Morphology, structure and composition of dust formed in Globus-M tokamak

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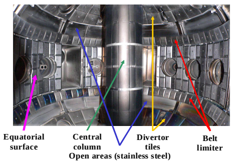
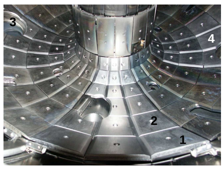
Motivation

Globus-M spherical tokamak is characterized by tight enveloping of plasma column and in-vessel plasma facing components [1]. The power launched into the Globus-M plasma during each discharge is usually 0.5-1 MW. Main part of the power is deposited onto graphite divertor tiles each with the area of 0.01-0.02 m^2. High specific auxiliary heating power makes plasma-wall interaction rather intensive which results in the material erosion and redeposition. The first results concerning formation of mixed layers in the plasma were presented in [2, 3]. Flaking, blistering and other mechanisms produce dust during the discharges. Current report is devoted to analysis of dust sources and post mortem study of morphology, structure and composition of dust particles.

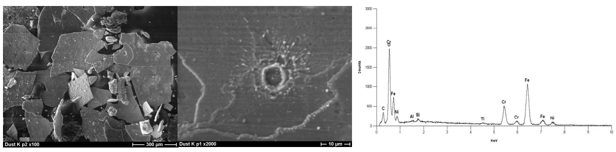
Globus-M



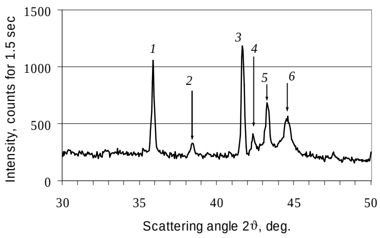
Inside view of Globus-M.



Lower part of Globus-M. RGTi divertor tiles (0.85 m^2) assembled inside vacuum vessel. Figures show the places of dust collected.



SEM micrographs and EDS spectrum of metallic dust collected from the shadowed zones underneath the bottom divertor. Plates formed during interaction of plasma with stainless steel had thickness of 2-4 µm. The most part of the plates consisted of terraces with microarc traces. The terraces were connected with consecutive cohesive separation of the plates from a massive matrix. The plates and terraces were formed due to hydrogen, carbon and oxygen accumulation in surface layers and development of mechanical stresses and corresponding strains. A boundary between the strained and unstrained steel was located at depth of some µm. During the arcing the plates were separated. There is a high oxygen peak caused by thick oxide film (thickness ~1 µm).



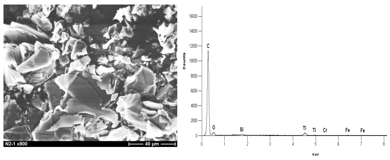
No	2θ, degree	I, counts	(hkl), phase	d, nm
1	35.9	1060	(111)TiC	0.255
2	38.4	330	(201)B_4C	0.234
3	41.7	1190	(200)TiC	0.216
4	42.35	410	(100)C_β, (200)FeO	0.213
5	43.3	680	(111) austenite	0.209
6	44.6	570	(110) ferrite, (101)C_β	0.203

XRD spectrum of the plates. There is magnetic ferrite phase due to austenite transformation. Ferromagnetic dust was observed in TEXTOR too [4].

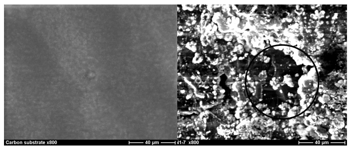
Experimental

After campaign 2006-2009 the dust for analysis was collected from the surfaces exposed to direct plasma impact as well as from the shadowed zones. Currently 98% of the inner tokamak surface is covered by RGTi tiles. The samples were characterized by SEM (morphology), XRD (structure) and EPMA (composition).

