hot zone before start of crystal  
20 growth. The hot zone may preferably be heated on a high temperature of 1.550 K or more, preferably 1.700 K or more, further preferably 1.900 K or more, 2.100 K or more, 2.300 K or more, or 2.450 K or more, and/or 3.000 K or less, or 2.750 K or less, or 2.500 K or less, or 2.200 K or less.

The process development information can be retrieved out of process status information. In other words, a process status information can for example be measured and a process development information may be retrieved, for  
25 example, from a comparison of several process status information data that are separated in time. Process development information may include at least one of a crystallization front determination or a crystal growth rate. Process status information may include at least one of a number or distribution of defects in the crystal or, as the case may be, a crystal thickness.

In the method, a probe signal that is returned may be received, for example, from a second surface of the  
30 crystal. For example, the signal generator may be designed such, that it is capable of transmitting the probing signal and as well of receiving the returned probe signal. A time-of-flight measurement may be performed of the probing signal. Using said probing signal may comprise imposing waves, for example ultrasound waves, on said first surface of said crystal. For this the probing signal may be generated by the active element. By using a transducer as the active element, good results have been obtained. In general, it is advantageous to couple one or more waves into the rod. There are  
35 other ways to generate and/or couple waves into the rod than with ultrasound waves. In another example, a laser is used to heat up the upper surface of the rod to generate thermal shockwaves, which in turn may induce waves into the rod. The skilled artisan will understand that the measurement principle is sufficiently described by coupling waves into the rod without, in a first place, defining the source of the waves, that may be adapted to the use or, as the case may be, when

new sources as wave generator are found they may be implemented in the invention without leaving the scope of the present invention and/or claims.

While the hot zone is hot or heated, said coupling rod, signal generator and/or the entrance channel may be cooled by means of a cooling device. In other words, the measurement device, and/or, signal generator may be subject to a worse environmental condition as what it would survive without said cooling device, where the cooling device provides for a sufficient temperature gap. For example, said temperature gap may be established in between the hot zone and the outer end of the coupling rod. Additionally or alternatively said signal generator may be cooled, e.g. by immersion into a cooling channel.

In one embodiment, the signal generator may be arranged such that it is arranged next to a cooling channel which is adapted to sufficiently shield the signal generator from heat (e.g. from radiation heat) and/or adapted to sufficiently cool down the signal generator.

Further, a temperature profile over the coupling rod, over the signal generator and/or over the entrance channel, may be determined or imposed. For example, the cooling device may be designed in such a way, that the temperature gradient is provided along the longitudinal axis in the extension of the cooling rod so that a temperature profile is imposed on the coupling rod. Therefore, the coupling rod may be significantly colder at its outer end as compared to the hot zone end of the coupling rod. A temperature effect on the propagation speed of said probing signal or of said reflected probe signal may additionally be estimated or corrected.

In accordance with the invention is the use of the method as described above during the making of a silicon carbide monocrystal.

#### Second embodiments

The present specification also provides for a realtime measurement system for obtaining information in realtime from a crystal growth process or crystal growth system in a high temperature environment, such as for growing a silicon carbide crystal, comprising a hermetically sealable or sealed hot zone for arranging a crystal or crystal seed in said hot zone of said crystal growth system, a signal generator outside said hot zone for providing a probing signal to direct said probing signal onto a first surface of said crystal inside said hot zone, and analyzation means for retrieving at least one process status or process development information. The analyzation means can be the same as the signal generator. In other words, the signal generator may be designed to produce a signal and also to detect a signal and even may be to evaluate the signal. Analyzation means may also be provided spaced apart from the signal generator, where a connection line may be provided in order to connect the signal generator with the analyzation means. For example, the analyzation means may also provide computing means.

The realtime measurement system may further be comprising a coupling rod for transporting said probing signal onto said first surface of said crystal. Said probing signal may preferably be directly coupled from the signal generator into said coupling rod. Said signal generator may further be arranged spaced apart from said first surface of said crystal, which might even preferably mean arranged outside of said hot zone.

Advantageously, the signal generator further may be composed of or comprise one or more ultrasound transducer(s) arranged at an outside end of said coupling rod, for example glued to or positioned (directly) next to. Such an ultrasound transducer may preferably be adapted for generating said probing signal, which is, in this case, an

ultrasound probing signal. In a further development, the ultrasound transducer may be designed for directly coupling said probing signal into said coupling rod. Directly coupling means a gap-free coupling and/or coupling with high transmittance. Further, the signal generator may be adapted to send and receive an ultrasound signal, whereas it may be the case that mode of transmission is simplex, that means, either send or receive, but not send and receive at the same time. The mode of transmission may also be duplex, that means, send and receive at the same time. In addition, the signal generator may comprise one means (transducer) for sending the signal and one other means (other transducer) for receiving the signal. Alternatively or cumulative the ultrasound transducer may be designed as a transceiver. The ultrasound transducer may be arranged directly at said outside end of said coupling rod, so that ultrasound waves generated by the ultrasound transducer can be coupled directly into the coupling rod and said signal response couples directly into the ultrasound transducer. The signal generator may also comprise a ceramic, such as a ceramic piezoelectric transducer. Additionally or alternatively the ultrasound transducer may be made as a foil. Preferably, the foil may comprise a thickness of 150  $\mu\text{m}$  or less, more preferably 100  $\mu\text{m}$  or less, or even 50  $\mu\text{m}$  or less. Depending on the measurement conditions, the foil may also comprise a thickness of 30  $\mu\text{m}$  or less, or even 15  $\mu\text{m}$  or less. The ultrasound transducer may comprise PVDF (polyvinylidene fluoride). The PVDF may preferably be comprised in the form of said foil. Such a foil may be arranged at the outer end of the coupling rod.

The analyzation means may be adapted to analyse a signal response, such as one or more ultrasound waves.

The realtime measurement system may also be combined with any features as described also with regards to the other embodiments, including the first embodiment above and following embodiments below.

