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Ceramic packages prototyping for electronic components by using laser micromilling technology

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Ceramic packages prototyping for electronic components by using laser micromilling technology

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Abstract. The use of adaptive laser micromilling technology for the fast prototyping ceramic package of electronic components in a miniature surface mount form factor (SMD) is describing. Current experimental results and practical evaluation of one show that using the developed software and hardware is possible successfully producing SMD packages starting from the SOT-723 form-factor in the direction of larger overall dimensions to SOT-475 form-factor. Also discussed are the limiting physical factors arising in the course of the application of laser micromilling technology, which affect the production speed and quality of the resulting product from monolithic ceramics.

1. Introduction
The use of pre-made ceramic SMD packages for electronic components requires the adaptation of microelectronic chips topology to the geometry of the package and to adjust the packaging process to the type of package used (glass-metal, sitall-ceramic, plastic). Adaptation is a complex process, especially for MEMS devices, and due to a number of physical reasons it is not always possible. Specialized ceramic packages can be manufactured using LTCC technology, but the process of manufacturing a test consignment takes from 1 to 2 months, is performed in batches (for example, on a frame of 100x100 mm substrates) and costs more than 5 thousand Euro, which is not economically feasible for a multi-product or specialized production of electronic components is always justified, especially when it comes to research involving the process of iterative changes in the topology and geometry of electronic devices based on the results of test debugging. The LTCC production site itself requires from several hundred to several thousand square meters of clean rooms and consumes from several hundred kilowatts to several megawatts of electricity to support the process (purification and regulation of the temperature and humidity of the atmosphere inside).

After a lot of experiments with a large list of glass-ceramic materials widely used in modern microelectronics (ZrO_2, Al_2O_3, LTCC, SiO_2, etc.) [1-5], our research group developed a combination of adaptive laser micromilling technology and inkjet printing for miniature custom-made microelectronic packages for surface mounting manufacture [6-9]. Packages for gas sensors were chosen as the object of our current experiments. Since this subclass of packages meets the most stringent requirements for its operation comparing to the existing list of radio-electronic components - due to work in conditions of increased gas pollution of the atmosphere with toxic and explosive gases,

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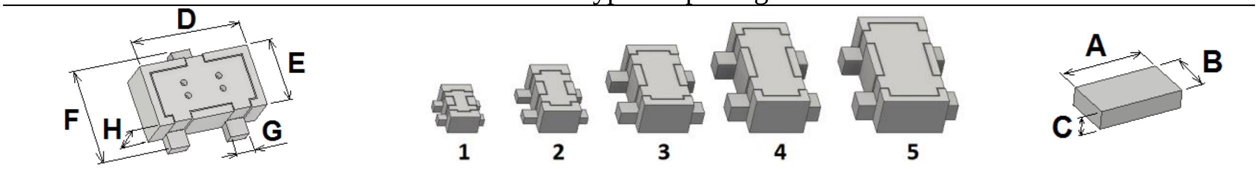
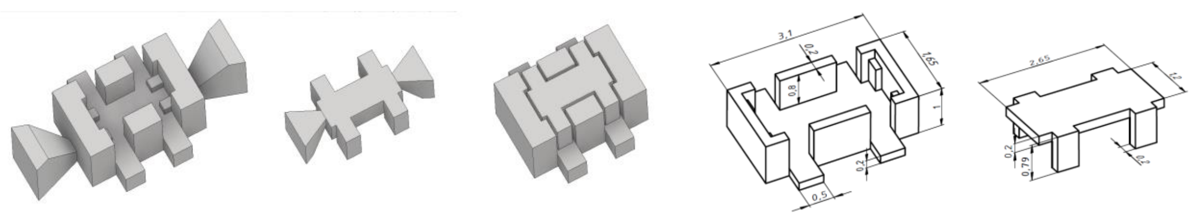
as well as constant manifestations of corrosion from the products of chemical reactions. Also, most of the packages of such gas sensors contain MEMS microheaters [10-12], which are actuators of chemical reactions at high operating temperatures, sometimes several times more than 500°C [13-14] and hence the requirement for the packages is to dissipate the power released by the MEMS crystal as well [16].

