# Creating Solid State Micro Joints through Micro Machining

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**Abstract**

Solid state joints are widely used in Micro Electro-mechanical Systems (MEMS), particularly if the systems are actuated. Solid state joints utilize the inherent compliance of a material, thus eliminating friction, slack, and wear. While micromachined single or poly crystalline Si represents an attractive solution used for micro joints, other materials may be even more advantageous. An example is isostatically hot pressed (HIP) $Al_2O_3$-TiC (Altic). While even superior in material properties, this material does not lend itself for batch fabrication, requiring micro joints to be fabricated by mechanical micromachining. This paper presents a fabrication process based on outside diameter grinding for creating Altic micro joints as well as evaluation results regarding their spring behavior.

## 1 Introduction

The solid state micro joints mostly used are flexures made of micromachined single or poly crystalline Si [1]. While Si material excels in material strength, it is also brittle. A material with even better mechanical properties than Si (especially in regard to fracture toughness) is isostatically hot pressed (HIP) $Al_2O_3$-TiC (Altic). It is a two-phase ceramic among other used for the fabrication of sliders in Hard Disc Drives (HDD) [2]. It is a very tough and extremely hard material suitable for the application in micro assemblies. However, by being a bulk material, it does not lend itself to MEMS type fabrication technologies, typically using a combination of thin-film deposition, etching, and photolithographic patterning. Instead, mechanical microfabrication techniques like dicing and profiling have to be applied [3].

## 2 Micro Joint Design and Fabrication

To demonstrate the capabilities of Altic micro joints, meander type structures were designed. The micro joint is shown in Fig. 1; it consists of two outside clamping parts and five meander elements in between. The wall thickness has the same dimension as the spacing between two adjacent meander walls. As fabrication processes, outside diameter grinding was chosen, allowing both to profiling grooves as well as executing separation cuts (Fig. 1a). The fabrication of such structures required a grinding parameter optimization as well as a development of handling and tape releasing techniques. Dicing was done on an ultra-precision dicing machine DISCO DAC551, located in a temperature controlled room. All the wheels feature a diamond grit size of 45 µm. For a damage-free removal of the parts after micromachining, a thermal-release tape REXPAN RP3 was used. The thermo-release tape was bonded on the surface of a standard blue tape Nitto SWT 20+ and mounted on the dicing machine.

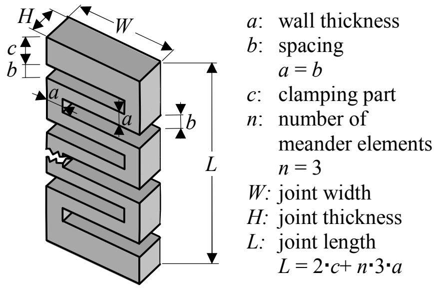


Fig. 1. Meander type micro joint design and dimensions.

Figure 2 depicts the fabrication process executed in three steps. First, U-shaped grooves were machined into one side of the workpiece (Fig. 2a).

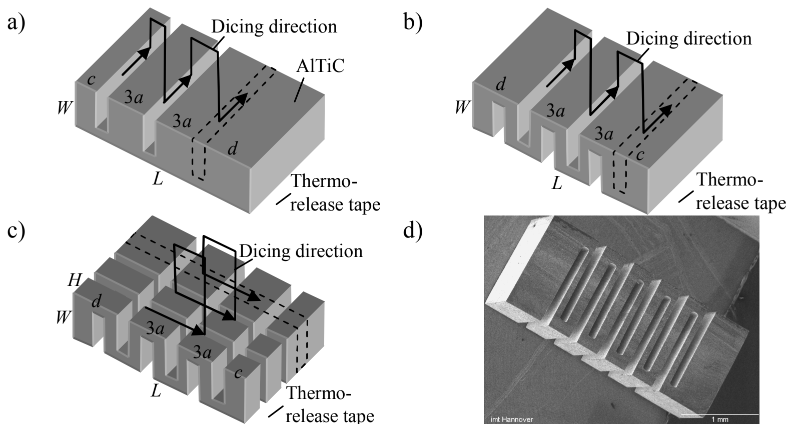


Fig. 2. Fabrication steps: a) Dicing of grooves, b) dicing of grooves into the other side, c) slicing the single parts, and d) SEM micrograph of the micro joint

