Abstract
The measurement of micro components and microstructures leads to special requirements of measuring gauges. State-of-the-art Confocal Laser Scanning Microscopes (LSM) are suited to meet these requirements. The paper shows examples of effective and accurate analyses of micro tools, micro components, and micro structures with a LSM. It becomes clear, that measurements with a confocal LSM lead to verifiable results in a very fast and simple way.

Introduction
The manufacturing of micro components of a volume smaller than 1 mm³ is of increasing importance for industry. Recently achieved technological improvements for the manufacturing of these components lead to a steadily increasing number of applications. The transfer of optimized traditional manufacturing technologies to micro system technology allows the manufacturing of smallest three-dimensional structures with accurate dimensions and geometries. Though, traditional measurement principles are often not sufficient to specify the manufactured structures. In contrast, the requirements on the quality of micro products are very high and are even growing by the increasing miniaturization /1/. For the measurement of microstructures, a measurement system has to be chosen that meets the following requirements:

- measurement of structure dimensions in a range of (sub-) micrometers with nanometer accuracy,
- damage-free measurement,
- wide measuring range,
- high vertical and lateral resolution,
- 3D measuring,
- various measuring possibilities (roughness, waviness, form accuracy, macroscopic geometry characteristics),
- high measuring speed with high measuring accuracy,
- simple use and
- possibility of automation.

Components are micro-scaled components (e.g. micro gear wheels), small components with variable micro structures (e.g. lab-on-chip structures) and macroscopic components with even or uneven micro-structured surfaces (e.g. dies or foils with structure dimensions in the range of a few micrometers). These examples demonstrate that the quantity, the material, and the dimensions of the basic geometry of manufactured workpieces are absolutely variable. Furthermore, measurements have to be carried out under laboratory conditions as well as under production conditions.
In case of measuring micro structures, the use of measuring systems is limited because of the dimensions of the gauge and a possible damaging of the surface. High performance measuring systems such as Atomic-Force-Microscopes (AFM) have extremely high resolutions, their measuring period, however, is far too long. It is especially the AFM, which is limited to a few micrometers in the vertical range. Optical systems such as auto-focus measuring systems or interferometers have typical disadvantages measuring steep slopes or structures with high aspect ratios.

State-of-the-art confocal laser scanning microscopes (LSM) are suited to meet the requirements listed above. The advantages like excellent contrast, the suppression of scattered light and improvement of lateral resolution are well-known /2/. The use of modern and efficient drive systems and computers results in further crucial advantages. Requirements of the daily use of confocal LSM are subject to research and are often transferred to commercial products /3/.

**Measurement Tasks**

Two representative examples of the great variety of possible measuring tasks are used to explain the functionality of confocal LSM for the analysis of micro structures. These examples are shown in figure 1 and 2 as SEM images. The measurement tasks at these components are multifaceted and challenging. The exact knowledge of the measuring task and basic knowledge about the measuring principle are the prerequisites of accurate measuring results.

Example 1 (Figure 1) shows a triple-edged micro end mill with a diameter of 0.5 mm. It serves the measurement of the topography of the face and the wear characteristics (cutting edge radius and crater wear) visible in this view.

A hot embossing tool is shown in figure 2. The tool is manufactured by path programmed electrical discharge machining (EDM) with rotating pin electrode. The dimensions x, y, z are 2 mm x 2 mm x 1 mm. One of the measuring tasks is to analyze the process and any changes in the tool length by accurate measurement of the path bottom. Another task is the analysis of the cavity profile to measure the wear of the tool diameter. This also requires the measurement and the depiction of the slopes.

![Figure 1: Micro End Mill](image1.jpg)  ![Figure 2: Hot Embossing Tool](image2.jpg)
Measurements and Results

Micro End mill

The analysis of the tool leads to excellent results. The imaging of the tool is realized by a stack of 50 slices. This allows the interpretation by iso-lines and an excellent valuation of the wear. Figure 3 shows that the signs of wear are very clear and to analyzable in terms of quality and quantity. An exact statement can be made on the wear pattern of the mill through the comparison of the measured data before and after machining. Today, there is still a lack of knowledge about the wear pattern of micro end mills under manufacturing conditions. The presented method can be used close to the manufacturing process. Furthermore, the flexibility of confocal LSM allows the analysis of tool and workpiece. The measurement conditions and the results can be thus compared.

![Image of LSM image of the face of the micro end mill (left), resolution 512 x 512 pixel, objective 20x/0.50, median-filtered; measurement of the abrasive wear at a cutting edge (right)](image)

Figure 3: LSM image of the face of the micro end mill (left), resolution 512 x 512 pixel, objective 20x/0.50, median-filtered; measurement of the abrasive wear at a cutting edge (right)

Hot Embossing Tool

The used technology allows a determination of the summarized tool length wear by measuring the height of the path bottom at the beginning and at the end of the programmed path (figure 4, right). This value gives no information about the wear pattern of the electrode during the manufacturing process. It is, however, sufficient for the rough programming of the feed of the electrode during the process. The analysis of the proceeding tool wear requires the measurement of the whole cavity and all its characteristics.

The capability of measuring steep slopes is one of the most important advantages of confocal LSM. A minimal roughness is necessary to get an image of slopes of an angle near 90° without any extra equipment. Thus, a damage-free analysis is possible without any cleaning process. Though, an objective with high resolution and numerical aperture must be used to achieve best results. Therefore, the lateral dimensions of a measuring field are often too small to fulfill the measuring tasks. A stitching tool is used to analyze the whole hot embossing tool and the wear pattern of the electrode. Depth and width of the path...
must be measured at any point of the path by the evaluation of profiles through the stitched image of the cavity (figure 5).

Figure 4: Single image of the hot embossing tool with points of start and end of the programmed paths (left), resolution 512 x 512 pixel, objective 20x/0.50, median-filtered; measurement of the length wear (right)

Figure 5: 3D image of the hot embossing tool, 3 x 3 single images (left), resolution 256 x 256 pixel, objective 20x/0.50, median-filtered; Measurement of the wear of the diameter (right) of the electrode

3D-Stitching

In material research, quality inspection, and micro production technology, there is often a rather large number of samples to be examined. Therefore, they can only be imaged with a low-power objective. Details get lost and have to be enlarged subsequently in additional detail micrographs. In combination with a motor-driven scanning stage a confocal LSM acquires, assembles, and measures height profiles over
long distances and large-area portions. Because of a large number of stacks and single measuring fields, there is a big amount of data to be processed. ZEISS is still in the process to file a patent for the algorithm that is used for the LSM series. This algorithm saves time and effort in the necessary calculation.

The most important advantage of this option is shown in figure 6. The quality of the vertical and lateral resolution of a stitched image is much higher than a single image. For the practical use, the software integrates many automatic procedures and adjusting functions, e.g. auto-focus, automatic brightness, and contrast optimization, automatic orientation of the scan field and precise correction of the objective’s residual field curvature.

Figure 6: Detected intensity by use of the objectives 2.5x/0.075 (left) and 20x/0.5 (right)

Conclusion

Confocal Laser Scanning Microscopy is suitable for the measurement of microstructures. With the help of representative examples, the practical use could be demonstrated. It is clear that this measuring principle is capable of three-dimensional imaging of microstructures with high lateral and axial resolution. The imaging of steep slopes is another important advantage. The big variety of functional analyses allows a very flexible use of the gauge in laboratories and close to the manufacturing process.

The requirements of special measurement tasks result from the daily use of a gauge. Manufacturer and research institutes must work together to solve upcoming problems and to transfer the discovered solutions into commercial products.

