Dust produced in Globus-M Tokamak

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Globus-M spherical tokamak is characterized by tight enveloping of plasma column and in-vessel plasma facing components (PFC) [1]. The power launched into the Globus-M plasma during each discharge is usually 0.5-1 MW. Main part of this power is deposited onto graphite divertor plates with the area of 0.6 m^2. First results concerning formation of mixed layers in the plasma are presented in [2, 3]. Current report is devoted to analysis of dust particle sources and post mortem study of dust size and composition.

To increase vacuum wall reflection coefficient required for RF heating experiments, the protection tile configuration used previously was changed. The part of graphite tiles placed on the wall continuously along the toroidal loop of outer plasma edge were removed and exchanged by eight discrete tungsten poloidal limiters of 4 cm width that are marked T in Fig. 1. The bold lines in Fig. 1 show graphite protection tiles.

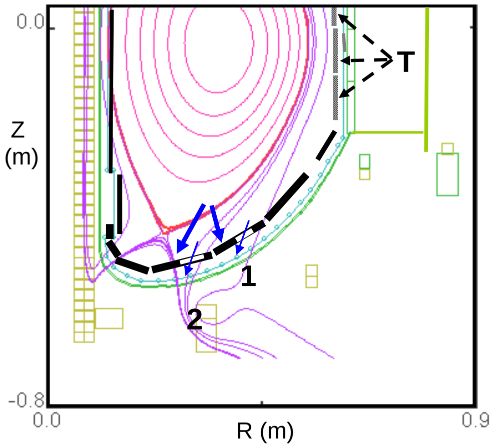


Fig. 1. Lower part of Globus-M. T – tungsten poloidal limiter. Arrows show the dust collected places

Dust collection has been performed in Globus-M during shut down in summer of 2009. The dust was collected from the surfaces exposed to direct plasma fluxes as well as from the shadowed zones underneath the bottom divertor plates. The dust collected from the surface of tiles 1 and 2 (Fig. 1) had a shape of broken stones. The electron probe microanalysis (EPMA) and X-ray diffraction have shown that the dust consisted primarily of well graphitized and amorphous carbon and TiC inclusions. Oxide of Fe_2O_3 was also observed. Formation of such phases clearly originated from fatigued graphite tiles and armor elements.

Scanning electron microscope (SEM) micrograph and EPMA spectrum of dust particle with size of 10 μm are shown in Fig. 2. Disruptions caused transient heat loads on the PFC surfaces that led to formation of the whole graphite particles with the size of several μm. The amorphous phase of the dust could be formed as a result of chemical (or physical) erosion of carbon and its subsequent redeposition on the tiles.

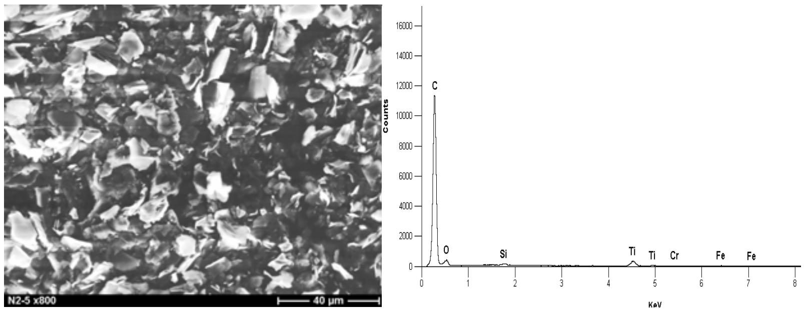
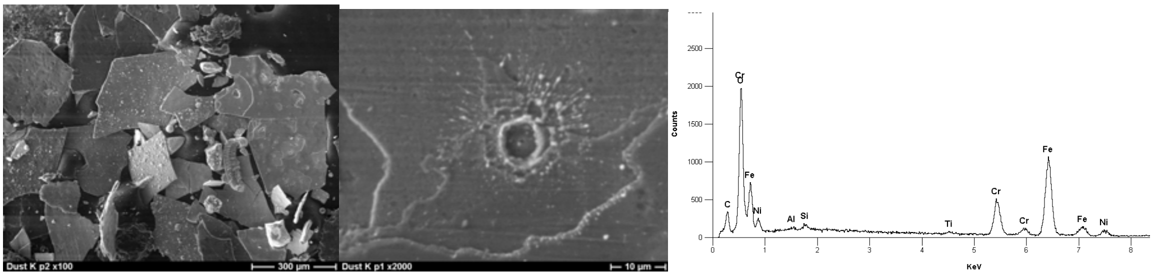


Fig. 2. SEM micrograph and EPMA spectrum of dust particles collected from surface of the tile 2

Samples of dust collected from a surface underneath the bottom divertor plates have been analyzed by means of SEM, EPMA, and magnet. The main part of the coarse fraction consisted of large lamellar plates of typically 10–1000 μm size, spherical particles with a smooth surface in diameter from 10 to 30 μm, and spongy particles with the size to few hundred μm.