### Third embodiments

In another aspect of the present specification a sensor arrangement for a hot furnace such as a crystal growth system is shown. Such a sensor arrangement may particularly be designed for a realtime measurement system, such as described above, or for performing a method for obtaining information in realtime from a crystal growth process or crystal growth system in a high temperature environment, such as described above. The sensor arrangement comprises a hot furnace entrance channel that connects from an outside into said furnace and comprising an interior section that is arranged inside said furnace, wherein the interior section extends for example from an outer furnace wall until an insulation layer around a hot zone housing. It further comprises a measurement device arranged in said interior section of said entrance channel. The measurement device is preferably designed to measure data from an inside of a hot zone, such as from a crystal arranged in said hot zone. The sensor arrangement further comprises a cooling device that is at least partly arranged in said entrance channel to provide cooling for said measurement device.

The sensor arrangement may further comprise a hot zone housing inside said hot furnace for housing said hot zone (or hot chamber). Said hot zone housing may further show an insulation layer on the outside of said hot zone housing.

Said entrance channel may comprise a hot zone outlet in said interior section for providing a through connection into said zone. the hot zone outlet may be arranged at a lower end of the entrance channel. The hot zone outlet may be designed as an opening, through hole or the like.

Said measurement device may extend from said entrance channel through said hot zone outlet and into said hot zone. Alternatively or cumulatively, a coupling rod may be comprised arranged at least partly in said hot zone outlet.

Preferably, a passage seal is comprised at a hot zone end of the entrance channel or at said hot zone outlet for sealing said hot zone outlet. In other words, the passage seal may be provided in order to seal the coupling rod, the signal generator and/or the transducer. Sealing is advantageously provided with regards to heat that is prevented from entering the hot zone in direction of the entrance channel, and/or with respect to the cooling fluid or any other fluid that is prevented from entering the hot zone by means of the passage seal.

The coupling rod may comprise or consist of, or may comprise a coating comprising or consisting of at least one of glass, ceramic, metal, silicon carbide, glassy carbon, Tungsten, Tantalum or fused silica quartz. Further, the coupling rod is preferably designed charge invariant.

The measurement device preferably comprises a piezoelectric transducer, for example a transceiver. The measurement device, that may be, for example, composed by the piezoelectric transducer, may advantageously comprise a ceramic, and/or PVDF, preferably in the form of a foil.

The measurement device may be arranged at said hot zone end of the furnace entrance channel. Alternatively or cumulatively the entrance channel may be arranged vertically. A vertical arrangement of the entrance channel has the advantage, that gravity alone aligns the entrance channel, and mass forces are imposed in the longitudinal extension direction of the entrance channel. The entrance channel may be arranged at an upper side of the hot furnace.

The entrance channel may comprise a channel housing, e.g. tube-shaped, like a metal tube. The channel housing is designed for housing the cooling device, any cabling from or to the measurement device, the measurement device, and may also be designed for protecting the beforementioned devices from the outside. The channel housing may further be designed to provide a good thermal conductivity, that improves cooling of the signal generator and/or measurement device. The entrance channel may also comprise a tube-shaped section.

Said measurement device may be fastened to said channel housing by means of fixation means. By way of example, said measurement device may be glued to said channel housing, whereby the adhesive material may also serve as a sealing measure.

Said cooling device may comprise at least one cooling channel arranged in said entrance channel for providing a cooling fluid to said measurement device. Such a cooling channel may be part of said channel housing, for example, the channel housing can comprise a double wall housing, where the cooling fluid is provided in between two outer walls. In other words, the channel housing comprises an inner wall and an outer wall, where an intermediate space is provided in between the inner and outer wall. Further by way of example, a first half circle of the round channel housing (e.g. tube-shaped) may be designed for use for the influx channel of a cooling fluid, and a second half circle of this channel housing is used for the outflux channel. Some separation wall may be provided in between the two half circles of the round channel housing.

Said hot zone may be designed to be heated during operation to an operation temperature of at least 1.500 K or more, preferably 1.750 K or more, and further preferably 2.000 K or more or even 2.150 K or more.

During operation of said hot furnace a temperature gradient may be maintained or adjusted, for example in between said hot zone and said measurement device. In other words, the distance between the hot zone and the measurement device may serve as a cooling distance, where the measurement device, when situated sufficiently far away from said hot zone may be in a region that is cool enough, so that any electronics of the measurement device may survive. The position of installation of the measurement device is also influenced by working principles of said cooling

device. Said temperature gradient is preferably a continuous temperature gradient. But said temperature gradient may also depend on materials and material gaps.

The sensor arrangement may be designed to be used for a process like PECVD, HTCVD, or, as the case may be, for a method for obtaining information in realtime from a crystal growth process or crystal growth system in a high temperature environment as described above, or for a Realtime measurement system for obtaining information in realtime from a crystal growth process or crystal growth system in a high temperature environment.

#### Fourth embodiments

Further in this specification a measurement device supporting unit is described for use with a hot furnace such as a crystal growth system. For example, such a measurement device supporting unit may be used for a realtime measurement system as described above, or for a method for obtaining information in realtime from a crystal growth process or crystal growth system. Such a supporting unit comprises a hot furnace entrance channel that extends from an outside at least until a hot zone housing inside the furnace, for example until an insulation around said hot zone housing. Further, it comprises a measurement device, for example arranged in said entrance channel, and a fixation arrangement spaced apart from the hot zone, wherein the fixation arrangement is designed to carry said measurement device and/or said hot furnace entrance channel. For example, the fixation arrangement is realised as a clamp arrangement. The supporting unit further comprises a top portion that is affixed to an upper support element. The upper support element could be the roof or ceiling of the room, where the furnace (crystal growth system) is situated, or any structure suitable to carry, in turn, the supporting unit and the measurement device, that is supported by the supporting unit. However, it is preferred that the upper support element is attached to the upper wall of the hot furnace so that it supports against the hot furnace and the total distance can be measured of the support element relative to the (upper wall of the) hot furnace. The supporting unit further comprises a lifting portion for supporting said fixation arrangement. Said top portion comprises an adaptation unit to compensate for a change in length of said hot furnace entrance channel and/or of said measurement device.

The adaptation unit may preferably be designed for adapting a total length of the entrance channel to a change of length of said entrance channel, e.g. due to heat elongation. In other words during heating up a rod length of the coupling rod, a device length of the measurement device and/or length of the entrance channel may change.

