

# Research of mechanical stresses in micromechanical structures based on silicon carbide films produced by magnetron sputtering

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**Abstract.** Investigations of the effect of residual atmosphere in the magnetron chamber on the mechanical stresses and the shape of micromechanical structure based on SiC film are discussed. Measurements of the curvature radius of SiC micromechanical structure deflection are presented.

## 1. Introduction

Mechanical stress is a film parameter of various materials. It determines the characteristics and shape of micromechanical structures formed on their basis. For example, it was found that an undesirable structure bending occurs during carrying out the micromechanical switch technology. This leads to an increase of the driving voltage value and deterioration of speed and reliability.

The reason of this deflection is the mechanical stress that occurs during the deposition process of a silicon carbide film. Thus, it is obvious that mechanical stresses in silicon carbide films are required further investigations.

## 2. Deflection and mechanical stresses in micromechanical structures based on silicon carbide films

In this paper, the mechanical stress of released micromechanical structures based on silicon carbide films was investigated. Structures were anchored to the substrate in various ways. These structures were produced by the surface micromachining technology with the help of sacrificial layers. These layers were subsequently etched, and a released micromechanical structure was formed. Silicon carbide films were deposited by magnetron sputtering.

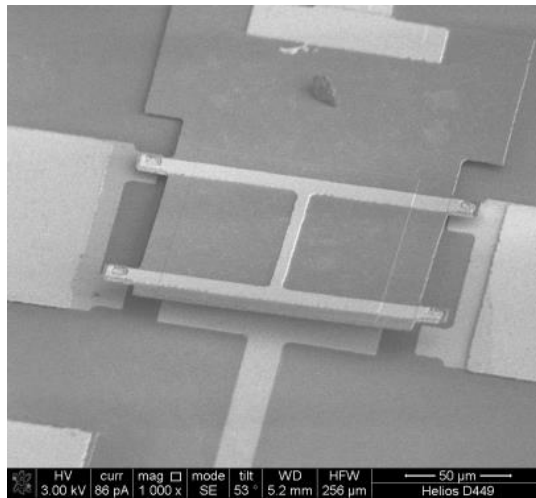
Silicon carbide films bent after releasing from the substrate during the process of sacrificial layers etching. An image of one of these structures is shown in figure 1. It was obtained with the help of a scanning electron microscope.

These deflections lead to malfunction and even a failure of micromechanical switches based on silicon carbide films. The measurements of the deflection were carried out by means of a three-dimensional model created with the help of the optical microscope KH 7700.

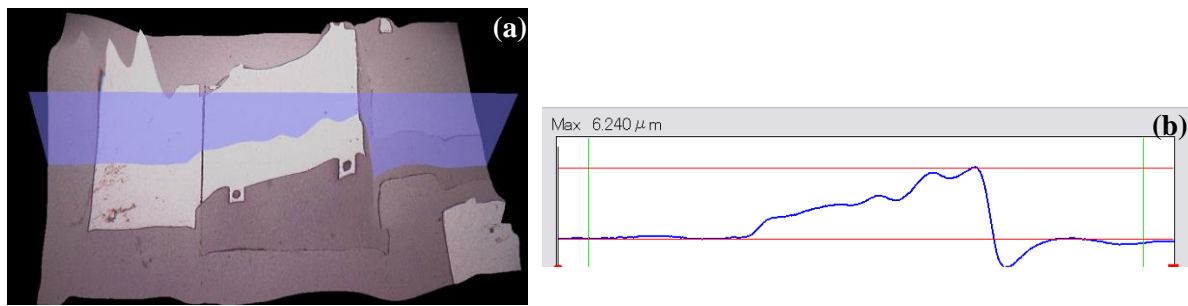
The created model was cut by a plane, and the deflection value was estimated from the cross-section profile. The maximum gap was 3.5  $\mu\text{m}$ , and the radius of curvature was 2.4 mm. The three-dimensional model and the cross-sectional profile are shown in figure 2.

Deflection can occur due to the occurrence of high compressive mechanical stresses in silicon carbide films and due to the nonuniform distribution of mechanical stresses along the thickness of the film. Conceivably it is connected to the conditions of the SiC film deposition process.





**Figure 1.** Image of a micromechanical structure bent under the action of mechanical stresses.



**Figure 2.** The three-dimensional model (a) and the cross-sectional profile of the micromechanical structure based on silicon carbide film (b).