Table 1. Types of packages



№	Package type	Number of outputs	Length of the package D (mm)	Width of the package E (mm)	Width of the package with outputs F (mm)	Width of the output G (mm)	Height of the package H (mm)	Maximum chip size for mounting in the package AxBxC (mm)
1	SOT723	from 2 to 4	1.15	0.75	1.15	0.2	0.5	0.5x0.3x0.07
2	SC89 (SOT490)	from 2 to 4	1.65	0.95	1.6	0.3	0.7	1.0x0.5x0.27
3	SC70 (SOT343)	from 2 to 6	2.15	1.25	2.1	0.3-0.4	0.9	1.5x0.8x0.47
4	SOT23 (SOT143)	from 2 to 8	2.85	1.35	2.25	0.3-0.5	1.0	2.2x0.9x0.57
5	SC59 (SOT475)	from 2 to 8	3.05	1.65	2.5	0.3-0.5	1.0	2.4x1.2x0.57

Packages manufactured on an adaptive laser micromilling setup described in more details in [8] cannot have hidden metallization layers as in LTCC technology [18], however, when manufacturing small series of packages with surface metallization, they are a more efficient and faster solution. An example of form factors of a group of packages on which experimental work was carried out to determine the speeds of micromilling is presented in table 1. Figure 1a shows a typical 3D model of SMD package in * .stl format widely used for 3D printers. The format of a typical group of scalable packages for laser micromilling was selected based on the criterion of ease of mounting gas sensor chips described in our numerous works [6-9]. Typical dimensions for the largest case in the SC59 form factor are shown in Figure 1b and can be compared with the tolerances in relation to the width to height with the world's best serial produced packages from KYOCERA [19] - for conventional alumina ceramics -0.25 / 0.35 mm, for strained 0.2 / 0.3 mm and in our case 0.2 / 0.8 mm.



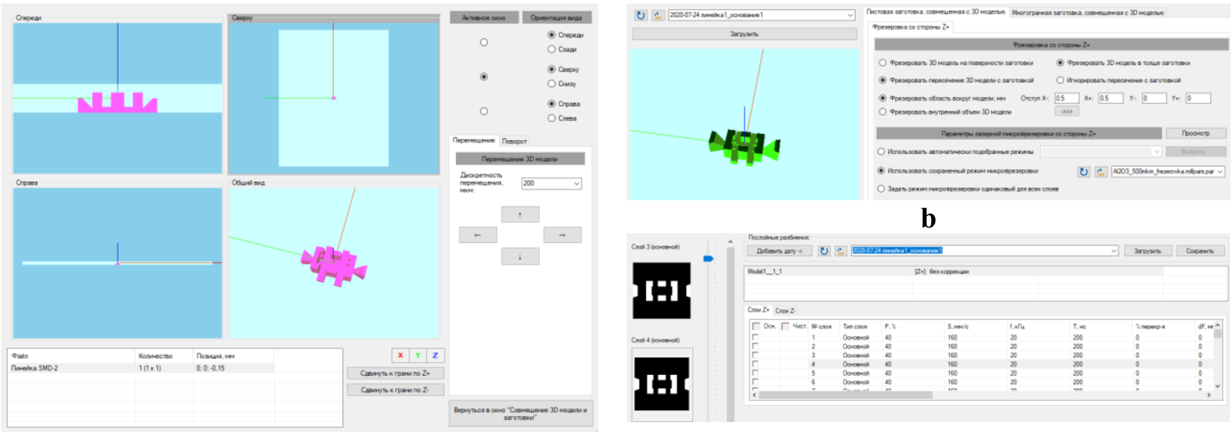
a b

Figure 1. Typical 3D model using for laser micromilling (a) and sketch of SMD package in form-factor SC59 with dimension given in mm (b).

2. Experimental

The production of the group of SMD cases, described below, is carried out using an adaptive laser micromilling installation based on an exclusive software and hardware platform implemented by the authors of the article. Al_2O_3 ceramic substrates of a standard size 48x60 mm with two thicknesses - 0.5 and 1 mm are used for the cases manufacturing, in the volume of which 3D models are milled. At the stage of 3D modeling, it is necessary to add jumpers to the model, which will hold it in the substrate (frame) array. The point of contact of the jumper with the 3D model depends on the size of the model, for all the models presented below it is a pyramid with a vertex in the form of a square of 150x150 microns (where it is attached to the chip). Preparation for milling a 3D object in specialized software is carried out in three stages and takes less than a minute with the following standardized operations:

- Positioning of the 3D model in the volume of the substrate. If the thickness of the model and the substrate are identical there is no need to adjust the position, otherwise it is necessary to move the model to the top or bottom surfaces of the substrate, which is done by pressing one button. At the same stage, an array of 3D models is specified, if necessary (Figure 2a).
- Choice of parameters of laser micro-milling. It is performed by loading the required laser micromilling mode from the data library (Figure 2b).
- Start of the micromilling and visualization of the process. If necessary, it is possible to adjust the processing modes, add additional main or cleaning passes (Figure 2c)