Alternatively or cumulatively the adaptation unit may comprise a self-adjusting (realtime) weight sensing unit for detecting a change of the weight loaded on the lifting portion. The adaptation unit may preferably be designed to maintain a total length  $L$ .  $L$  may be defined from the hot zone end of the coupling rod to the upper support element. The adaptation unit may be designed to maintain or alter the spacing in between said fixation arrangement and said upper support element. Alternatively or cumulatively the hot furnace entrance channel may be movable along its main elongation axis by means of said adaptation unit. Alternatively or cumulatively the adaptation unit may comprise at least one of a fluid cushion or a step motor.

The supporting unit may comprise a cooling device at least partly arranged in the hot furnace entrance channel.

Further, a unit housing may be comprised wherein at least said fixation arrangement is housed in the unit housing.

Said entrance channel may comprise a hot zone outlet in said interior section for providing a through connection into said hot zone. Alternatively or cumulatively the entrance channel may comprise a channel housing, e.g. tube-shaped, like a metal tube as defined above. Alternatively or cumulatively the hot furnace entrance channel may comprise a tube-shaped section.

5           The measurement device may also be arranged at said hot zone end of the furnace entrance channel. Alternatively or cumulatively the measurement device may be fastened to said channel housing, e.g. glued as defined above. Alternatively or cumulatively said measurement device may extend from said hot furnace entrance channel through said hot zone outlet and into said hot zone.

Said supporting unit may be designed such that said lifting portion is preloaded with an additional base weight.

10           Said adaptation unit may be adapted to detect a change of length of said hot furnace entrance channel. Alternatively or cumulatively said adaptation unit may be adapted to detect a change of length of said measurement device. The length detection may be performed in that a weight carried by said lifting portion is sampled and a change of said weight is evaluated.

15           The invention is described in more detail and in view of preferred embodiments hereinafter. Reference is made to the attached drawings wherein like numerals have been applied to like or similar components.

#### Brief Description of the Figures

It is shown in

- 20   Fig. 1   a schematic of an embodiment of the invention;  
Fig. 2       a schematic of one option of measurement principle;  
Fig. 3       a schematic of the measurement principle with a grown crystal layer;  
Fig. 4       an embodiment of the invention for a hot furnace;  
Fig. 5       a detail of an installed entrance channel with measurement device;  
25   Fig. 6       an embodiment of a sensor head,  
Fig. 7       a process flow chart,  
Fig. 8       another embodiment of the invention for a hot furnace,  
Fig. 9       further embodiment of the measurement device,  
Fig. 10      detail of a further embodiment of the measurement device with coupling rod.

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#### Detailed Description of the Invention

**Fig. 1** shows a schematical view of an embodiment of the invention that is designed for and in use with a crystal growth system 2. Inside the hot furnace 4 a chamber housing 50 is arranged, where a crystal 52 (or seed crystal) is placed. The hot zone 55 is heatable by means of a heating system 15. Typically, the hot zone 55 is operated in a  
35   temperature range above 1300 °C. The hot furnace 4 with its outer walls 6 provides for separation from the outside 10, so that e.g. the electronics for the heating system 15 are covered and touching of the chamber housing 50 from outside 10 is prevented. A measurement device 26 is arranged inside the hot furnace 4 but outside of the hot zone 55 or the chamber housing 50, respectively. The measurement device 26 is arranged in an entrance channel 20 that comprises a

channel housing 18. This channel housing 18 comprises an interior section 21 that is arranged inside the hot furnace 4, so that the entrance channel 20 extends from an outside 10 into an inside of the hot furnace 4. On an outer side of the chamber housing 50 a thermal insulation layer 8 is arranged, by means of which heat generation (and conservation) inside the hot zone 55 is improved. The insulation 8 may be composed of a multilayer insulation. The heat is generated in this example by means of an induction coil system 15 that is situated around the and surrounding the chamber housing 50.

Due to the proximity of the signal generator 26 to the hot zone 55 and the very high temperatures provided in the chamber housing 50 for the generation process of a crystal 52, a cooling system 25 is provided for a temperature adaptation of the signal generator 26, or the entrance channel 20. The cooling system 25 provides a cooling channel 22 along the outer wall of the channel housing 18. For example, the cooling channel 22 can comprise a through bore along the longitudinal extension dimension of the entrance channel 20. In another embodiment, the cooling channel can also be provided by means of a double wall housing, where the cooling fluid may be provided in between an inner wall and an outer wall of the channel housing 18. For example, two channels may be provided in the double wall arrangement, for influx and outflux of the cooling fluid, respectively. Inside the entrance channel 20 a connection line 24, for example for electrical connection and/or data connection of the signal generator 26 to or from outside 10.

In the example shown in **fig. 1**, between the signal generator 26 and the crystal 52 a coupling rod 28 is positioned. The coupling rod 28 extends from the signal generator 26 through an opening in the chamber housing 50 and onto a first surface 53 of the crystal 52. At best, the contact on either side of the coupling rod 28 is a direct contact, that is without any gap or, as the case may be, with a coupling paste or adhesive provided on one or either end surface of the coupling rod 28.

When the temperature in the hot zone 55 changes, e.g. when it is heated up, a total length  $l$  between the first surface 53 of the crystal 52 and the supporting unit 100, or more precisely the lifting portion 140 of the supporting unit 100 and/or relative to the supporting structure 150, may change. This total length may be measured, for example, in between the outer furnace wall 6 and the lifting portion 140. There may be involved different temperature constants in between the materials involved, such as used for the channel housing 18, the coupling rod 28 and so on. In addition, in between the hot zone 55 and the signal generator 26, and further along the channel housing 18, a temperature gradient may be developed. This temperature gradient may be regulated in a limited manner by means of the implementation (use, shape, length etc) of the cooling device 25 and/or length ratios of coupling rod 28 to channel housing 18. However, still a change of length during heating up the hot zone 55 will have typically to be managed, as has been observed during the making of this invention. At the same time, the material(s) used for the coupling rod 28 may be sensitive to stress, in particular regarding the enormous temperature difference between the entrance channel 20 and the hot zone 55 where, as a result, the total length  $L$  between the lifting portion 140 and the hot zone end 28b of the coupling rod 28 may vary substantially.

But when the extent of length variation of the total length  $l$  exceeds the tolerances the weakest part might break, or, as the case may be, the crystal 52 might be damaged or moved out of its position. Therefore, in a preferred embodiment, the measurement device 12 may comprise a length and/or temperature compensation system, as will be described in many details and with reference to the respective figures.

