Forming Planar Micro-structures into 3D Objects

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Abstract

A huge variety of micro-sized sensors and actuators are created using methods of Micro Systems Technology (MST). The limitation of this technology is the use of stacked layers so that no real 3D-structures can be created. This barrier can be overcome by combining MST-processes with subsequent forming-processes to transform the flat structures into 3D objects. This is demonstrated in this paper with the forming of a planar coil arrangement into a cylindrical micro motor. This work has been realized in close cooperation with the application center embedded microsystems Bremen (emb).

1 Forming task and development process

A known technology to create relatively large structures with heights of several hundreds of µm is the UV-LIGA process. It uses micro-moulds of SU-8 photo resist that are filled with metallic materials using galvanic processes. This enables the fabrication of very complex and precise metallic structures embedded in an insulating polymer. For example small electric coils can be built up on a wafer using different layers [1], [2], [3]. With this technology inductive micro components and systems for sensing and actuating applications can be manufactured [4]. With a simple arrangement of plain coils it is possible to build the primary part of a micro linear motor [5].

Commonly micro AC motors with an outer diameter of 4 mm are produced with the same technologies like bigger motors. The windings of the stator are built up from copper wire. But at a certain size this method is ineffective due to the small size of the wire and high rejection rates.

To avoid these problems the stator coils of the micro motor are fabricated as a plain arrangement with the mentioned MST processes, Figure 1, left. According to the required function of these coils as stator windings of an AC synchronous motor, a

subsequent forming process is needed to transform the flat arrangement into cylindrical shape, figure 1, right. For getting a higher motor efficiency two layers with three coils each are distributed along the circumference. These layers are shifted 60° against each other. This results in overlapping ends of the cylinder that make the forming process even more challenging, because the steps have to be placed very accurately in the cylindrical form. To reduce the mechanical stress inside the material heat is applied to the process to get a forming temperature of about 180°C.

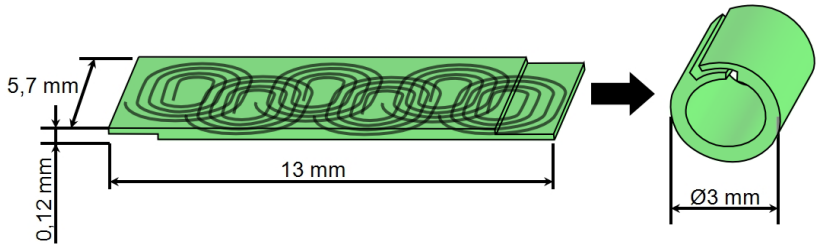

Figure 1: Coil arrangement with overlapping ends

In principle more than one mechanical method can be used to perform this forming operation. For getting optimal forming results a new forming machine has be realized.

2 Optimized forming principle

The forming is realized in a semi-automatic machine especially suited for the use with small and flat workpieces like the coil arrangement of the micro motor, figure 2. A thin metallic band enlaces a small cylindrical pin and the plain coil arrangement is placed and aligned on the horizontal part of the metallic band. By moving the band the workpiece is drawn into the gap between band and pin. A second pin holds down the metallic band to maximize the enlacing angle. This is important to optimize the forming result and to assure that the workpiece rotates several times around the forming pin. So the plain coil arrangement is wrapped around the pin. Plastic and elastic portions of the forming are controlled by heat to set the springback to the given tolerance. After forming the cylindrical coils stick on the central pin. To remove them, the band is automatically lifted from the pin and the cylinder can be

drawn off in axial direction. This forming process is performed within 50 seconds and with good reproducibility.

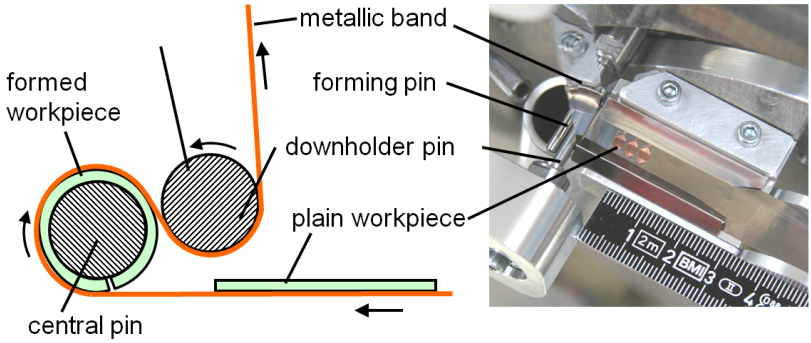

Figure 2: Forming principle

Figure 3, left, shows the result of the forming process of a SU8 Matrix with embedded micro coils. The gap between the ends of the cylindrical workpiece is an indicator of the springback. A defined amount of it is necessary to fix the tube in the cylindrical housing of micro motor, figure 3, right.

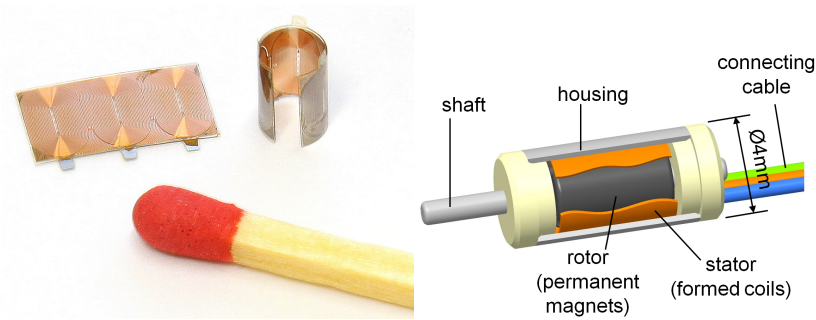

Figure 3: Formed coils and section of the micro motor

3 Conclusion and Outlook

This example shows the capabilities of creating 3D objects by using MST-processes with subsequent forming-processes. The shown machine enables easy and efficient forming of cylindrical stator coils of a micro motor form a MST pre-product. In this

motor the electrical components can fulfill new tasks that are not possible with plain arrangements.

Investigations on other forming steps to create more complicated and smaller 3D shapes of plane MST systems are carried out. Bending of small antennas or the alignment of sensor components to detect measurement values in cartesian space may be further applications.

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