INVESTIGATION OF THE SELF-SIMILAR STRUCTURE OF THE CARBON THIN FILMS

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ABSTRACT

Self-similar structure of the carbon thin films, obtained by magnetron sputtering is investigated numerically. Statistical parameters are calculated within two dimensional multifractal detrended fluctuation analysis. The numerical model for the surfaces under investigation was build from the SEM images of the carbon thin films. It is shown that the self-similarity in surface roughness preserves over all fragments of the sample, and through different resolutions of the SEM images.

Key words: self-similarity, carbon thin films, fractal dimension.

INTRODUCTION

The self-similar or self-affine structures are widely presented in all areas of the nature science [1]. The self-similarity means that the each segment of the initial set has the same structure as the whole object. The properties of such systems can be described by special parameters, like fractal dimension (or set of dimensions or multifractal spectrum in case of complex structures), mass exponent and other [2]. In our work we introduce the investigation of the self-similar structure of the carbon films by numerical methods of scaling analysis. The samples of the carbon condensate were obtained in nanoelectronic department of Sumy State University. Our calculation allows to present a quantitative characteristic of the surface roughness, and to compare it for different part of the sample.

DEPOSITION OF THE THIN FILMS UNDER INVESTIGATION

Carbon condensates were obtained by deposition of the ion-sputtering substance onto (001) KCl facets according to original technique [3].

In order to investigate the self similarity in the structure of the surface of the film, we select the four SEM pictures of the same area of the surface at different resolutions, and also four pictures of the different areas of the film at equal resolution. For each SEM image a numerical model was build. This model presented by surface in Cartesian coordinates, where each point defined by the numbers and brightness of the pixel in related image. Example of the surface image and corresponded numerical model presented in *figure 1*

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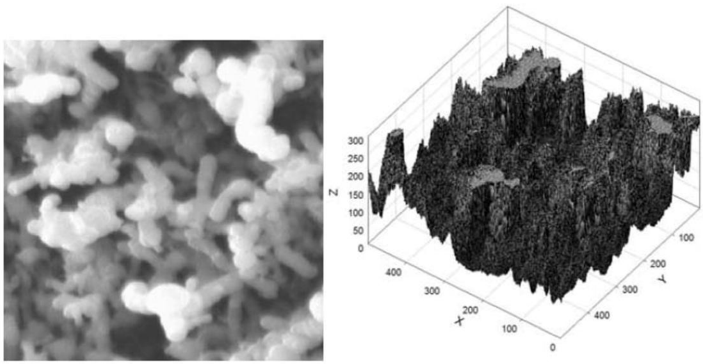

Fig. 1 – SEM images of the carbon thin films and related numerical model

METHOD FOR IMAGE ANALYSIS

All surfaces were investigated within two dimensional multifractal detrended fluctuation analysis (MF-DFA) [4]. This algorithm allows for calculation of main parameters of the self similar structure, such as mass exponent, and multifractal spectrum [1,2]. The base of the MF-DFA is a fluctuation function F_q, which satisfies the scaling relation:

$$F_q(s) \sim s^{h(q)}, \tag{1}$$

where s is a scaling parameter, $h(q)$ – generalized Hurst exponent. If the object under investigation has a self similar structure, the dependence (1) must be linear in logarithmic scales. Examples of relation (1) for the surfaces of the carbon thin films presented in *figure 2*.

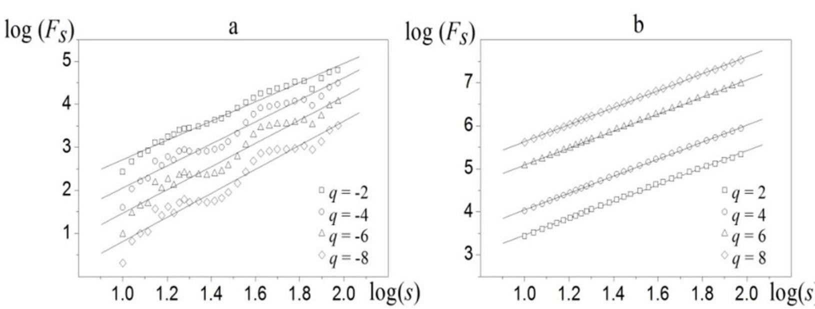

Fig. 2 – Relation (1) in logarithmic scales for the surfaces of the carbon thin films plotted at different negative (a) and positive (b) q values

RESULTS AND DISCUSSION

We calculate and compared the mass exponent and multifractal spectrum for all surfaces. The results are shown in *figure 3*.

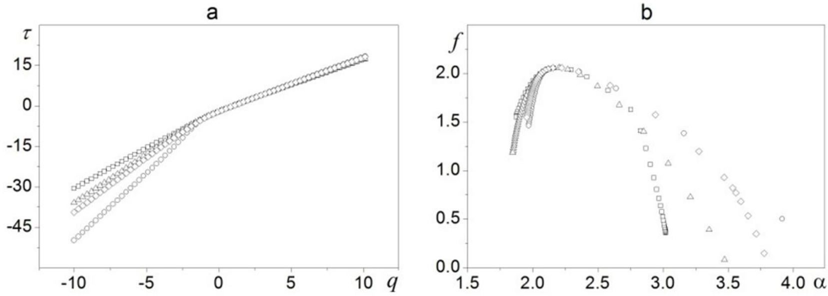

Fig. 3 – Mass exponent (a) and the multifractal spectrum (b) of the carbon thin film surfaces at different SEM images resolutions

As it can be seen from the figure, the calculated parameters for different parts of the surfaces are almost coinciding for $q > 0$ values. This result confirms the surmise about self-similar structure of the condensate surface.

CONCLUSIONS

Above consideration shows, that the carbon condensates has the self-similar structure. This conclusion follows from the coinciding parameters at positive deformation parameter q. Nevertheless, when $q<0$, calculated parameters are strongly distinguishing. We explain this situation by the statistical meaning of the q parameter, which negative values related to the small fluctuations of the surface roughness, i.e. the self –similarity parameters at $q<0$ represent the small details of the SEM images and can include the technical noise, which are always present in the image.

REFERENCES

[1] A.I. Olemskoi, Fractals in Condensed Matter Physics, in: Physics Reviews, ed. I.M.Khalatnikov, 1995, 18, Part 1, 1.
[2] J. Feder, Fractals, Plenum press, New York and London, 1998.
[3] V.I. Perekrestov, A.I. Olemskoi, Yu. O. Kosminska, A.A. Mokrenko, Phys. Lett. A, 2009, Vol. 373, P.3386.
[4] Gao-Feng Gu, Wei-Xing Zhou, Phys. Rev. E, 2006, Vol.74, P. 061104(8).