This is also proved by experimental measurements of mechanical stresses in micromechanical membranes based on silicon carbide film [1]. At the thickness of  $0.24 \mu\text{m}$ , the average mechanical stresses in the silicon carbide film are compressive and range from  $-500$  to  $-100 \text{ MPa}$ , depending on the deposition conditions.

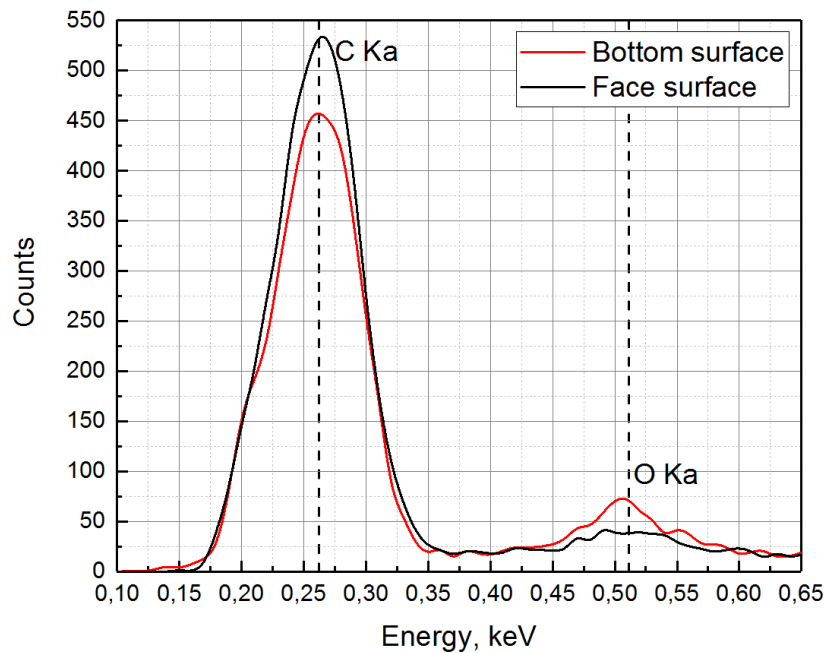
As the thickness of the film was increased to  $1.2 \mu\text{m}$ , the mechanical stress becomes tensile and reaches  $120 \text{ MPa}$ , which may indicate a nonuniform distribution along the thickness and possible influence of the oxidation process at the initial stages of the film deposition process.

### 3. Technological parameters correction of SiC film deposition process to minimize mechanical stresses and micromechanical structure deflection

High compressive stress in silicon carbide films can occur because of plasma-stimulated oxidation. This process can be nonuniform during the magnetron deposition of the film. It was really noted that the residual pressure at the beginning of the process is almost twice as much as the value at the end of deposition process. This fact indicates that growth conditions of the film varies at different stages of its deposition.

The silicon carbide film was investigated by X-ray spectral microanalysis. It was found that the concentration of oxygen impurities from the bottom surface of the release film are greater than from the upper surface. X-ray characteristic radiation spectra was obtained with the help of a scanning electron microscope and results are shown in figure 3.

So, the chamber was preliminary pumped for a long time. This operation made it possible to reduce the influence of plasma-stimulated oxidation at the initial stages of silicon carbide film growth. The change of the chamber residual pressure during the silicon carbide film deposition was reduced by a factor of over 3. Besides, the radius of curvature increased and the maximum gap decreased by a factor of 3.5.



**Figure 3.** The X-ray spectra from the bottom and face surface of the film.

#### 4. Results and discussion

Thus, one can draw a conclusion that the deflection shape of the released micromechanical structures based on silicon carbide films depends on the parameters of the deposition process namely the pressure change of the residual atmosphere during deposition process of the silicon carbide film by the magnetron sputtering plant.

Nonuniform distribution of mechanical stress along the film thickness occurs because of the time nonuniform process of plasma oxidation. These stresses results in high bending of the film after releasing from the substrate.

#### 5. Conclusions

If one wants to obtain uniform mechanical stress distribution along the film thickness, it is necessary to preliminary pumped the magnetron chamber for a long time and maintain the same residual pressure during the whole deposition process of the silicon carbide film.

#### References

- [1] Astashenkova O N and Korlyakov A V 2014 *Modern science researches, ideas, results, technologies* **2(15)** 57–61