The plates formed by plasma interaction with stainless steel components had thickness of 2-4



a) b) c)

Fig. 3. SEM micrograph and EPMA spectrum of a plate

μm (Fig. 3a). The most part of plates consisted of terraces with microarc traces (Fig. 3b). The microarc traces represent craters with welts of about 1 μm high. It is obviously that material melted under arc discharges. The melted spherical particles in diameter from 0.1 to 1 μm which have taken off from the crater were scattered in radial directions up to 30 μm. Formation of terraces was connected with cohesive consecutive separation of plates from a massive matrix. An average area of detached plate was approximately 30x30 μm^2 (for one microarc). We assume that plates and terraces were formed due to carbon and oxygen accumulation in surface layers of stainless steel (Fig. 3c) and development of mechanical stresses and corresponding strains. A boundary between the strained and unstrained steel was located at depth of some μm, where, probably, deuterium incoming from plasma was retained. During

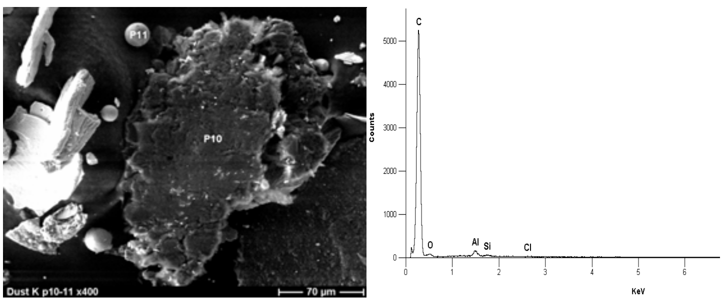


Fig. 4. SEM micrograph and EPMA spectrum of the spherical carbon particles with the size of 10-30 μm

the arcing the plates were separated from the massive material because of deuterium presence on the boundary.

Spherical particles with the size of 10-30 μm and a smooth surface consisted of carbon (Fig. 4). It is likely that the particles were grown from hydrocarbon precursors in the cold plasma regions close to the wall. Usually such plasma has electron temperatures of a few eV and a high concentration of neutrals with a large fraction of hydrocarbons due to chemical erosion. It is necessary to notice that dust particles of any form with the size of about 10 μm, being injected in plasma quickly become almost spherical. The spherical form specifies also that the dust particle is in plasma, instead of "sites" on a wall. Only in this case the fluxes of deposition material will be isotropic.

Spongy particles in the size of 100 μm consist of boron and carbon (P12 in Fig. 5) with the characteristic form of "cauliflower". The formation of such particles is connected with flaking of deposited layers. The layers are formed during vacuum vessel conditioning and boronization in helium glow discharge.

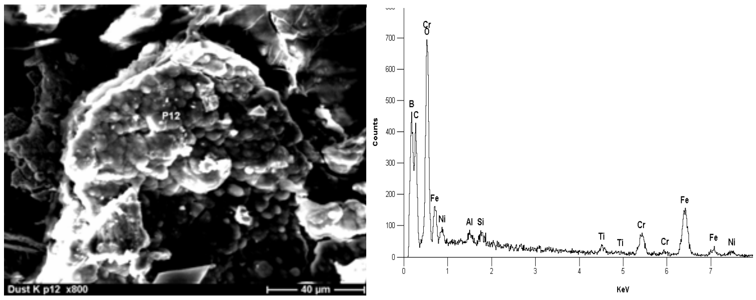


Fig. 5. SEM micrograph and EPMA spectrum of the spongy particles with the size of 100 μm

A fraction of about 10 % of the dust found in Globus-M is magnetic. In TEXTOR about 15% of the dust is ferromagnetic [4].