With respect to **fig. 2** an embodiment of a signal generator 26 and its interaction with the crystal 52 is sketched. In this example, the signal generator 26 is composed as a transducer that is in direct contact with the first surface 53 of the crystal 52. The transducer generates a probing signal, that is in this example an ultrasound signal. In other words, the ultrasound signal is generated in the transducer and coupled into the first surface 53 of the crystal 52. The probing  
5 signal crosses the width  $w$  of the crystal 52 where the probing signal is reflected at least in part at the second surface 54 of the crystal 52. The reflected signal is the probe signal, which returns to the ultrasound transducer 26 where the returned probe signal is detected. For example, by means of a time-of-flight measurement the thickness or width  $w$  of the crystal 52 is identifiable. In case of crystal growth the thickness or width will increase to a width  $w_2$ , as is depicted in **Fig. 3**. When the emission of the probing signal is continued, the probing signal as well as the returned probe signal will pass  
10 through the thicker crystal  $w_2$ , so that the returned probe signal is delayed by 2 times the added thickness of the crystal, that is added due to crystal growth. In other words, the deposited crystal volume delays the measurement, where the delay is a direct indication of crystal thickness  $w$ ,  $w_2$  and such of crystal growth.

By means of the exemplified time-of-flight measurement, not only a process status information such as the crystal thickness may be obtained, but as the measurement is performed in realtime during crystal growing process also  
15 additional information such as crystal growth rate can easily be estimated or measured. The crystal growth rate can give a direct feedback about the atmosphere composition inside the hot zone 55 as well as the temperature, and of other process parameters which have a direct influence on crystal growth rate. In other words by obtaining the crystal thickness and/or the crystal growth rate it is possible to adjust in Realtime the process parameters, such as atmosphere composition or temperature inside the hot zone 55, and, in return, observe such influence of the respective process  
20 parameters on the crystal growth rate. Furthermore, it is possible to observe whether crystal growth has come to a halt or whether crystal growth is performing in line with the requirements, such as with regards to the number of defects and purity.

With regards to the defects or purity, the probing signal that propagates through the crystal 52 can give an indication about such defects in the crystal. As the signal passes through the crystal material, any defect broadens the  
25 frequency spectrum so that a broad signal response gives an indication that more defects are present in the crystal 52.

Referring now to **figs. 4, 5 and 6**, another embodiment of the hot furnace 4 or crystal growth system 2 with a measurement device 12 is shown. **Fig. 4** gives an overview of the system, where **fig. 5** shows details of the signal generator and **fig. 6** details of the supporting unit 100. The entrance channel 20 extends from the insulation 8 of the chamber housing 50 through the outer furnace wall 6 and up to the supporting unit 100, where the entrance channel 20  
30 is supported. Inside the hot furnace 4, that is as well, inside the interior section 21 of the entrance channel 20, the signal generator 26 is arranged. A coupling rod 28 is coupled to the signal generator 26.

With respect to **fig. 5** the signal generator 26 is shown inside the entrance channel 20. In this example, the coupling rod 28 is arranged between the transducer 26 and the first surface 53 of the crystal. The transducer 26 is in direct contact with the coupling rod 28 on an outer side 28a of the coupling rod 28 and with the first surface 53 of the  
35 crystal 52 on the hot zone end 28b of the coupling rod 28. The transducer 26 generates a probing signal, that may be an ultrasound signal that propagates along the coupling rod 28. In other words, the ultrasound signal is generated in or using the transducer 26 and coupled into the outer end 28a of the coupling rod 28, propagates along the elongation direction of the coupling rod 28 and is coupled into the first surface 53 of the crystal 52 on the hot zone end 28b of the

coupling rod 28. The probing signal crosses the width  $w$  of the crystal 52 where the probing signal is reflected (at least in part) at the second surface 54 of the crystal 52. The reflected signal is the probe signal, which returns through the coupling rod 28 to the ultrasound transducer 26 where the returned probe signal is detected. For example, by means of a time-of-flight measurement the thickness or width  $w$ ,  $w_2$  of the crystal 52 is identifiable. In case of crystal growth the thickness or width will increase to a width  $w_2$ , as is depicted in **Fig. 3**. When the emission of the probing signal is continued, the probing signal as well as the returned probe signal will pass through the thicker crystal  $w_2$ , so that the returned probe signal is delayed by 2 times the added thickness of the crystal, that is added due to crystal growth. In other words, the deposited crystal volume delays the measurement, where the delay is a direct indication of crystal thickness and such of crystal growth.

Returning to **Fig. 5** the signal generator is fixed to the channel housing 18 by means of fixation means 34, such as an adhesive or clamping material or screws. It is further coupled to the coupling rod 28 that extends until the first surface 53 of the crystal 52 arranged in the hot zone 55. The coupling rod 28 extends through a hot zone outlet 30 of the entrance channel 20, where a passage seal 32 seals the inside of the entrance channel 20 against its outside, that may be the connection to the hot zone 55. The passage seal 32 fulfils a double feature in that it is additionally designed to seal the cooling device 25. Cooling fluid flows through the cooling channel 22 and into a cooling reservoir 22a, where the signal generator is submerged in the cooling fluid of the reservoir 22a. In order to avoid any fluid (such as the cooling fluid) to enter the hot zone 55, where a direct evaporation of any cooling fluid would take place instantaneously and would destroy or worsen the crystal 52 that is grown in the crystal growth chamber 50. The passage seal 32 may also cushion the coupling rod 28 to seal the inside of the entrance channel.

Turning now to **fig. 6** the supporting structure is depicted in more detail, where the supporting unit 100 comprises a supporting unit housing 102. The entrance channel 20 is affixed to a fixation arrangement 130. Technically, the fixation arrangement 130 may also be provided as a part of the entrance channel 20, that could be easier to construct. But in terms of a logical order the fixation arrangement 130 is described as a separate part herein. By means of the fixation arrangement the entrance channel 20 is hung onto a lifting portion 140. In this example, the lifting portion 140 comprises at its outer side a pyramid-like side flange 142 where the fixation arrangement 130 comprises at an inner side an inverse pyramid-like flange 132. In other words, the lifting portion 140 comprises a receiving surface 142 and the fixation arrangement 130 comprises a complementary surface 132 that is attempted to be laid or applied onto the receiving surface 142 of the lifting portion. The lifting portion is supported by means of an adaptation unit 160 that is capable of measuring the weight. The fixation arrangement 130 in this embodiment comprises several clamping portions 134A, 134B, 134C, 134D of a clamping arrangement 134, that are clamped together by means of screws (not shown) that are arranged in bolt holes 136.

