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Surface morphology, X-ray crystal and element analysis of fractal films from tokamak T-10

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Introduction

As a result of interaction of plasma with a limiter the hydrocarbon films are deposited on internal surfaces of tokamak T-10 chamber. It was revealed that these films being formed at different distances apart from the place of eroding limiter have different properties. Scanning tunnel and atomic force microscopes show that films have different morphology. It was possible to determine the roughness and relief height of films by means of profiler in each point. Using roughness measurements we have evaluated statistic properties of the surfaces. This has allowed us to detect different ways of the surface growth [1].

The X-ray crystal analysis indicates that the films have a disordered graphite-like structure. Two peaks in the plot of dependence of X-rays intensity from the angle of diffraction specify are indicating fullerenes. The element analysis of films surface has been lead. It has been shown that films, formed close to eroding limiter consist 96 % of hydrocarbon (C-H) and 4 % - of oxygen. The films grown in areas placed farther the limiter, contain higher impurity. Electron emission properties of films, deposited at different distance from eroding limiter have been received.

Inevitable consequences of graphite limiter utilization in ITER are hydrocarbon films formation on vacuum vessel elements. Therefore one of the key processes, determine of reactor ITER economy in use, is tritium absorption of these films.

As it was mentioned earlier [1] in the vacuum chamber of tokamak T-10 have been found out carbon globular films and flakes with friable structure and with big ratio of D/C~0.8. Investigations of this films all over again on an scanning electron microscope (SEM), and then on stationary scanning tunneling (STM) and atomic force (AFM) microscopes, has found out fractality of a surface microstructures, from the characteristic dimensions ~ 100 microns and till the dimensions ~ 10 nanometers.

In the report results of research of a surface and internal globular films structure, estimation of a surface fractal dimension, model of films growth are submitted, the reasons of occurrence of such structure are discussed.

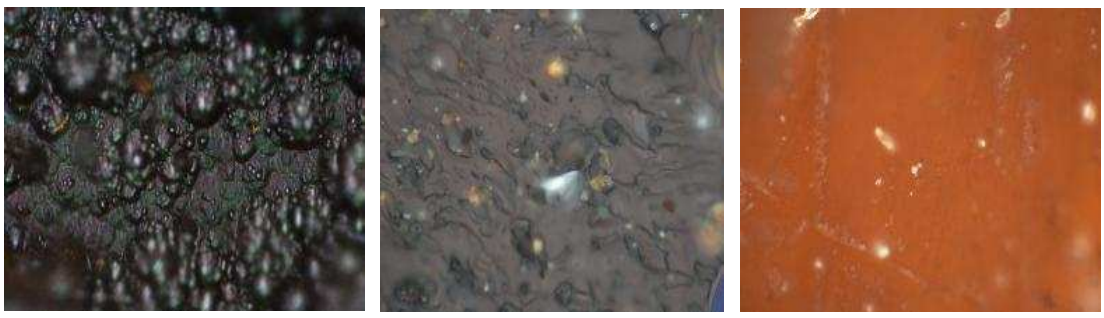
Experimental conditions. Diagnostics

Fig.1 – chamber of T-10, covered by films

T-10 is a middle tokamak, having circular cross side section. T-10 has 2 types of limiter: movable mushroom limiter and ring limiter. They are covered by graphite tiles. The material of vacuum chamber is stainless steel. To determine how changing properties of films with distance of limiter, we have taken films from different places of tokamak T-10: on a limiter, near limiter, 90 degrees on tore from a limiter and 180 degrees on tore. Films were investigated by means of microscope STM and AFM. The principle of their work is based on probe and sample interactions. Pictures have a high resolution of 1-3 nanometers. The panoramic view of a surface is given by means of an optical microscope Olympus GX-51 with thousand multiple magnifications. The morphological analysis of a surface was carried out with profiler, which allows receiving a surface profile on length to 3 sm. In work were used for X-ray crystal analysis the analysis – diffractometer URD-6, for the element analysis - a Field Emission Scanning Electron Microscope (FESEM).

Morphology analysis

In a microscope the films taken from various areas of the internal chamber tokamak T-10 were investigated. The films formed near to the disruption limiter, as is shown in drawing 1, have globular structure. The size of particles varies from 100 microns to 2 microns, thus each of them in turn consists of particles of the smaller size. Thus, it is possible to observe structural hierarchy, referring to the photos displaying a surface of a film (fig.2a). The similar surfaces have films, growing on a limiter, near erosion surface.



a) b) c)

