STRUCTURAL AND MECHANICAL PROPERTIES OF THE AMORPHOUS SILICON CARBIDE FILMS FOR MEMS APPLICATIONS

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At present time the development of micro-electro-mechanical-systems (MEMS) technologies is of the great interest and the range of their application is steadily and rapidly increasing. Usually the standard silicon based technology is used for fabrication of functional elements in MEMS devices. But for some applications the use of other materials with unique properties, such as SiC, is strongly needed [1]. But deposition of polycrystalline SiC films is possible only at substrate temperature over 600^0C, that strongly restricts the applicability of CMOS technology for MEMS fabrication. But it is known that some mechanical and chemical properties of crystalline SiC can be preserved in amorphous state and amorphous silicon-carbon alloy films can be deposited at low substrate temperature.

The main goal of the present work was studying of the potentiality of amorphous silicon carbide films (hydrogenated a-$Si_{1-x}C_x$ and non-hydrogenated a-$Si_{1-x}C_x$:H) as a material for functional elements in MEMS. Possibility of the adjustment of mechanical properties by technological regimes was also estimated.

Films had been deposited by RF-magnetron sputtering of polycrystalline SiC target and reactive DC-magnetron sputtering of silicon target in Ar:CH_4 gas mixture at substrate temperature about 250^0C. P-type Si (100) was used as a substrate.

FTIR measurements of the as deposited near-stochiometric a-SiC:H films show the two strong absorption bands due to Si-C stretching vibration mode (about 800 cm^{-1}), SiC-H_n banding/waging (about 1000 cm^{-1}), weak band due to Si-H_n stretching (about 2100 cm^{-1}) and very weak C-H_n stretching (2800-3000 cm^{-1}). Incorporation of the hydrogen and carbon can be controlled by argon-to-methane ratio in the working gas mixture and can be varied over a wide range.

In the FTIR spectra of a-SiC films a strong and broad absorption band with maximum at about 800 cm^{-1} had been detected. A weak high frequency shoulder can be attributed to residual oxygen (Si-O stretching mode).

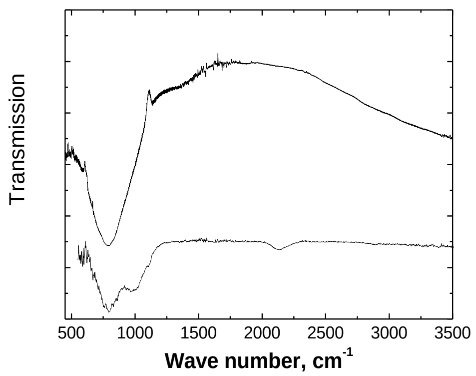
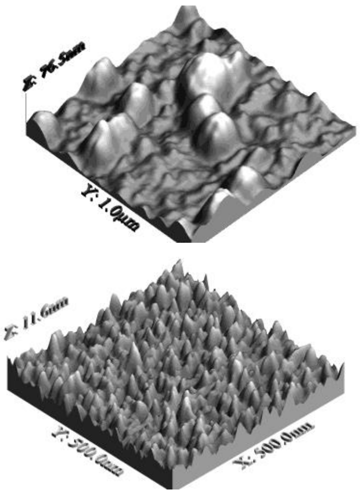


Fig. 1. FTIR absorption spectra of a-SiC and a-SiC:H.

Surface morphology of the films was analyzed by means of atom-force microscopy (AFM). Typical AFM images of the surface for the a-SiC:H and a-SiC films are presented in Fig. 2a and 2b, respectively. Surface morphology of the a-SiC:H deposited by DC-magnetron sputtering exhibits a feature those are typical for columnar porous growth morphology that is inherent for the films deposited at low surface mobility of the adsorbed atoms (radicals) conditions. In contrast, it can be seen that surface of the a-SiC films is very flat that implies the good homogeneity of the bulk morphology of a)



b)

Fig. 2. Surface morphology of the a-SiC:H (a) and a-SiC (b).

these films. High flatness of the surface can be explained by intense ion bombardment of the growing film that is provided by our RF-magnetron configuration.

Hardness of the films had been examined by means of nano-indentation (Berkovich indenter, Nano Indenter-II) based on the Oliver-Pharr method [2]. Results of the measurements for near-stochiometric a-SiC:H and a-SiC deposited at different RF-discharge regimes are presented in Table 1. Nano-hardness values of standard samples of crystalline Si and SiC measured at the same conditions are also represented. It can be seen that hardness of the a-SiC films can be managed by RF-discharge conditions.

In some MEMS applications the sign and value of mechanical stress in the films play a key role. It had been showed that residual mechanical stress can vary around the weak compressive stress in a-SiC:H (about 70 MPa) and strong compressive stress in a-SiC (about 600 MPa).

Table 1. Mechanical properties of the amorphous silicon carbide films.

Sample	Magnetron power density, Watt/cm^2	Elastic modulus, GPa	Hardness, GPa
a-$Si_{1-x}C_x$	0.37	75	8.1
	0.55	116	13.3
	0.65	145	15.4
	1.0	167	16.9
	1.4	209	21.4
a-$Si_{0.5}C_{0.5}$:H	2.0	132	12.5
Si		175	13.8
SiC (6H)		475	45.3

Presented results demonstrate the possibility of application for amorphous silicon carbide films as a material for the structural layer of MEMS devices. Mechanical properties of the films can be managed by sputtering conditions and low deposition temperature allows integrating MEMS fabrication process into current CMOS technology.

References:

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