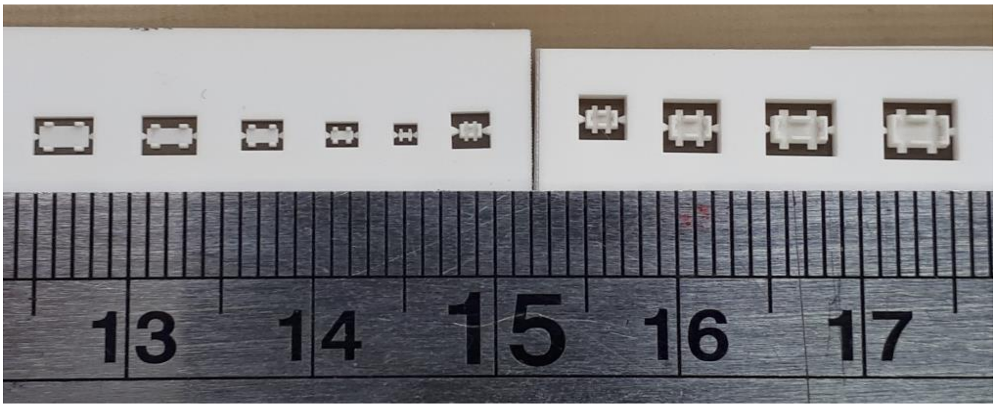
a c

Figure 2. Self-developed software for laser micromilling – model for micromilling takes from figure 1: (a) The interface window of the software responsible for aligning the substrate with the 3D model; (b) The interface window of the software responsible for the selection modes for laser micro-milling; (c) The interface window of the software responsible for start of laser milling and visualization current of steps micromachining process.

The process of laser micromilling of Al_2O_3 ceramics was carried out at a speed of 39.4 mm^3/h, the scanning speed of the laser beam is 160 mm/s. Depending on the required product quality, the milling speed can be changed up or down. After starting the micromilling process the process can be paused at any time to view the milled object using a microscope with 400-2000x magnification or measure the roughness / height of the milled layer using a point laser profiler integrated into the adaptive laser micromilling unit, and then continue milling from the point of stop.

3. Results

The result of a group of SMD packages manufacturing with dimensions shown in Table 1 is presented in Figure 3. Figure 3a shows an optical image of two micro-milled substrates 0.5 and 0.1 mm thick made of 99.9% Al_2O_3 ceramics containing the lower and upper parts of SMD packages, further in Figure 3b on the same metal ruler are the parts of the packages, which are metalized using silver inkjet ink, and the smallest form factors (SOT723 and SC89) of the packages are already assembled, which indicates the full functional suitability of the manufactured prototypes.