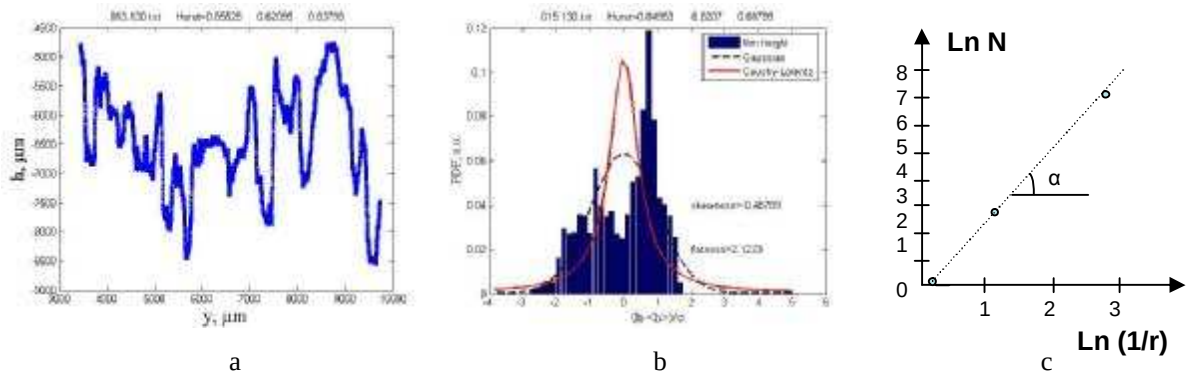
Fig.2 – Photo (100x 70 μm) by Olympus GX-51, a - films near limiter , b - 90 from limiter, c - 180 from limiter.

The films generated in 90 degrees from a limiter, at the first approach, have more homogeneous superficial structure (fig.2b). The agglomerates big particles are not observed

on a surface, small flutes in radius from 3 microns to 20 microns, depth no more than one micron are visible only. If to observe this surface in one thousand multiple increase the surface not seems homogeneous any more, and possesses more likely friable and porous structure. Particles, of which it consists, have about the identical sizes (20 nanometers).

The surface of the films formed in 180 degrees from a limiter, has a smooth and homogeneous surface. The structure of these films doesn't change in different scale ranges (fig.2c).

Films were investigated with the help profiler. It has allowed receiving profile characteristics of the films formed in different sites tokamak T-10. Increments of heights Δh in the next points of a surface $\Delta h_i = h_{i+1} - h_i$ were investigated (fig.3).



a b c

Fig.3 –data from profiler (a), functions of distribution increments of heights Δh (b). Identification of self-similarity (c)

Experimental functions of distribution by comparison with normal gauss distribution were analyzed. It is defined fractal dimension D in a kind $\Delta h = \Delta L^{(3-D)}$. Thus, for films the fractal dimension increases with distance from a limiter, and it means that porosity of structures with distance goes down. One more way of calculation of fractal dimension, consists in definition of the characteristic sizes of particles for several dimensional ranges a method of reception of distribution of particles in the sizes (fig.3c). In logarithmic system of co-ordinates three points corresponding N and r in three scale ranges are put. If all three points keep within on one straight line, means self-similarity (fractality) takes place, tgα =D (fractal dimension) =2.1 (for films, which is grow near limiter).

Having the data about fractal dimension it is not difficult to estimate SSA of films. As it is known, the number of particles in cluster submits to law $N = r^D$, therefore the specific surface area of an internal surface of fractal clusters, making a film, pays off as follows: $\frac{S_0}{\rho V} = \frac{3}{\rho r_0}$ Thus, the specific surface for the films formed near to a limiter makes 130 m^2/g.

Element and X-ray crystal analysis

The X-ray crystal analysis spent on hydrocarbon films has shown that all films generated in various areas of installation, have amorphous structure. It explains by wide peaks on dependence intensity from angle of diffraction (θ). Narrow peaks of films, growing near limiter and 90 degree from limiter are indicating fullerenes (θ = 7°).

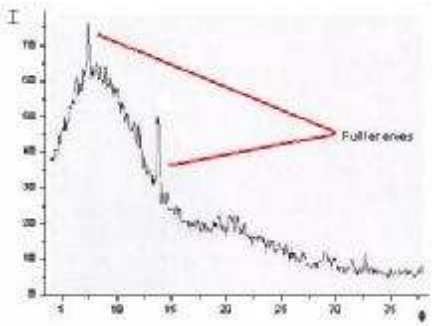


Fig. 3 – X-ray for films, formed in different places T-10.

The data on the element structure, received by means of a raster electronic microscope is presented on table. According to this data, the greatest quantity of elements contains in the films located 180 degree from limiter on tore.

Films near limiter			Films 90 degree from limiter			Films180 degree from limiter				
	C	O	C	O	K	C	O	Fe	Cr	Ni
Atomic %	65.1	34.8	65.1	30.8	0.7	68.2	16.4	7.9	2.5	1.6

Summary

The hydrocarbon films collected from a surface of the tokamak chamber have amorphous structure.

Toroidal dependence of films properties is defined: at distance from a limiter the elements quantity in films is increasing. Morphological feature of films is defined: with increase in distance from a limiter, formed films have smoother surface.

The functions of distribution (gets by statistical methods) of an increment of profile heights of the surfaces having ungausse type, and also fractal dimension have been received indicator within 2.16 – 2.45 (changing on toroidal detour), characterizing fractal surfaces.

Distribution of particles to surfaces of films in the sizes, has power dependence, calculated value of an exponent corresponds D=2.1, it means that films have fractal a surface, and, also, will be coordinated with the data received by statistic method.

Calculated value of the SSA of fractal films (for films growing near to a limiter) correspond 130m2/g that is characteristic for high porous materials.

Acknowledgement

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References

[1] V.P. Budaev, L.N. Khimchenko, “Fractal growth of deposited films in tokamak”, Moscow, 2006.