PTB news
Metrology
Technology
Services
Cooperation
98.2

Thin-Film Multijunction Thermal Converter at Production Stage

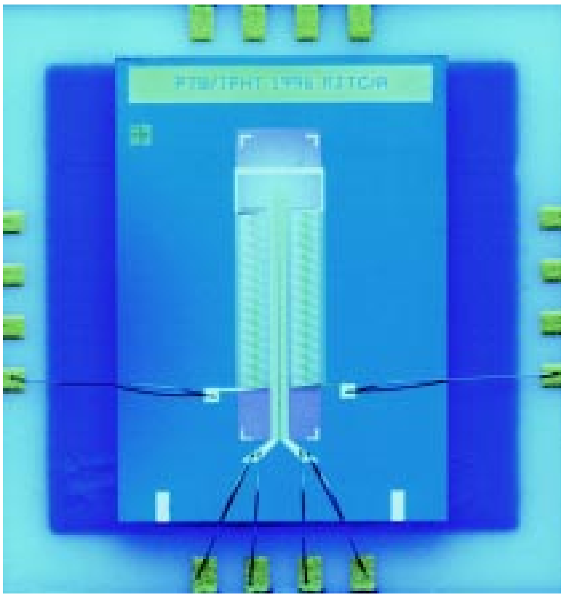
The thin-film Multijunction Thermal Converter (MJTC) jointly developed by PTB and IPHT (Institut für Physikalische Hochtechnologie, Jena) is today's most sensitive and accurate standard for the precise measurement of electrical ac quantities in the frequency range from 10 Hz to 1 MHz. Thin-film technology and micromechanics in silicon paved the way for this success.

Thermal converters are based on the equivalence of the Joule heat generated by either ac or dc quantities in a resistor. The Joule heat leads to a temperature increase of the resistor (heater), which can be measured with high sensitivity by thermocouples distributed along the heater and connected in series.

The new planar converter is designed on a small silicon chip. It is the successor to the earlier developed three-dimensional MJTC of PTB, which was hard to manufacture in a manual process under the microscope using wires of only 10 µm in diameter. The most attractive high sensitivity of the new converter comes from the thin-film heater and the bismuth-antimony thermocouples with high Seebeck effect which are deposited on a thin membrane of low heat conductance. This enables voltages to be measured down to 100 mV. The ac-dc voltage transfer differences of the MJTC are smaller than $2 \cdot 10^{-6}$ up to 100 kHz and below $20 \cdot 10^{-6}$ up to 1 MHz. New transfer standards for voltages up to 1000 V, based on these converters, can be used for calibration with a relative uncertainty of $2 \cdot 10^{-6}$ in the frequency range from 40 Hz to 50 kHz. As a result of this development, DKD calibration laboratories are already now leading worldwide in ac voltage measurements.

Cost-effective production of the thin-film MJTC has started at IPHT. The first hundred converters have been delivered to national metrology institutes. In future, these converters will constitute the basis of worldwide uniform measurements of ac quantities.

For further information please contact M. Klonz, fax: (+49 531) 592-22 05, email: manfred.klonz@ptb.de



Thin-film Multijunction Thermal Converter
100 bismuth-antimony thermocouples connected in series measure the temperature increase of a NiCrSi-thin-film resistor deposited on an 800 nm dielectric membrane of 1,3 mm × 5,2 mm area.

Metrologists from All Over the World Meet in Braunschweig

During the week from 15 to 19 June 1998, more than 200 metrologists from more than 80 countries and representatives of 17 international and regional organizations came to Braunschweig to participate in a seminar dealing with «The role of metrology in economic and social development». The main purpose of the seminar was to provide a forum for discussion of the special challenges which result for metrology from the increasing globalization of economic activities.

The seminar was held on the initiative of PTB in cooperation with the principal organizations supporting worldwide cooperation in the field of metrology: the International Bureau of Weights and Measures (BIPM), the International Organization of Legal Metrology (OIML), and the International Measurement Confederation (IMEKO). International cooperation has a long-lived tradition among metrologists, and the metrological prerequisites for world trade have already been established in 1875

continued on page 2

Metrologists from All Over the World Meet in Braunschweig
continued from page 1

when the Metre Convention for the introduction of the metric system came into force.

Nevertheless, the complex current problems of the protection of the environment and climate, of the reliability of technological applications, and of the quality assurance of products require new efforts to safeguard uniform, correct and reliable measurements all over the world. The participants in the seminar discussed the question of how this goal can be achieved.

Representatives of the World Trade Organization (WTO) and of the UN Conference on Trade and Development (UNCTAD) as well as donor organizations supporting the establishment of metrological infrastructure informed on programmes to meet the global challenges.