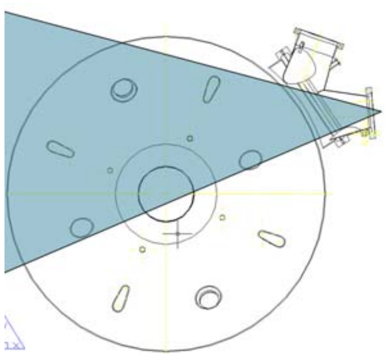


Fig. 6. View of fast camera in a horizontal plane

Fast CCD-videocamera Olympus I-SPEED 2 was applied to investigate the motion of large particles (0.05-1 mm) inside the plasma column in Globus-M tokamak. View of fast camera in the horizontal and vertical planes provides video registration in angles of 50^o and 45^o, respectively, that is enough for observation of external and internal boundaries of plasma column and also divertor area (Fig. 6). A frame in Fig. 7 shows the discharge initiation stage of Globus-M tokamak. These data were taken by the fast camera without a filter at 1000 frames s^{-1}. The dust particles arising near to an inner wall of the vacuum vessel in an equatorial plane and moving along toroidal field lines are clearly visible. The magnetism of a significant part of the dust fraction will lead to an interaction with the magnetic fields of the Globus-M

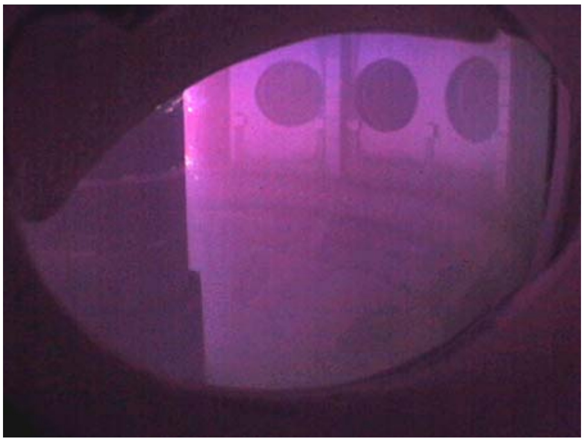


Fig. 7. Plasma discharge initiation stage

tokamak. It can be expected that dust particles are repeatedly sucked into the main volume of the discharge chamber and accumulate at the inner wall around the midplane because the field is largest there.

The release of dust particles is sometimes observed by the fast camera following the plasma interacting with the outboard wall PFCs after small disruption. The sequence of frames in Fig. 8 shows areas of intense plasma–material interaction at the outboard wall and dust being released from these areas. The time intervals between frames are 1 ms. When the vacuum vessel walls are well conditioned and there are no main disruptions, the fast camera typically observes between 10 and 20 events per discharge.

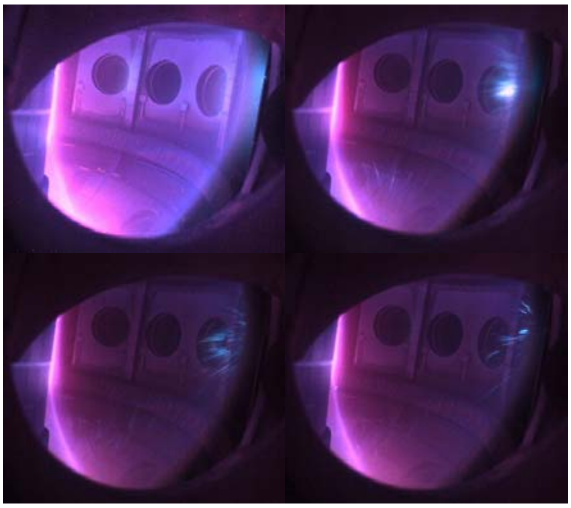


Fig. 8. The release of dust particles after small disruption

Conclusions. The dust in the Globus-M has much in common with other devices, but few specific features exist. First is the large fraction of lamellar plate particles with a high ratio of the length to the thickness (~1000 μm /3 μm). Those are mainly consisted of stainless steel components and originate from microarcs-wall interaction. The lamellar plate large fraction in the total dust amount could be explained by temporal removing of the graphite tiles from outer cylindrical part of vacuum vessel which led to unprotected stainless steel wall area expansion. Future tungsten protection of this wall area may helps to resolve the problem. Second is the presence of small size (~10-30 μm) spherical carbon particles with smooth surface. The origin of such particles is not clearly understood yet. The future plans include thermodesorption and SIMS dust analysis which could give new information.

References.

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