Whenever the weight imposed on the lifting portion changes, i.e. decreases, the change of weight is detectable by the adaptation unit 160. In a figurative example, when the entrance channel 20 is lifted up sufficiently it may even potentially started to detach from the lifting portion 140. If the zone 55 is heated up and the signal generator 26, the entrance channel 20 and/or coupling rod 28 extends due to heat extension, and at the same time the signal generator 26 or coupling rod 28 is directly coupled and arranged on top of the first surface 53 of the crystal 52 (that is: in touch with the first surface), the crystal 52 would potentially be moved, e.g. to a downside. This could destroy the crystal 52. However, as is described herein, the system as presented is able to tolerate such changes  $\Delta l$  of length  $l$ . In case the

total length  $l$  increases by  $\Delta l$ , the weight imposed on the lifting portion 140 by the fixation arrangement 130 would decrease, as the hot zone end of the coupling rod would start to impose weight on the crystal 52. The adaptation unit 160 will note a decrease in weight and will react accordingly in order to adapt the total length  $l$  such that the length up to the supporting structure 150 is remained constant. In other words, the adaptation unit 160 is adapted to change its own length  $L_A$  or comprises a compensation distance  $L_A$  to react to or compensate for a change  $\Delta l$  of length  $l$  of the entrance channel 20 (channel housing 18), the signal generator 26 and/or the coupling rod 28.

In order to provide such a change of length the adaptation unit 160 may provide, for example, a fluid cushion that is adjustable by pressure means, where a higher pressure increases the length  $L_A$  of the adaptation unit 160 and a decrease of pressure decreases the length  $L_A$  of the adaptation unit 160. In another embodiment, the adaptation unit 160 may comprise a step motor that is adapted to provide length adaptation steps and/or weight adaptation steps. The length adaptation steps may be chosen to be  $0.05\text{ }\mu\text{m}$  or more per step, preferably  $0.5\text{ }\mu\text{m}$  or more, further preferably  $0.15\text{ }\mu\text{m}$  or more per step. Further, said step size of a length adaptation step may be  $0.5\text{ }\mu\text{m}$  or less, preferably  $0.3\text{ }\mu\text{m}$  or less, further preferred  $0.2\text{ }\mu\text{m}$  or less or even  $0.1\text{ }\mu\text{m}$  or less. The adaptation unit provides for a multifunctionality in that it measures the weight of the supported structure and, from a change of weight is able to estimate (or calculate) a change of length. It also is capable of adapting its own length (or an inner length as provided for the supported structure)  $L_A$  in response to the change of length  $\Delta l$  in order to compensate for any thermal expansion of the supported structure, for example of the entrance channel 20, the signal generator 26 and/or the coupling rod 28. The adaptation unit 160 itself is hooked or mounted to the upper surface 150 of the supporting unit housing 102.

Turning now to **fig. 7** a flow chart is depicted, wherein as a first step 210 the crystal 52 (that may initially be a crystal seed) is arranged in the hot zone 55. In step 211 the signal generator 26 is arranged, for example in the entrance channel 20 or together with the entrance channel 20 on top of the hot furnace 4. In step 215 a coupling rod 28 is coupled. Coupling of the coupling rod 28 can be on the outer side 28a with the signal generator 26 and at the hot zone end 28b with the first surface 53 of the crystal 52. The coupling rod 28 may be positioned in step 216, where steps 215 and 216 can be alternative or cumulative to each other.

Thereafter, the hot zone 55 is sealed in step 220. When the hot zone 55 is sealed, it can be heated up in step 225. At the same time or later, it may be advantageously to start cooling of the measurement device 26 in step 227.

In step 238 the probing signal is provided to the crystal 52 by means of the signal generator 26. For example, the probing signal may be transported through the coupling rod 28 in step 232. The signal response (probe signal) may be analyzed in step 240, for example by means of the signal generator 26.

With respect to Fig. 8 another embodiment of a measurement device 12 arranged in a hot furnace 4 is shown. The measurement device 12 comprises an entrance channel 20 with a cooling channel 22 to provide cooling to the active element 26 and a connection duct 23, that provides space e.g. for cable connection to and from the active element 26. A coupling rod 28 is coupled to the active element 26 and penetrates the insulation 8 of the hot zone 55 and extends until the crystal 52. The active element 26 is surrounded by the cooling channel 22 of the cooling device 25. The entrance channel 20 is fixed with the mounting flange 105 at an upper side of the hot furnace 4. The mounting flange 105 may also be designed as a throughhole so that cables and coolant lines can go to the outside 10 of the hot furnace 4.

Turning now to Fig. 9 a technical drawings of an embodiment of the measurement device 12 is shown. The measurement device 12 is designed as a drop-in device that provides a mounting flange 105 where it is mounted to the top portion of the hot furnace 4. The entrance channel 20 extends, in a mounted position, from the inside of the hot furnace 4 to the outside 10, as all the portion that is shown situated above the mounting flange 105 remains at the outside 10 of the hot furnace 4. The connection duct 23 provides for space for the connection line 24 such as a cable. The connection line 24 can provide e.g. frequency information and/or electrical energy to the active element 26, but also measurement data can be retrieved from the active element. The connection line 24 may be contacted outside of the hot furnace 4 at the connection terminal 106.

With respect to the cooling device 25 a coolant is fed from the coolant inlet 36 that is in connection with the cooling channel 22 and thus to the proximity of the active element 26. In this embodiment the active element is surrounded by the cooling channel 22, that may be one circumferential cooling channel 22 or a multitude of cooling channels 22 (22a, 22b, 22c,...) which has the same cooling effect. After passing the cooling channel 22 the coolant is expelled through the coolant outlet 38. The cooling channel 22 may be made from metal, such as iron or stainless steel.

