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O. Breitenstein M. Langenkamp

Lock-in Thermography

Basics and Use for Functional Diagnostics of Electronic Components

With 61 Figures
Including 24 Color Figures

Springer

Dr. Otwin Breitenstein
Dr. Martin Langenkamp*
Max-Planck-Institut für Mikrostrukturphysik
Weinberg 2
06120 Halle, Germany

*Present Address:
Peter Wolters Surface Technologies GmbH & Co. KG
Büsumer Strasse 96
24768 Rendsburg, Germany

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Preface

Although the first publication on lock-in thermography appeared in 1988 concerning electronic device testing, this technique only became popular in the 1990s in connection with the nondestructive testing of materials (NDT, especially photothermal and thermoelastic investigations). In the early 1990s our group at the Max Planck Institute of Microstructure Physics in Halle had the task to image small leakage currents in silicon solar cells. We soon realized that neither conventional (steady-state) thermography nor the only available lock-in thermography system of that time was sensitive enough to image the tiny temperature differences caused by these leakage currents. Therefore we developed the "Dynamic Precision Contact Thermography" technique (DPCT), which was the first lock-in thermography system having a detection limit below 100 µK. However, this system turned out to be too impracticable for general use, since it worked in a mechanical contacting mode, and its measurement time was necessarily many hours. With the availability of highly sensitive focal plane array thermocameras at the end of the 1990s, the way was opened to construct highly sensitive IR-based lock-in thermography systems. This was done independently by groups working in NDT and by us working in electronic device testing, whereby the different demands in the different fields lead to partly different approaches in the realization. For photothermal investigations a low lock-in frequency is usually used in order to see sub-surface details, and for thermoelastic investigations the thermocamera cannot usually be synchronized to the temperature modulation. In electronic device testing, on the other hand, the main challenge was to achieve a noise level as low as possible and to work at high frequencies in order to detect weak heat sources at the surface with a good spatial resolution. For NDT the heat introduction is usually harmonic and is realized externally, e.g. by light irradiation, ultrasonic incoupling, or mechanical vibration. In electronic device testing the heat introduction has to be rectangular and is realized internally by applying bias pulses, which can easily be synchronized to the thermocamera. It emerged that our highly sensitive lock-in thermography system is very useful not only for investigating solar cells, but also for many other kinds of electronic device testing such as integrated circuit (IC) testing, characterizing bonded semiconductor wafers, and mapping gate oxide integrity (GOI) defects in MOS devices. Our developments led to the construction of the TDL 384 M 'Lock-in' system at Thermosensorik GmbH Erlangen (Germany), which has been available since 2000 and is specialized for the functional testing of electronic components. For the above-mentioned reasons, this system differs considerably from those constructed for NDT purposes.

This book addresses, in particular, the application of lock-in thermography for the functional testing of electronic devices. Deliberately we have not treated here the issue of theory and practice of infrared technology for NDT, since this topic is thoroughly covered e.g. in the recently re-edited book of X.P.V. Maldague. However, the technique of lock-in thermography is only briefly considered in that book, without even mentioning that it can also be used for electronic device testing. Since we are convinced that lock-in thermography will play a considerable role in electronic device testing in future, and since many of the physical and technical details of this technique are so far only described in the original literature, we believe that this book will be useful to everybody wishing to use lock-in thermography, especially in electronic device testing and failure analysis. There is some original material first published here, such as the technique for correcting temperature drifts and some new aspects for deconvoluting thermograms, which may also become interesting in the field of NDT. We have tried to restrict the mathematical treatment to the extent necessary for understanding the basic principles of the technique. Thus this book will be useful not only for physicists but also for technicians, engineers, and students who wish to become acquainted with the technique of lock-in thermography. Readers are encouraged to inform the authors about any errors found in this book or to propose further topics which could be included in a later edition.

Halle/Saale,
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Otwin Breitenstein
Martin Langenkamp

Contents