Among the widely diversified topics covered by the extensive exchange of information and experience, the main subjects were:

- The significance of a reliably functional metrology for economic and social development
- The establishment and further development of a national metrological infrastructure, in particular for development countries and countries in transition towards a market economy
- The necessity for active regional and international cooperation aiming at a worldwide uniform metrology and also serving as a prerequisite for the international acceptance of calibration certificates
- Model programmes for information and support, especially of small-scale and medium-scale industries in the metrological and related fields.

For further information please contact E. Seiler, fax: (+49 531) 592-82 25, email: eberhard.seiler@ptb.de

Silicon Metrology

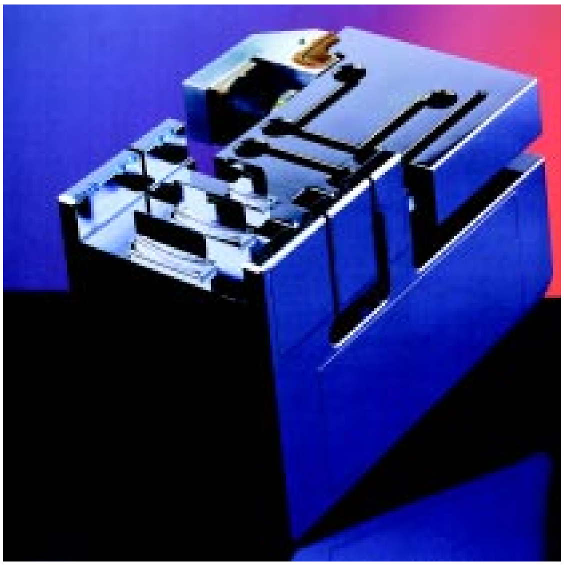
In a collaboration of PTB with other national metrological institutes the lattice parameter of well-characterized silicon single crystals has been determined for use as a dimensional physical constant in precision metrology.

Perfect single crystals of silicon are excellently suited for a variety of metrological applications which are based on the lattice parameter of the silicon crystal. An example is the calibration of length and angular measuring devices used in nanometrology. Another example is the determination of Avogadro's constant and consequently of the atomic mass unit. The precise determination of these quantities can give way to a new realization of the mass unit kilogram which could eventually supersede the present definition by the kilogram prototype.

However, the perfection of real silicon crystals is limited by lattice perturbations due to variations of the impurity contents, dopants, point defects, isotope ratio, or due to conditions of the crystal growth process. These result in actual relative variations of the lattice parameter of up to 10^{-5} and relative variations of the density up to several 10^{-6}.

These effects are currently under investigation in the silicon metrology programme of PTB, utilizing different methods such as infrared microscopy, prompt (n, γ) spectroscopy, x-ray diffractometry and x-ray topography. High-precision density measurements performed at PTB and x-ray topographic investigations at the National Institute of Standards and Technology (USA) indicated the existence of tiny voids or gas-filled bubbles with diameters in the nanometre region which are created during the cooling-down phase of the crystal from the melt.

These investigations show that a small uncertainty of the lattice parameter can only be reached with a well-defined crystal growing process. In collaboration with the Istituto di Metrologia «G. Colonetti» (Italy) and the National Research Laboratory of Metrology (Japan) it has now been shown by precise measurements that the lattice parameter can be reproducibly realized as a dimensional physical constant with a relative uncertainty of $1 \cdot 10^{-8}$ by means of silicon crystals, provided that the relevant environmental conditions such as temperature or pressure are kept with sufficient accuracy during the crystal growing process.



Monolithic x-ray interferometer cut from a silicon single crystal for calibration of length measuring devices
The x-ray Moire structures generated by the three crystal lamellae on top of the device allow to resolve the displacement of the movable part in the hundred picometre regime.

The sophisticated methods of Silicon metrology presently developed are also expected to find increasing industrial applications as the electronic industries proceed towards the era of Gigabit silicon memory chips.

For further information please contact P. Becker, fax: (+49 531) 592-60 15, email: peter.becker@ptb.de

PTB*news* 98.2
English edition
August 1998

Published by
Physikalisch-Technische
Bundesanstalt (PTB)
Braunschweig and Berlin
Germany

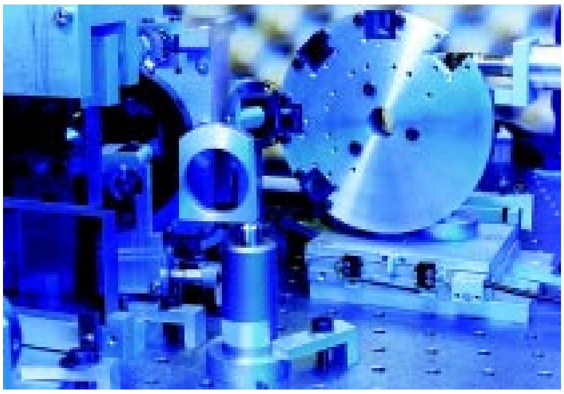
Chief Editor *Burkhard Wende*
PTB, Abbestr. 2–12
D-10587 Berlin
phone: (+49 30) 3481-480
fax: (+49 30) 3481-503
email: ptbnews@ptb.de

Novel Method for Calibration of Photodiodes

A new and fast method for broad-band secondary calibrations of silicon photodiodes against transfer standard detectors has been developed by PTB. The new method is based on Fourier-transform spectroscopy and allows measuring the spectral responsivity ratios of three unknown photodiodes compared to a reference photodiode from 200 nm to 1000 nm with an uncertainty of 0,05 % within 10 minutes.

