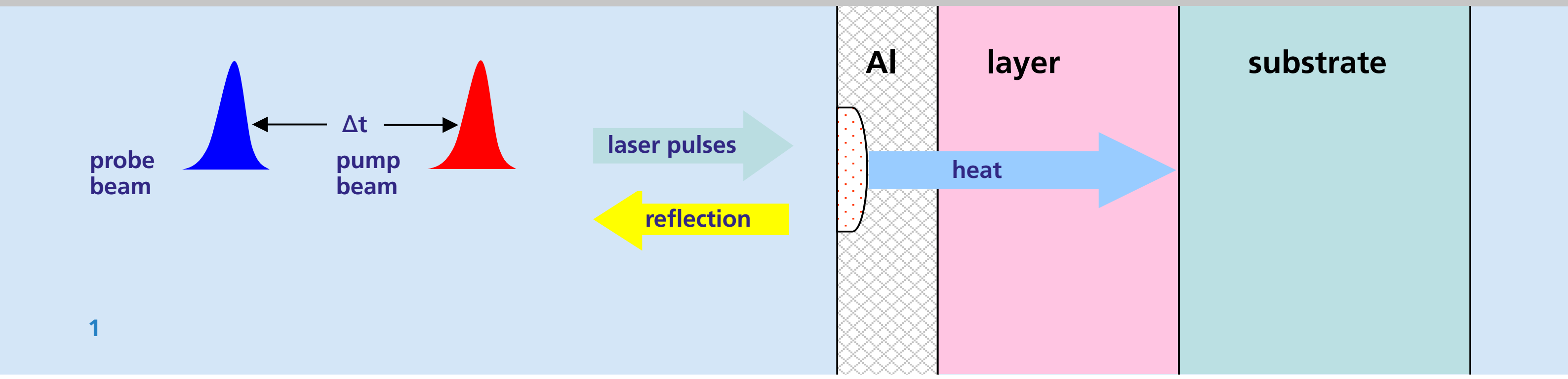

1 *Basic principle of the TDTR method. A »pump« beam heats a localized region of the sample. The temperature change causes a change in the layer's reflectivity. The »probe« beam hits the layer after a time span of Δt and detects the change in reflectivity.*

TIME DOMAIN THERMAL REFLECTANCE (TDTR)

MEASURING THE THERMAL CONDUCTIVITY OF THIN FILMS

In many high-tech products, materials formed of thin layers just a few nanometers or micrometers thick are deposited on a substrate, where they perform specific functions. For many applications, the thermal conductivity of these materials has to be known. However, these values cannot be taken from literature since they are strongly dependent on the crystalline film structure and, mostly, only values for bulk material are given. This is why special measuring methods are required for characterizing thin films.

The TDTR method

The time-domain thermoreflectance (TDTR) method provides an effective, inexpensive and relatively fast method for measuring the thermal conductivity of thin layers. Working on the basis of a pump-and-probe process, it uses two laser beams with different beam paths. Firstly, a pump beam is directed onto the surface of the sample, which is heated as a result of absorbing some of the beam power. The heat diffusion and temperature on the surface of the sample depend on its properties, in particular the thermal conductivity of the individual layers. The reflectivity, i.e. the proportion of the laser beam that is reflected from the surface of the sample, is influenced by the temperature. This means that the surface temperature can be determined by a probe beam that falls onto the sample surface after the pump beam with a time delay of Δt. The reflected probe beam consequently provides information about the surface temperature of the sample and its thermal properties. The reflected probe beam falls on a photo diode, allowing to retrieve the measurement data. A mathematical model is fitted to the

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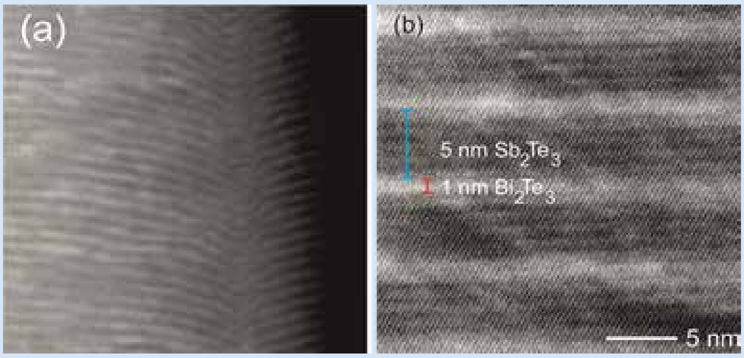

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acquired measurement data and used to determine the thermal conductivity of the layer in question.

temperature or for higher sample temperatures up to 550 °C (maximum achievable temperature depending on sample).