A further detailed embodiment of the measurement device 12 is depicted in Fig. 10, where only a detail is shown. For example, the extract shown in Fig. 10 could be the bottom-most portion of the embodiment as shown in Fig. 9, but it is not limited thereto. The active element 26 is attached to the rod 28, e.g. glued thereto. The rod – with the active element 26 – can move upwards and downwards, it has play between the sealant 29 and a stop 31 at the lower end of the cooled section 27. The measurement device 12 is thus designed such that e.g. when the crystal moves, e.g. due to heat effects, or when the rod 28 changes its elongation due to increasing heat, that a relative movement between the rod 28 and the entrance channel 20 is allowed for. To improve this, the rod 28 may comprise a portion 28a (outer end) that may hit against the stop 31, such as a bead, bulge or thickening. In other words the diameter of the rod 28 may be greater at the outer end 28a of the rod. For example, the (vertical) play may be up to 5 mm or less, preferably up to 10 mm, further preferably up to 20 mm or up to 30 mm or less. The (vertical) play may also be 3 mm or more, preferably 8 mm or more, further preferably 18 mm or more.

It will be appreciated that the features defined herein in accordance with any aspect of the present invention or in relation to any specific embodiment of the invention may be utilized, either alone or in combination with any other feature or aspect of the invention or embodiment. In particular, the present invention is intended to cover a method for obtaining information in realtime from a crystal growth process or crystal growth system in a high temperature environment, a Realtime measurement system designed for the same, a sensor arrangement for a hot furnace such as a crystal growth system and/or a measurement device supporting unit configured to include any feature described herein. It will be generally appreciated that any feature disclosed herein may be an essential feature of the invention alone, even if disclosed in combination with other features, irrespective of whether disclosed in the description, the claims and/or the drawings.

It will be further appreciated that the above-described embodiments of the invention have been set forth solely by way of example and illustration of the principles thereof and that further modifications and alterations may be made therein without thereby departing from the scope of the invention.

Reference list:

|    |     |                                   |     |                                                  |
|----|-----|-----------------------------------|-----|--------------------------------------------------|
|    | 2   | crystal growth system             | 160 | Adaptation unit                                  |
|    | 4   | hot furnace                       | 210 | arranging of a crystal or crystal seed           |
| 5  | 6   | outer furnace wall                | 211 | arranging of a signal generator                  |
|    | 8   | insulation                        | 215 | coupling of a coupling rod                       |
|    | 10  | outside                           | 216 | positioning of coupling rod                      |
|    | 12  | measurement device                | 220 | sealing the hot zone                             |
|    | 15  | heating system                    | 225 | heating up said hot zone                         |
| 10 | 18  | channel housing                   | 227 | cooling of the measurement device                |
|    | 20  | entrance channel                  | 230 | providing probing signal                         |
|    | 21  | interior section                  | 232 | transporting the signal through the coupling rod |
|    | 22  | cooling channel                   | 240 | analysing a signal response (probe signal)       |
|    | 22a | cooling reservoir                 | l   | total length                                     |
| 15 | 23  | connection duct                   | w   | width of crystal 52                              |
|    | 24  | connection line                   |     |                                                  |
|    | 25  | cooling device                    |     |                                                  |
|    | 26  | active element / signal generator |     |                                                  |
|    | 27  | cooled section                    |     |                                                  |
| 20 | 28  | coupling rod                      |     |                                                  |
|    | 28a | outer end of the coupling rod     |     |                                                  |
|    | 28b | hot zone end of the coupling rod  |     |                                                  |
|    | 29  | sealant                           |     |                                                  |
|    | 30  | hot zone outlet                   |     |                                                  |
| 25 | 31  | stop                              |     |                                                  |
|    | 32  | passage seal                      |     |                                                  |
|    | 34  | fixation means                    |     |                                                  |
|    | 36  | coolant inlet                     |     |                                                  |
|    | 38  | coolant outlet                    |     |                                                  |
| 30 | 50  | chamber housing                   |     |                                                  |
|    | 52  | crystal                           |     |                                                  |
|    | 53  | first surface of crystal          |     |                                                  |
|    | 54  | second surface                    |     |                                                  |
|    | 54a | second surface                    |     |                                                  |
| 35 | 55  | hot zone                          |     |                                                  |
|    | 100 | supporting unit                   |     |                                                  |
|    | 102 | supporting unit housing           |     |                                                  |
|    | 105 | mounting flange                   |     |                                                  |
|    | 106 | connection terminal               |     |                                                  |
| 40 | 120 | top portion                       |     |                                                  |
|    | 130 | Fixation arrangement              |     |                                                  |
|    | 132 | inverse pyramid-like flange       |     |                                                  |
|    | 140 | Lifting portion                   |     |                                                  |
|    | 142 | pyramid-like flange               |     |                                                  |
| 45 | 150 | supporting structure              |     |                                                  |

Claims:

1. Method (200) for obtaining information in realtime from a crystal growth process or crystal growth system (2, 4) in a high temperature environment, such as for growing a silicon carbide crystal (52), the method comprising the steps:
- 5 arranging (210) a crystal or crystal seed in a hot zone (55) of said crystal growth system, hermetically sealing (220) said hot zone, providing (230) a probing signal by means of a signal generator (26) and directing said probing signal onto a first surface (53) of said crystal inside said hot zone,
- 10 analysing (240) a signal response and retrieving at least one process status or process development information.
2. The method (200) according to the preceding claim, comprising at least one of the additional steps
- 15 coupling (215) a coupling rod (28) to said signal generator (26) and/or transporting (232) said probing signal by means of said coupling rod into said hot zone, and/or positioning (216) said coupling rod such that it is in direct contact with said first surface (53) of said crystal (52).
- 20 3. The method (200) according to any of the preceding claims, comprising at least one of the additional steps
- arranging (211) the signal generator (26) spaced apart from said first surface (53) of said crystal (52), in particular outside of said hot zone (55), and/or
- 25 directly coupling said probing signal from the signal generator (26) into said coupling rod (28) and transporting said probing signal into the hot zone (55) and onto said crystal (52) by means of said coupling rod, and/or
- coupling said probing signal, for example directly, into the first surface (53) of said crystal (52).
- 30 4. The method (200) according to any of the preceding claims, comprising at least one of the additional steps
- arranging an ultrasound transducer (26) at an outer end (28a) of said coupling rod (28) as defined in claim 2, or
- generating said probing signal by means of at least one active element, such as an ultrasound transducer arranged outside the hot zone (55).
- 35 5. The method (200) according to any of the preceding claims, wherein the crystal (52) is at least one of initially provided as a seed crystal, composed or to be composed of silicon carbide, and/or

a monocrystal or monocrystalline crystal.

