Best practice for AbsoluT temperature calibration to reduce system-to-system variations

In the past years, the requirements for temperature monitoring and control during epitaxial processes for compound semiconductors increased significantly. Hence, the calibration of the in-situ monitoring systems becomes increasingly challenging. Unavoidable, small optical variations within different metrology systems (EpiTT/EpiCurve® TT) and the calibration tools (AbsoluT) lead to minor, but significant deviations of the calibration between growth reactors. LayTec has therefore introduced a solution to improve the precision, reproducibility and accuracy of the temperature calibration that also reduces system-to-system variations. The result of this development will be discussed in this application note.

LayTec is continuously improving its products in order to reduce system-to-system variations and improve performance. To improve specifically the temperature measurement and calibration, both a new generation of the AbsoluT calibration tool and a new generation of detection units within EpiTT and EpiCurve® TT was released. Since the new generation AbsoluT* and detection units are ideally matched, they provide the best possible precision, reproducibility and accuracy. Therefore, LayTec recommends using this new generation hardware for optimum performance: AbsoluT version 1.5, shipped after November 2019, SN after 2039-00331-2019. EpiTT/EpiCurve® TT with detector (DTT) version TC, shipped after June 2021, SN after 2534-2577-2021.

However, even the ideally matched hardware, is not free of unavoidable tolerances. To further increase precision, reproducibility, and accuracy of the calibration, LayTec has developed a procedure to match individual EpiTT/EpiCurve® TT systems with an individual AbsoluT used for calibration. Each pair of EpiTT/EpiCurve® TT and AbsoluT can be assigned an individual reference temperature (so called paired reference temperature) that is then used in the calibration process. This procedure works best with a combination of new EpiTT/ EpiCurve® TT and new AbsoluT. However, it can also be used with older EpiTT/EpiCurve® TT and older AbsoluT – in any combination. The increase in precision, reproducibility, and accuracy might not be as big as with the new generation, though.

As most fabs in the field will employ a variety of different generation metrology tools, focus in this Application Note is laid on a factory which is equipped with a combination of old and new generation detector modules and AbsoluTs. Using the novel approach of "paired reference temperatures" will cancel out some deviations, especially for old generation LayTec-tools. Therefore, a measurable change in temperature after calibration is possible in some cases. Hence, there are two options that can be targeted: (1) Best global accuracy or (2) historical consistency of the calibrations in the factory. The first option is the best choice in terms of PTB/NIST-traceable temperature and accuracy. The second option is the best choice if the processes on the reactors are qualified and any changes to the temperature values should be minimized.

Both options are generally aiming to reduce temperature deviations. The deviations are caused by unavoidable variations of the spectral properties of the LayTec systems. The variations are reduced with the new hardware generation. With the full knowledge of the spectral properties, the temperature deviation of a specific AbsoluT used on a specific EpiTT/EpiCurve® TT can be calculated to a paired reference temperature. Fig. 1 (see page 2) shows the principle of a situation in a fab. There are six LayTec systems installed and calibrated with one AbsoluT – all showing some deviations from the (theoretical) true value.

**The new AbsoluT has been improved for stability, is internally temperature stabilized, has a much shorter warm up time, is less sensitive to changes of ambient temperature and has defined spectral properties.*

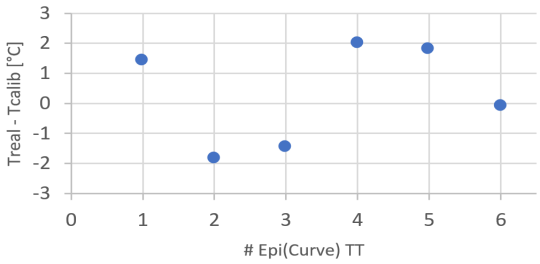

Fig. 1: Sketch of an original calibration with an (old) AbsoluT device. Plotted is the difference between calibrated temperature and real temperature on the EpiTT in °C (simulated data), highlighting a typical system-to-system variation.

Option 1: Best possible accuracy (system-to-system reproducibility/precision)

The best overall accuracy can be achieved by strictly using the new "paired reference temperatures" for each used EpiTT/EpiCurve® TT paired with each used AbsoluT. To do that, the spectral properties of the systems must be known. For EpiCurve TTs and AbsoluTs of the new hardware generation this data is known and available at LayTec. In case of the usage of an AbsoluT of generation 1, the AbsoluT needs to be characterized at LayTec (please contact support@laytec.de for further information). To achieve the best accuracy, the paired reference temperatures will be provided by LayTec customer support on request:

1. Send EpiTT/EpiCurve® TT system serial numbers to LayTec customer support
2. Send AbsoluT system serial number to LayTec
3. LayTec will inform you if your AbsoluT needs to be sent back for recalibration and characterization
4. LayTec will send calibration certificate for paired reference temperatures
5. Calibrate the EpiTT/EpiCurve® TT in the fab by entering the new paired reference temperatures into the EpiNet AbsoluT calibration device

This option can lead to a temperature offset when comparing to the old calibration on each system. The offset depends on the hardware generation of both AbsoluT and EpiTT and laboratory tests at LayTec application engineering have shown values up to 6K.

Option 2: Consistency in calibration history

Consistency in calibration history may be more important than absolute accuracy (e.g. due to a qualified process or a desired long-term stability of calibration values).

Even in this case, usage of a new generation AbsoluT will increase long-term stability of the calibration. In order to avoid a change in absolute values, the "house calibration" of the old AbsoluT needs to be transferred to the new AbsoluT. The best consistency between old and new AbsoluT can be achieved by transferring the calibration with the old AbsoluT over to the new one:

1. Calibrate the EpiTT/EpiCurve® TT with the old AbsoluT that was formerly used for calibration
2. Measure the temperature of the new AbsoluT on that EpiTT/EpiCurve® TT system for a specific corrected reference temperature
3. Generate your own paired reference temperature table
4. Using the new AbsoluT for calibration: to keep the consistent calibration value, use the corrected temperature generated in step 3

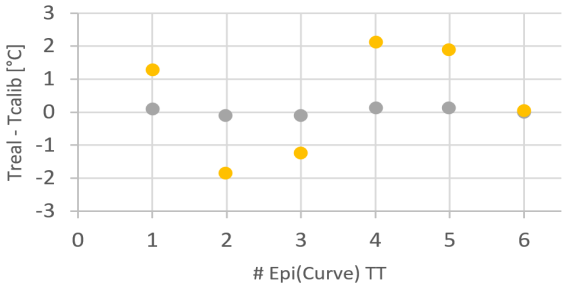

Fig 2: Sketch of the comparison between the two options: The calibration with paired reference temperatures (option 1 in gray) leads to very accurate calibration results. The calibration with self generated paired reference temperature (option 2 in yellow) mirrors the results of the original calibration with the old AbsoluT device.(Simulated data)

Recommendation

Generally, it is recommended to use a new generation AbsoluT due to its higher stability and accuracy. It is recommended to use the paired reference temperature for calibration, especially for new fabs/systems. In case of qualified processes, quality control specifications or other reasons, the method for keeping a consistent calibration is possible. In any case it is necessary to decide for one of the options and not mix them.

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