Evaluation of Surface Characteristics of Highly Oriented Pyrolitic Graphite

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Abstract. Thanks to several outstanding optical and electrical qualities highly oriented pyrolitic graphite (HOPG) is considered a promising material in nanostructures preparation process. It has been successfully employed in scanning probe microscopy technique as a material for calibration. This work characterizes the surfaces of graphite that went through a mechanical processing and their following usage as substrates for obtaining semiconducting thin films by deposition.

Introduction

The auspicious organization of atomic positions in HOPG (highly oriented pyrolitic graphite) allows for its application in a number of nano-technological calibrations \cite{1, 2}. HOPG is basically an allotropic modification of carbon. It possesses a perfect combination of qualities enabling its usage in electronic and potentially recommend it as a replacement for presently used substances. The most significant parameters of HOPG are mosaic spread and surface treatment; they define the surface texture, roughness and defects of various scales. Another superiority of HOPG lies in its fragility which allows it to be processed so as to meet the requirement of smoothness as a substrate.

There are many areas they could benefit from introduction of HOPG. For example, it can find an application in devices that operate under high temperatures. The desired surface roughness can be achieved by subtle manipulations in chemical and physical processing of HOPG. For applications in optics the mean surface roughness is from $\lambda/10$ down to $\lambda/20$ which is possible to obtain by aforementioned processing procedures. Consequently, we should employ reliable techniques to measure and characterize the surface since morphology is a crucial parameter to take into account when constructing high-quality structures \cite{3-6}. Surface quality of HOPG is one criterion for the surface integrity and plays an important role in term of surface functionalities.

Experimental Results

In order to examine the surface morphology and microstructure atomic force microscopy (AFM) has been applied. AFM is a convenient instrument and can also be used to attain precise surface control in serial manufacturing \cite{7-12}.

These methods are important in electronics and optoelectronics and are widely spread in areas of manufacture and science \cite{13-16}.

Dependability of a device is defined by surface condition of the substrate. It is the criterion of performance and also affects heterostructure properties. Texturing is a valid method to enhance the
quality of the devices in specific situations. In preparation of heterostructures the first steps are the treatment and processing of high-quality substrates [17-20].

The AFM image of HOPG after ordinary exfoliation by tape is shown in fig. 1.

The 3-D topography data were obtained by AFM method; the following information can be extracted from the results: grains and holes sizes as well as the character of their distribution; numerical assessment of correlation areas.

The stereometric analysis was made with the SPIP™ 6.7.4 software [21], according to ISO 25178-2:2012 [22] and ASME B46.1-2009 [23].

In figs. 2 and 3 are shown the graphical representation of Abbott–Firestone curve and material probability curve.

The height distribution histogram and the angular spectrum are shown in figs. 4. and 5.
The radial spectrum, isotropic Area Power Spectral Density (IAPSD) function, and the integrated radial spectrum are shown in figs. 6-8.

![Figure 6. The radial spectrum.](image)

![Figure 7. The IAPSD function.](image)

![Figure 8. The integrated radial spectrum.](image)

The graphical representations of correlation length at 20% and correlation length at 37% are shown in figs. 9 and 10.

![Figure 9. The correlation length at 20%.](image)

![Figure 10. The correlation length at 37%.](image)

In Table 1 are shown the statistical parameters of the AFM images, according with ISO 25178-2: 2012 and ASME B46.1-2009.

| Parameter | Szie [nm] | Sz_{tph} [nm] | Sdr [%] | Svk [nm] | Sc_{120} [nm] | 452.3 |
|-----------|-----------|---------------|---------|----------|-------------|-------|
| SAs       | 3.04      | 44.2          | 0.1352  | 4.147    | 12.76       |       |
| Sq        | 3.99      | 55.47         |         |          | 12.76       |       |
| Ss        | 0.377     | 0.00195       |         |          | 89.26       |       |
| Ssk       | 2.42      | 24.04         | 0.1498  | 35       | 0.4643      |       |
| Ss_{mean} | 56.95     | 32.91         | 1.572   | 0.6231   | 26.48       |       |
| St        | 56.95     | -2.4E-10      | 0.12    | 3176     | 1.712       |       |
| Sz        | 56.95     | 0.0521        | 6.012   | 0.0626   | 5.022       |       |
| S10z      | 44.2      | 0.0505        | 8.645   | 1185     | 5.82        |       |

The graphs of average X and Y-Fourier profile and of average X and Y-PSD (Power Spectrum Density) profile are shown in fig. 11.
Figure 11. a) The average X-Fourier profile; b) The average Y-Fourier profile; c) The average X-PSD profile; d) The average Y-PSD profile.

Conclusion

In this work a stereometric analysis of AFM images of HOPG was performed. The statistical roughness parameters can help the researchers to exclude irrelevant samples and find a unique optimal parameter set to characterize the surface properties in quality control stage processes. Complementary studies on surface microtexture with regard to a specific application will be investigated to identify the 3-D optimum surface microtexture of HOPG.

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