- 5
6. The method (200) according to any of the preceding claims,  
wherein performing the method is done as a non-disturbing measurement.
7. The method (200) according to any of the preceding claims,  
including heating up (225) the hot zone (55) before start of crystal growth, and/or  
wherein the hot zone (55) is heated on a high temperature of 1.550 K or more, preferably 1.700 K or  
more, further preferably 1.900 K or more, 2.100 K or more, 2.300 K or more, or 2.450 K or more, and/or  
10 3.000 K or less, or 2.750 K or less, or 2.500 K or less, or 2.200 K or less.
8. The method (200) according to any of the preceding claims,  
wherein process development information can be retrieved out of process status information, and/or  
wherein process development information includes at least one of a crystallization front determination  
15 or a crystal growth rate, and/or  
wherein process status information includes at least one of a number or distribution of defects in the  
crystal or crystal thickness.
9. The method (200) according to any of the preceding claims,  
20 including at least one of the steps  
receiving a probe signal that is returned, for example, from a second surface (54) of the crystal (52),  
and/or  
performing a time-of-flight measurement of the probing signal.
10. The method (200) according to any of the preceding claims  
25 wherein using said probing signal comprises imposing waves, for example ultrasound waves, on said  
first surface (53) of said crystal (52).
11. The method (200) according to any of the preceding claims  
30 further including, while the hot zone (55) is hot or heated, cooling said coupling rod (28) by means of a  
cooling device (25), and/or  
cooling said signal generator (26), e.g. by means of a cooling device, such as by immersion into a  
cooling channel (22).
12. The method (200) according to any of the preceding claims, further including at least one of the following  
35 steps  
determining a temperature profile over the coupling rod (28) and/or  
estimating or correcting a temperature effect on the propagation speed of said probing signal or of said

reflected probe signal.

13. Use of the method (200) according to any of the preceding claims during the making of a silicon carbide monocrystal (52).
- 5
14. Realtime measurement system (12) for obtaining information in realtime from a crystal growth process or crystal growth system (2, 4) in a high temperature environment, such as for growing a silicon carbide crystal (52), comprising
- 10 a hermetically sealable hot zone (55) for arranging a crystal (52) or crystal seed in said hot zone of said crystal growth system,
- an active element (26) such as a signal generator outside said hot zone for providing a probing signal to direct said probing signal onto a first surface (53) of said crystal inside said hot zone,
- analyzation means (26) for retrieving at least one process status or process development information.
- 15
15. The realtime measurement system (12) as defined in the preceding claim, further comprising
- a coupling rod (28) for transporting said probing signal onto said first surface (53) of said crystal (52),
- wherein said probing signal is preferably directly coupled from the signal generator (26) into said coupling rod, and/or
- wherein said active element (26) is arranged spaced apart from said first surface (53) of said crystal (52), in particular outside of said hot zone (55).
- 20
16. The realtime measurement system (12) as defined in any of the preceding claims 14 or 15, the active element (26) further comprising
- 25 an ultrasound transducer at an outside end (28a) of said coupling rod (28) defined in the preceding claim, wherein said ultrasound transducer is preferably adapted for generating said probing signal and, more preferably, for directly coupling said probing signal into said coupling rod.
17. The realtime measurement system (12) as defined in any of the preceding claims 14 to 16, further
- 30 wherein the analyzation means (26) are adapted to analyse a signal response, such as one or more ultrasound waves.
18. The realtime measurement system (12) as defined in any of the preceding claims 14 to 17,
- wherein the active element (26) is adapted to send and receive an ultrasound signal, and/or
- wherein the ultrasound transducer is designed as a transceiver.
- 35
19. The realtime measurement system (12) as defined in any of the claims 16 to 18,
- wherein the ultrasound transducer is arranged directly at said outside end (28a) of said coupling rod (28), so that ultrasound waves generated by the ultrasound transducer can be coupled directly into the

coupling rod and said signal response couples directly into the ultrasound transducer.

20. The realtime measurement system (12) as defined in any of the preceding claims 14 to 19,  
wherein the active element (26) comprises a ceramic, such as a ceramic piezoelectric transducer,  
5 and/or comprises PVDF, preferably in the form of a foil.
21. Sensor arrangement (12) for a hot furnace (2, 4) such as a crystal growth system, and/or for a realtime  
measurement system according to the preceding claims 14 to 20, the sensor arrangement comprising  
10 a hot furnace entrance channel (20) that connects from an outside (10) into said furnace and  
comprising an interior section (21) that is arranged inside said furnace, wherein the interior section extends  
for example from an outer furnace wall (6) until an insulation layer (8) around a hot zone housing (50),  
a measurement device (26) arranged in said interior section of said entrance channel to measure data  
from an inside of a hot zone,  
a cooling device (25) that is at least partly arranged in said entrance channel to provide cooling for said  
15 measurement device.
22. The sensor arrangement (12) according to the preceding claim, further comprising at least one of  
a hot zone housing (50) inside said hot furnace (2, 4) for housing said hot zone (55),  
an insulation layer (8) on the outside of said hot zone housing.  
20
23. The sensor arrangement (12) according to any of the two preceding claims,  
wherein said entrance channel (20) comprises a hot zone outlet (30) in said interior section (21) for  
providing a through connection into said hot zone (55).
24. The sensor arrangement (12) according to the preceding claim,  
25 further comprising a coupling rod (28) arranged at least partly in said hot zone outlet (30), and/or  
wherein said measurement device (26) extends from said entrance channel (20) through said hot zone  
outlet (30) and into said hot zone (55), and/or  
further comprising a passage seal (32) at a hot zone end of the entrance channel (20) or at said hot  
30 zone outlet (30) for sealing said hot zone outlet, and/or for allowing for movement with respect to said  
entrance channel and/or said coupling rod (28).
25. The sensor arrangement (12) according to the preceding claim,  
wherein the coupling rod (28) comprises at least one of glass, ceramic, metal, silicon carbide, glassy  
35 carbon, Tungsten, Tantalum or fused silica quartz, and/or  
wherein the coupling rod (28) is designed charge invariant.