The thickness of the workpiece corresponds to the desired width of the micro joint. Afterwards, the workpiece was debonded from the thermo-release tape, turned upside down, and bonded again. Then, the same grooves were cut into the other side (Fig. 2b). By using a thermo-release tape, the delicate parts could be debonded without breakage. For the meander walls to be symmetrical, it was very important to define one of the workpiece sidewalls as a reference. The third step was slicing and thus separating the single micro joints (Fig. 2c). This step defined the thickness of the micro joints. As shown in Tab. 1, the joints were fabricated in five different thicknesses. The smallest Altic meander walls / wall-to-wall spacing were 100 µm thick (Fig. 2d). A further miniaturization of Altic meanders was limited by a heavy wear of the dicing wheels for thicknesses below 90 µm.

Table 1: Dimensions of fabricated solid joints

| | *a* [mm] | *c* [mm] | *d* [mm] | *L* [mm] | *W* [mm] | *n* |
|---|---|---|---|---|---|---|
| | 0.1 | 0.5 | 0.7 | 2.5 | 1.2 | 9 |
| *H* [mm] | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | |

## 3 Characterization of the Micro Joints

For determining the spring constant of the micro joints, a nanoindenter was used for causing a deflection. The measurements were conducted with a Hysitron TriboIndenter™ [4]. It allows applying a load between 1 µN and 10,000 µN; the desired displacement range for our measurements was between 200 nm and 1 µm. For applying the load, a conospherical diamond tip with the radius of 1 µm was used. Such a tip allows a deflection of the micro joints without causing an indentation. To achieve a minimal hysteresis, neither a tip penetration nor a tip sliding is desirable. Figure 3 depicts the measurement results.

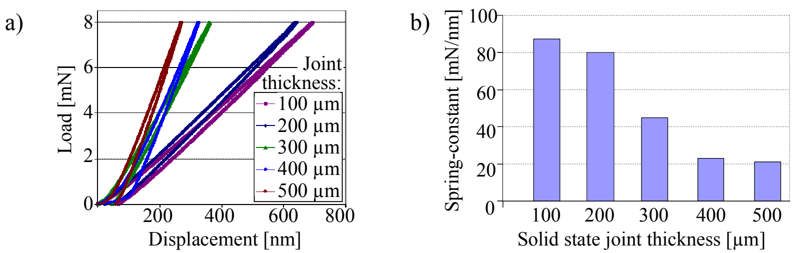


Fig. 3. Characterization of the elastic behavior: a) Hysteresis measurement and b) dependency of the spring constant to the joint thickness

T he micro joints were deflected by a force of 8 mN (Fig. 3a). The tip displacement for the smallest micro joint with a wall thickness of 100 µm was 700 nm. The deflection increases linearly with the applied load. During the unloading, a very small hysteresis of 50 nm occurred. Nonetheless, the spring constant could be determined. Due to the grinding process, a taper occurs. The desired spring width of 100 µm is only achieved on the side the grinding wheel enters. At the other end, the width is 130 µm. The bottom radius of the U-groove edges was 20 µm. Figure 3b presents the results. With increasing the micro joint thickness, the stiffness increases. Between 200 µm and 300 µm joint thicknesses is a bigger gap which indicates the threshold state and thus a stronger influence of the taper.

## 4 Conclusion and Outlook

Micro joints fabricated by mechanical micro machining are an alternative to similar micro joint structures fabricated by applying Si micromachining techniques. It could be demonstrated that the HIP ceramic Altic represents a material well suited for such an approach. By creating meander type structures, mechanically machined solid state micro joints could be created, which exhibit good flexure capabilities. For smaller joint thickness, an influence of the taper must be considered.

**References:**

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