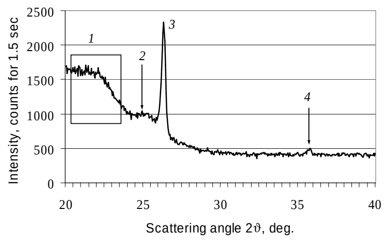
Results



SEM micrograph and EDS spectrum of dust collected from divertor plate 2.

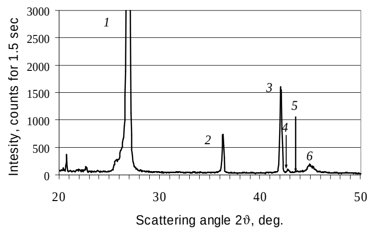


SEM micrographs of the initial divertor plate 1 and after campaign 2006-2009. The traces of graphite brittle fracture are marked by a circle.



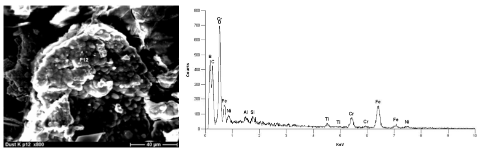
No	2θ, degree	I, counts	(hkl), phase	d, nm
1	20-24	1700	Polymer substrate	0.37-0.44
2	25	1040	Amorphous B_2O_3	0.209
3	26.35	2340	(002)C_β	0.337
4	35.8	500	(111)TiC	0.251

XRD spectrum of dust collected from the divertor plate 2.

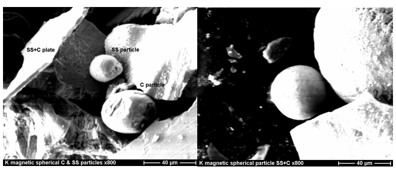


No	2θ, degree	I, counts	(hkl), phase	d, nm
1	26.8	28000	(002)C_β	0.333
2	36.4	740	(111)TiC	0.248
3	42.05	1610	(200)TiC	0.215
4	42.8	110	(100)C_β	0.211
5	43.6	60	(101)C_β, rhomb.	0.208
6	44.9	190	(101)C_β	0.202

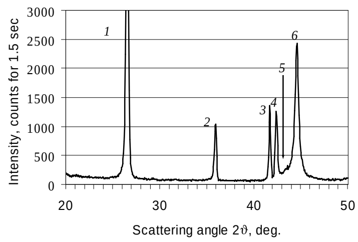
XRD spectrum of the initial divertor plate 1.



SEM micrograph and EDS spectrum of spongy particles with the size up to 100 microns. The spongy particles consisted of boron, carbon and oxygen with the characteristic form of "cauliflower". Formation of such particles was connected with flaking of deposited layers. The layers are formed during vacuum vessel conditioning and boronization in helium glow discharge.



SEM micrographs of lamellar and spherical magnetic particles. Some particles are covered with carbon.



No	2θ, degree	I, counts	(hkl), phase	d, nm
1	26.5	8340	(002)C_β	0.336
2	35.9	1040	(111)TiC	0.250
3	41.7	1360	(200)TiC	0.216
4	42.4	1260	(100)C_β	0.213
5	43.5	320	(101)C_β, rhomb.	0.208
6	44.6	2430	(101)C_β	0.203

XRD spectrum of the divertor plate 1 after campaign 2006-2009. Intensities of peaks 4 and 6 increased due to tilts of crystallites and texture destruction after plasma pulses.

Conclusions

The dust in the Globus-M has much in common with other devices, but few specific features exist.

First is the lamellar stainless steel plates with a high ratio of the length to the thickness (~1000 µm/3 µm) that contain microarc traces. Appearance of the plates is connected with temporal removing of the graphite tiles from outer cylindrical part of vacuum vessel which led to unprotected stainless steel wall area expansion.

Second is the presence of spherical magnetic (ferrite or iron oxide) particles (10-30 µm) part of which are covered with carbon.

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References

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[2]. V.K. Gusev et al., Nuclear Fusion 49 No 9 (2009) 095022
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[4]. J. Winter, Plasma Phys. Control. Fusion 46 (2004) B583-B592

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