26. The sensor arrangement (12) according to any of the preceding claims 21 to 25,  
wherein the measurement device (26) comprises a piezoelectric transducer, for example a transceiver,  
and/or  
wherein the measurement device (26), for example the piezoelectric transducer, comprises a ceramic,  
and/or comprises PVDF, preferably in the form of a foil.
27. The sensor arrangement (12) according to any of the preceding claims 21 to 26,  
wherein the measurement device (26) is arranged at said hot zone end of the entrance channel (20),  
and/or  
wherein the entrance channel (20) is arranged vertically, and/or  
wherein the entrance channel (20) is arranged at an upper side of the hot furnace.
28. The sensor arrangement (12) according to any of the preceding claims 21 to 27,  
wherein the entrance channel (20) comprises a channel housing (18), e.g. tube-shaped, like a metal  
tube, and/or  
wherein the entrance channel (20) comprises a tube-shaped section.
29. The sensor arrangement (12) according to the preceding claim,  
wherein the measurement device (26) is fastened to said channel housing (18).
30. The sensor arrangement (12) according to any of the preceding claims 21 to 29,  
wherein said cooling device (25) comprises at least one cooling channel (22) arranged in said entrance  
channel (20) for providing a cooling fluid to said measurement device (26).
31. The sensor arrangement (12) according to the preceding claim,  
wherein said entrance channel comprises a cooled section (27) that is cooled by the cooling channel  
(22) and wherein the active element (26) is arranged in the cooled section.
32. The sensor arrangement (12) according to one of the claims 21 to 31,  
wherein the entrance channel (20) comprises a connection duct (23) for connection means such as  
cables to connect with the active element (26).
33. The sensor arrangement (12) according to one of the claims 21 to 32,  
wherein the cooled section (27) is separated or sealed against the connection duct (23) by means of a  
sealant (29).
34. The sensor arrangement (12) according to one of the claims 21 to 33,  
wherein the active element (26) is attached to the rod (28), and/or

wherein a play of the rod (28) against the entrance channel (20) is allowed for by means of a movement of the rod in the cooled section (27).

- 5 35. The sensor arrangement (12) according to one of the claims 21 to 34,  
further comprising a stop (31) at the lower end of the entrance channel (20) to limit relative movement of  
the rod (28) against the entrance channel, and/or  
the rod (28) comprising an outer end (28a) that comprises a greater diameter in order to limit the movement  
of the rod against a stop (31).
- 10 36. The sensor arrangement (12) according to any of the preceding claims 21 to 33,  
wherein said hot zone (55) is designed to be heated during operation to an operation temperature of at  
least 1.500 K or more, preferably 1.750 K or more, and further preferably 2.000 K or more or even 2.150 K  
or more.
- 15 37. The sensor arrangement (12) according to any of the preceding claims 21 to 34,  
wherein during operation of said hot furnace (2, 4) a temperature gradient is maintained or adjusted in  
between said hot zone (55) and said measurement device (26), wherein said temperature gradient is  
preferably a continuous temperature gradient.
- 20 38. The sensor arrangement (12) according to any of the preceding claims 21 to 35 designed to be used for a  
PECVD or HTCVD process.
- 25 39. A measurement device supporting unit (100) for use with a hot furnace (2, 4) such as a crystal growth  
system, and/or for use in a realtime measurement device as claimed in any of the preceding claims 1 to 20,  
the supporting unit comprising:  
a fixation arrangement spaced apart from a hot zone (55) arranged in that hot furnace, wherein the  
fixation arrangement es designed to carry a measurement device and/or hot furnace entrance channel,  
wherein said hot furnace entrance channel (20) extends from an outside (10) at least until a hot zone  
housing (50) inside the furnace, for example until an insulation (8) around said hot zone housing, and  
30 wherein said measurement device is arranged, for example, in said entrance channel (20),  
a top portion (120) that is affixed to an upper support element (150), comprising a lifting portion for  
supporting said fixation arrangement,  
wherein said top portion (120) comprises an adaptation unit (160) to compensate for a change in  
length ( $\Delta l$ ) of said hot furnace entrance channel (20) and/or of said measurement device (26).
- 35 40. The supporting unit (100) according to the preceding claim,  
wherein the adaptation unit (160) is designed for adapting a total length  $l$  of the entrance channel (20) to a  
change of length ( $\Delta l$ ) of said entrance channel, e.g. due to heat elongation, and/or

the adaptation unit (160) comprising a self-adjusting weight sensing unit for detecting a change of the weight loaded on the lifting portion (140).

- 5 41. The supporting unit (100) according to any of the preceding claims 37 or 38,  
wherein the adaptation unit (160) is designed to maintain or alter the distance in between said fixation arrangement (130) and said upper support element (150), and/or  
wherein the hot furnace entrance channel (20) is movable along its main elongation axis by means of said adaptation unit (160), and/or  
the adaptation unit (160) comprising at least one of a fluid cushion or a step motor.
- 10 42. The supporting unit (100) according to any of the preceding claims 37 to 39 comprising a cooling device (25) at least partly arranged in the hot furnace entrance channel (20).
- 15 43. The supporting unit (100) according to any of the preceding claims 37 to 40 comprising a unit housing (102) wherein at least said fixation arrangement (130) is housed.
- 20 44. The supporting unit (100) according to any of the preceding claims 37 to 41,  
wherein said entrance channel (20) comprises a hot zone outlet (30) in said interior section (21) for providing a through connection into said hot zone (55), and/or  
wherein the entrance channel (20) comprises a channel housing (18), e.g. tube-shaped, like a metal tube, and/or  
wherein the hot furnace entrance channel (20) comprises a tube-shaped section.
- 25 45. The supporting unit (100) according to any of the preceding claims 37 to 42,  
wherein the measurement device (26) is arranged at said hot zone end of the furnace entrance channel (20) and is fastened to said channel housing (18), and/or  
wherein said measurement device (26) extends from said hot furnace entrance channel (20) through said hot zone outlet (30) and into said hot zone (55).
- 30 46. The supporting unit (100) according to any of the preceding claims 37 to 43,  
designed such that said lifting portion (140) is preloaded with an additional base weight.
- 35 47. The supporting unit (100) according to any of the preceding claims 37 to 44,  
wherein said adaptation unit (160) is adapted to detect a change of length ( $\Delta l$ ) of said hot furnace entrance channel (20) and/or of said measurement device (26) in that a weight carried by said lifting portion (140) is sampled and a change of said weight is evaluated.