Thermal influence of interfaces in epitaxially grown superlattices

M. Grashei, G. Böhm, R. Meyer and M.-C. Amann

Walter Schottky Institut, Am Coulombwall 4, Germany

Today, a large variety of epitaxially grown opto-electronic devices exists, which have to fulfill several requirements according to their operating conditions. Opto-electronic devices are often limited by the operation temperature and an optimized thermal design is necessary to achieve maximum performance. For instance, heat removal in a vertical cavity surface emitting laser (VCSEL) is limited by the thermal conductivity of the cavity and the distributed Bragg reflector (DBR). Especially in an upside-up design, the DBR limits the heat removal, since the superlattice (SL) often contains ternary and even quartenary materials of varying, but usually very low, thermal conductivities and corresponding interfaces between these materials. Whereas the thermal conductivities of the bulk-materials are usually well known, the influence of interfaces remains often unclear or is neglected.

Here, we present an investigation of the interface influence on the thermal properties of epitaxially grown superlattices.

For determination of the thermal properties we employed the 3-ω-method which was introduced by D. Cahill in 1987[1] and is widely used for film-on-substrate thermal characterization (see Fig 1. Inset).

The principle is based on the excitation of thermal waves, which penetrate into the sample. From the temperature rise in the heater stripe the thermal properties can be calculated.

A set of samples with constant total film thickness d_F but varying number n from 1 to 512 of GaAs/AlAs-superlattice pairs of equal layer thickness was grown with a Varian Gen II MBE-system.

Platinum stripes were photolithographically fabricated on top of the samples for harmonic Joule heating. By measuring the temperature rise in the heater for each sample we can determine the different thermal resistances of the samples with varying number of SL-pairs.

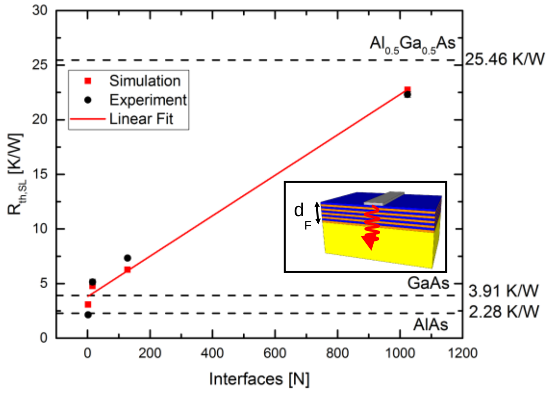

Fig. 1: The thermal resistance of a superlattice increases linearly with number of the interfaces. Reference values of bulk film are plotted as dashed lines. Inset: Thermal waves, excited by an oscillating current in the heater stripe, penetrate into the epitaxial superlattice to determine the influence of interfaces on the thermal conductance.

We can attribute these differences directly to the thermal resistance of the interfaces, since the overall thickness of the superlattice is kept constant. In addition, we verified our results via heat transfer simulations in Comsol Multiphysics and compared them to additionally measured data from a ternary $Al_{0.5}Ga_{0.5}As$ film. By accurate thermal modeling of the entire multilayer structures, knowledge for further thermal design of opto-electronic devices and related epitaxial growth of multilayer-structures can be gained. From Fig. 1 we identify good agreement between experiment and simulation together with a linear increase of the total SL-thermal resistance as a function of the interface number, which is a superposition of additional one-dimensional thermal interface resistances and two-dimensional heat spreading effects in the multilayer structure.

[1] David G. Cahill, R. O. Pohl, *Phys. Rev. B*, **35**, 4068-4073 (1987).

*Contact martin.grashei@wsi.tum.de
gerhard.boehm@wsi.tum.de