Today, a spectral responsivity scale for radiation detectors with an uncertainty of 0,01 % in the visible and near IR and of 0,2 % in the UV can be realized by primary calibration of silicon photodiodes as transfer standard detectors at a cryogenic radiometer. However, calibrations at a cryogenic radiometer are lengthy and costly. Therefore the scale is normally disseminated by means of photodiodes calibrated against transfer standard detectors using a spectral comparator based on a monochromator. This kind of secondary calibration can be largely automated, but it still remains time consuming.

A new and fast method has been developed for broad-band secondary calibrations of photodiodes against transfer standard detectors, which is based on the use of a Fourier-transform spectrometer (FTS). The new method does not require any exchange of the light source, grating, or higher-order filter at all. With the present setup, only 10 minutes are required to measure the spectral responsivity ratios of three unknown photodiodes compared to a reference photodiode from 200 nm to 1000 nm with an uncertainty of 0,05 %. This small uncertainty was verified by measurements using intensity-stabilized laser radiation at 12 wavelengths between 238 nm and 1000 nm. The method has already been successfully utilized for investigations of the UV-stability of photodiodes which would have been prohibitively time-consuming otherwise.



The photodiodes to be calibrated and the reference diode are mounted on a detector wheel in the Fourier spectrometer.

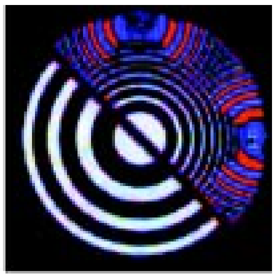
Combining the uncertainty of the new secondary FTS calibration method with the uncertainty of the primary calibration of the reference diode at the cryogenic radiometer results in a total uncertainty of 0,05 % in the near IR and the visible and of 0,2 % in the UV. This shows that an efficient, practicable way has been found to provide customers with photodiodes as working standards of spectral responsivity for wavelengths from 1000 nm down to 200 nm with adequate uncertainties.

For further information please contact L. Werner, fax: (+49 30) 3481-490, email: lutz.werner@ptb.de

Benchmarking Digital Cameras

High-precision measuring facilities have been developed at PTB to assess the imaging performance of digital still-picture cameras.

The rapidly growing use of electronic digital image acquisition systems in industrial imaging, machine vision, remote sensing, medical imaging, optical metrology, and digital photography call for new metrological definitions and procedures because many of those developed for conventional chemical photography are no longer applicable.



Small part of the ISO test chart for resolution measurements (left) and image taken with a digital still camera showing colour artefacts (right)

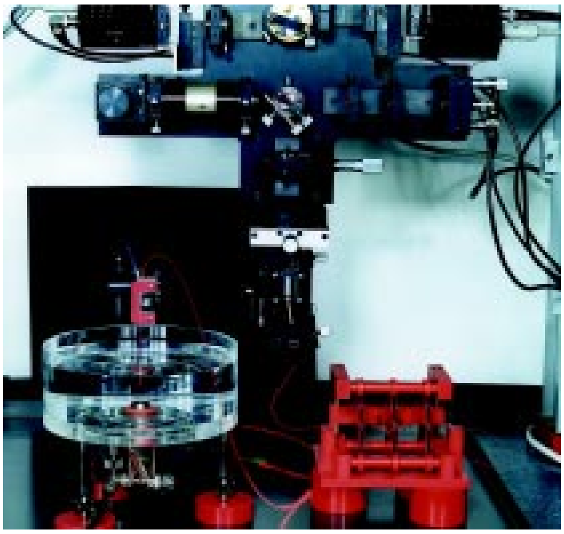
Due to the specific properties of these digital camera systems which include different methods of built-in data processing, a standardized, objective comparison of different cameras was not possible up to now. Therefore PTB is engaged since 1992 in the development of new ISO standards which are to standardize definitions, dimensions, and methods for measuring and testing in the field of digital still photography. Currently, seven different ISO standards are being developed, some of which have already reached the final international draft status.

Along with these standardization efforts, PTB has set up a facility to develop and implement appropriate measuring techniques for the determination of the relevant parameters of digital still cameras such as resolution, modulation transfer function, characteristic curve, speed, and noise. The new facility will allow measurements according to the new ISO standards. The facility is now already available to customers who need high-precision measurements and traceability to the national standards, for instance in the course of an ISO 9000 certification.