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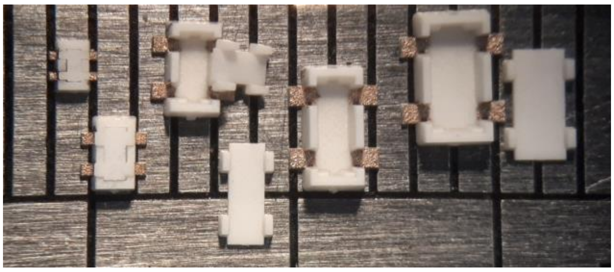
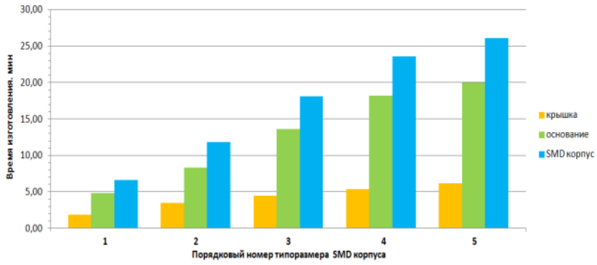
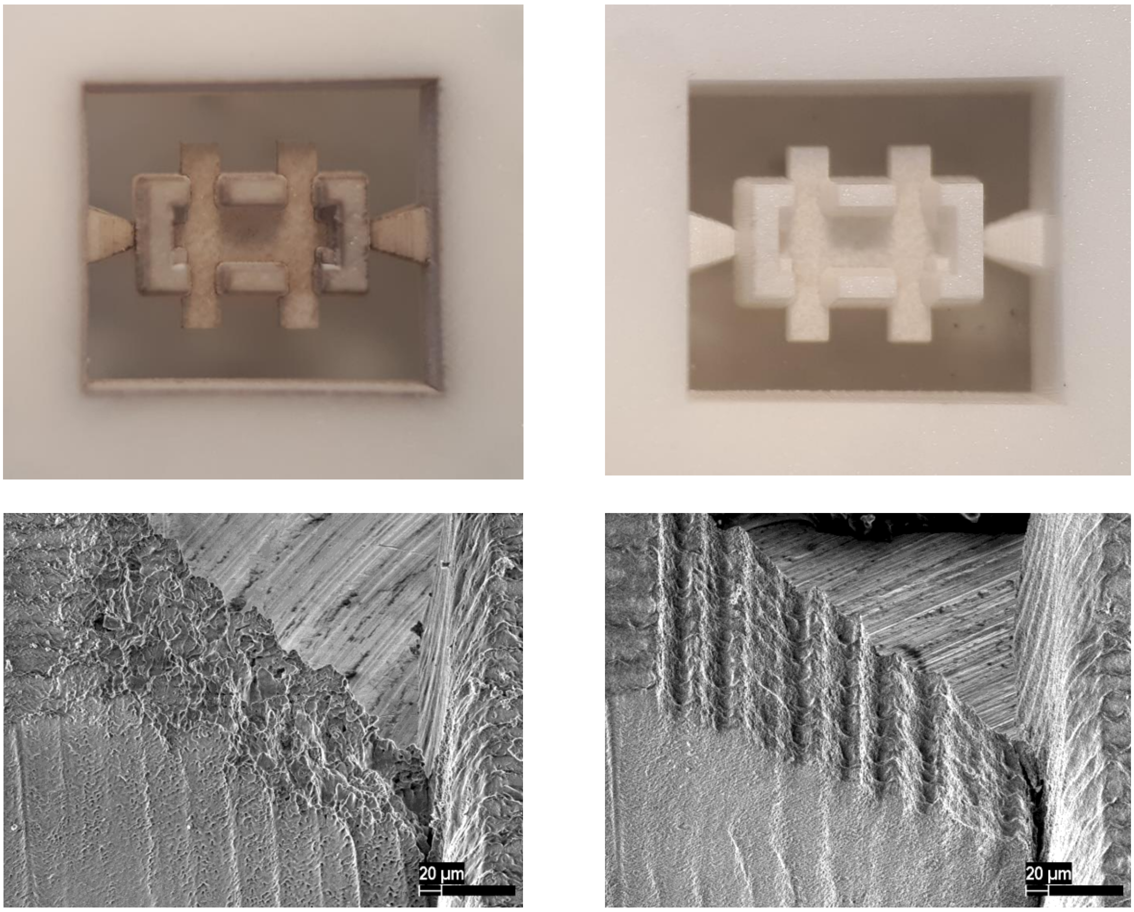




b c

Figure 3. Result of SMD package fabrication by using laser micro-milling: (a) 0,5 mm (left) and 1,0 mm (right) thicknesses 99,9% Al_2O_3 substrate with bottom and top part of SMD packages - linear scale on top of substrates are given in mm and cm; (b) SMD packages already separated from ceramic frame and with deposited Ag metallization on contact pads of bottom parts; (c) Time diagram of laser micromilling of SMD packages – number of packages form-factor is according present in table 1.

The technology of laser micromilling of ceramics requires additional post-processing of the resulting products due to the formation of dust and inclusions during laser ablation. Figure 4 shows the Al_2O_3 ceramic bottom of an SMD package made with the laser micromilling mode removing 9 microns in one ablation layer before and after cleaning. Figure 4b shows a ZEISS EVO 50 XVP SEM image in the area of the jumps connecting the base of the case with the ceramic frame, where the post-processing result is most clearly visible - if the initially inclined structure after laser micromilling resembled a "destroyed" pyramid due to the presence of dust and "foamed" ceramics, then after post-processing the stepped marks left by the laser passes are clearly visible. It is also logical that obtaining an inclined structure that can withstand a strict orientation angle to the original substrate in this technology is not achievable, however, as for the standard LTCC technology, where there is also a "quantization step" in the form of a green tape thickness, the only advantage of adaptive laser micromilling is the possibility of more precise quantization of steps, down to fractions of a micron, but this possibility must be used with caution, since it prolongs the micromilling time.



a b

Figure 4. Optical and SEM image of fabricated bottom part of SMD package in form-factor SC89: (a) before cleaning and (b) after cleaning.

4. Conclusion

Our experience has shown that if the adaptive laser micromilling technology is used by a qualified operator, it gives a fantastic speed in the design and manufacture of ready-to-use SMD ceramic packages for electronic components, in a miniature design, starting with the smallest form factors. The developed software allows replicating SMD cases and other miniature ceramic products without additional modifications to the original 3D models. The software is actually similar to software for 3D printers and, therefore, the requirements for the operator are at the level of a specialist who can work with a 3D printer that implements DLP or SLA printing technologies.

Acknowledgment

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