Benefits of the TDTR method

The TDTR method is able to characterize both individual layers and multilayer coating systems with layer thicknesses spanning a few nanometers to a few micrometers or millimeters. It is also possible to determine the thermal conductivity of bulk materials. Generally speaking, any type of material can be measured, from polymers to ceramics and metals or glass. The sample is very easy to prepare, as a thin Al layer simply needs to be deposited before the measurement is carried out, without the need for any further structuring. The measurements can be performed at room

Applications

Thermoelectric thin films

The performance of thermoelectric devices is dependent on the ratio of electrical to thermal conductivity. The possibility of using nanostructures to lower the thermal conductivity of thermoelectric materials is currently being investigated. One example is the creation of stacks of layers with thicknesses in the nanometer range, which are known as superlattice systems (figure 3). Here, the TDTR method was able to demonstrate that superlattices of this kind can reduce the thermal conductivity of the layer system by more than 50 percent.

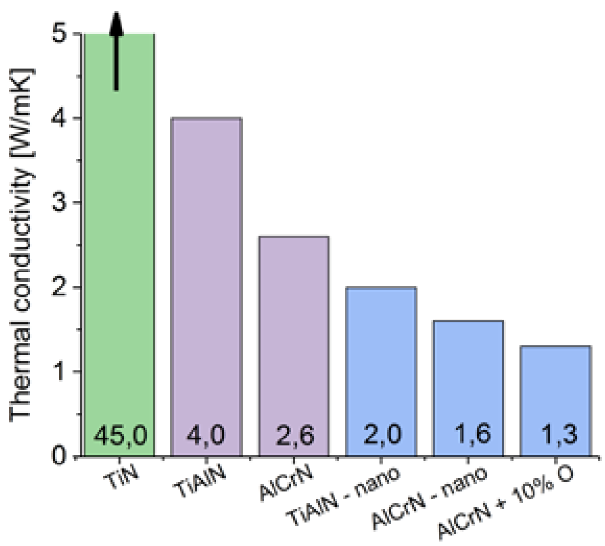
Hard coatings

To minimize wear and corrosion, machining tools are protected with a hard coating, such as titanium nitride (TiN) (figure 2). During use, these tools are often exposed to high temperatures. In order to understand how the protective layers and tools respond to such temperatures and to optimize these layers, one must be familiar with their thermophysical properties such as thermal conductivity. However, this information is rarely documented for the deposition techniques used. We used TDTR to determine the thermal conductivity of various coatings during a recent collaboration project (figure 4).

Measurement services

We analyze the thermal conductivity of your materials. Don't hesitate to get in touch!

4 TDTR MEASUREMENTS OF THERMAL CONDUCTIVITY OF VARIOUS HARD COATINGS



F. Barthelmä, H. Frank, M. Schiffler, PVD-Hartstoffschichten zur Zerspanung hochfester Werkstoffe, WOMag WOTech Technical Media, 2016, DOI: 10.7395/2016/FrankH1

2 *Indexable cutting inserts with TiN protective coatings. In order to enhance the properties of such protective coatings, it may be necessary to determine and optimize their thermal conductivity. This can be achieved using the TDTR method.*

3 *Superlattice layered stacks made of the thermoelectric materials Bi_2Te_3 or Sb_2Te_3. TDTR measurements have proven that these nanoscale superlattices are capable of significantly reducing thermal conductivity in comparison to homogeneous materials.*

4 *Compared to compounds of two elements such as TiN, AlN and CrN, the thermal conductivity of solid solutions of three elements such as TiAlN and AlCrN is lower by orders of magnitude. Adding nanostructures and oxidation further reduces thermal conductivity.*