For further information please contact M. Schulz, fax: (+49 531) 592-4015, email: michael.schulz@ptb.de

Fibre-optic Ultrasound Sensors

PTB has developed new fibre-optic sensors for ultrasound detection with high spatial and temporal resolution. The sensors promise novel applications.



Fibre-optic ultrasound sensor with optical interferometer

Precise measurement of the sound pressure in ultrasonic fields is of great importance in a variety of technical and medical applications. Small-sized sensors with high temporal and spatial resolution which can be calibrated and used in fluid media are of particular interest to optimise ultrasonic field configurations in commercial devices or in sonochemistry. The sensors may furthermore find application in the characterization of the acoustic output of clinical devices and in the investigation of problems of basic research such as stone disintegration processes in shock-wave lithotripsy or biological effects of high-power ultrasound, for example.

PTB has developed two different sensors using fibre tips as active elements. One sensor uses a metal coated tip of a fibre which forms the measuring arm of a Michelson interferometer. If the fibre tip is placed in the field of an ultrasonic source its front facet is moved by the acoustic pressure, and the corresponding change in the optical phase is measured by the interferometer. This sensor was calibrated in the frequency range from 0,5 MHz to 50 MHz and applied to measure shock waves generated by commercial lithotripters.

The recently developed second sensor system uses dielectric optical layers deposited on the fibre tip forming a Fabry-Perot interferometer. Its deformation by the incident pressure wave is detected by an optical reflectivity measurement system. Compared to conventional systems, this results in a signal-to-noise ratio which is about 15 dB higher. The reduced technical expense of the novel fibre-optic hydrophone and the simplicity of the method allow easy modification for optimum adaptation to the actual measurement problem. These improvements are expected to lead to new commercial applications in ultrasonic measurements requiring high spatial and temporal resolution.

For further information please contact Chr. Koch, fax: (+49 531) 592-10 15, email: christian.koch@ptb.de

Laser Pulse Mammograph

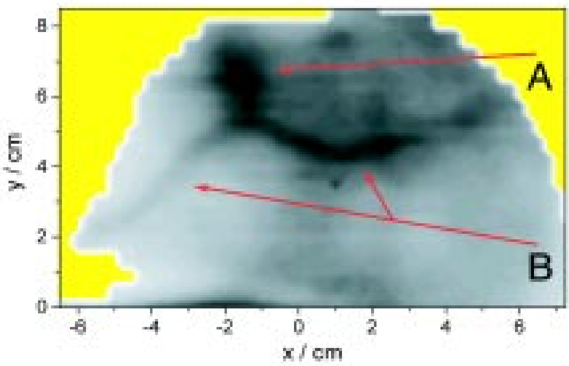
A prototype laser pulse mammograph has been developed at the PTB to detect tumors of the female breast by measuring its absorption and scattering properties for near-infrared light.

Although x-ray mammography is the method of choice to detect breast cancer and is routinely used clinically, it still suffers from false positive diagnoses. Therefore, other techniques such as ultrasound mammography are employed to obtain additional information. A prototype laser pulse mammograph has been developed at the PTB, which allows to determine absorption and scattering properties of breast tissue for near-infrared light. In principle, physiological information about breast tissue and pathological alterations can be obtained in this way.

In order to record an optical mammogram the transmittance of short (0,4 ns) near-infrared laser pulses produced by a diode laser is measured through the slightly compressed breast at a large number (1000 to 2000) of scan positions. Multiple scattering of photons inside the breast tissue broadens the laser pulses up to several nanoseconds. The distribution of times of flight of photons is recorded by means of time-correlated single photon counting at each scan position. From such distributions, the absorption and scattering properties of the breast tissue are derived and used to generate optical mammograms. Furthermore, transillumination images of improved contrast between tumor and surrounding healthy tissue can be obtained from photon counts in suitably chosen time windows of the measured distributions of times of flight. The prototype is capable of recording mammograms along different projection directions within 3 to 5 minutes each.

Up to now, optical mammograms of five patients have been recorded in collaboration with the Robert-Rössle-Klinik (Berlin-Buch). Tumors also visible in x-ray and magnetic resonance mammograms were detected due to their larger absorption of the near-infrared laser radiation compared to the surrounding breast tissue. Future studies are needed to assess the potential of optical mammography for clinical diagnostics, in particular as a supplement to x-ray mammography.

For further information please contact H. Rinneberg, fax: (+49 30) 34 81-505, email: herbert.rinneberg@ptb.de



The optical mammogram of the left breast of a patient was generated from photon counts. Besides blood vessels (B), a tumor (A) ($x = -1{,}75$ cm, $y = 6{,}5$ cm) with a size of 2,5 cm is visible due to its increased absorption.