Plasma Surface Interaction Characterize of New Type Multi-elements Doped Carbon-Base Materials

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Outline

- Multi-elements doped considered
- Properties Improved
  - mechanical properties
  - Chemical sputtering
  - Temperature Desorption Spectrum
  - Thermal Shock
  - Radiation Enhance Sublimation
  - Exposing to plasma
- Summary

? Multi-elements doped considered

what are the synthesis effects

Si, Ti , B_4C doped into graphite and CFC

Collaboration:

Southwestern Institute of Physics,

doped graphite : Institute of Coal Chemistry, Chinese Academy of Science,

doped CFC :The First Institute of Space Science & Technology Corporate

The parameters of mechanical properties of Multi-elements doped graphite

MATERIALS No	COMPOSITIONS (WT%)			DENSITY (G/CM^3)	POROSITY （%）	BEND-RESIST STRENGTH （MPA）	THERMAL CONDUTIVITY （W/MK） AT 300K
	TI	SI	B_4C				
GST126-01	5.5	12		1.954	11.3		105.54
GST126-02	5.5	12		1.968	11.0		116.26
GST315-01	2.5	15		2.110	8.67	97	278.25
GTB10610	6		10	2.18	4.18	67	
GB105			5	2.00	6.14	81.1	48.6
GBS33		3	3	2.0	6.5		
GBS33-1/2	3		3	1.942	8.1/6.5		100

The parameters of mechanical properties of Multi-elements doped CFC

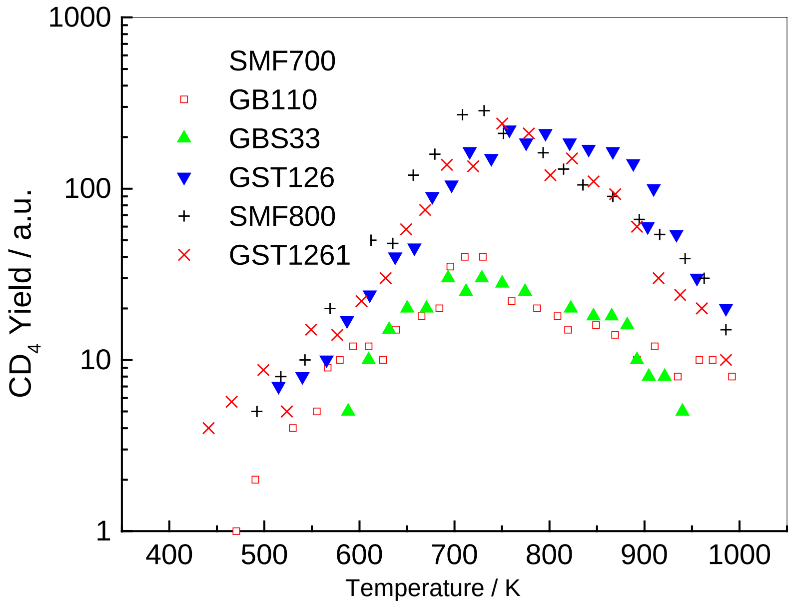
MATERIALS No	COMPOSITIONS B_4C	SI(WT%)	DENSITY (G/CM^3)	POROSITY (%)	THERMAL CONDUTIVITY (W/MK) AT 300K
3D C/C 0#			2.03	3.16	197/190
3D C/C 1#			1.94	3.06	119/81
3D C/C 2#	6.0		1.99	3.9	124
3D C/C 3#	4．5		2．0	4．4	95/34
3D C/C 4#		3.7	2.0	5.3	128/37
C/C+B_4C 6#	7.0		2.07	3.05	125/122
C/C+B_4C 12#	10		2.09	3.0	120/128
2D thin plate	0.4,0.6,0.8mm plate, the bend-resist strength is 69.2, 64.9, 54.7 MPa, respectively. Thermal conductivity is 0.225 W/m K at 300K (Made in Germany 0.75mm plate, the bend-resist strength is 141 MPa. Thermal conductivity is 0.72 W/m K at 300K				
AEROLOR[a]	Made in. France		1.80		300/85
CX_20028[a]	Made in Japan		1.74		325/186

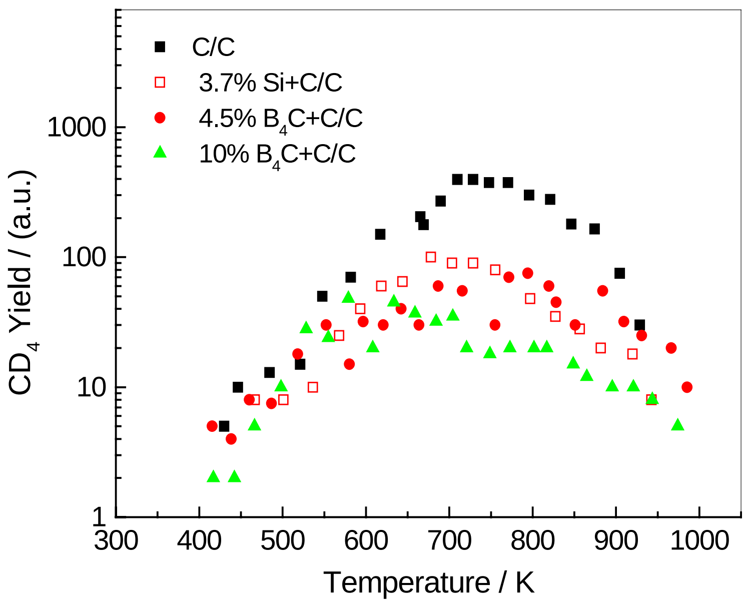
a: as compare materials.

Chemical sputtering--experiments

Chemical sputtering: using 3KeV D^+ irradiated specimens under dose rate at 4.6×10^{15} D^+ $cm^{-2}s^{-1}$ and rising up temperature during D^+ irradiating and measured CD_4 gas partial pressure at the same time. It was took about 170min

Chemical sputtering--results



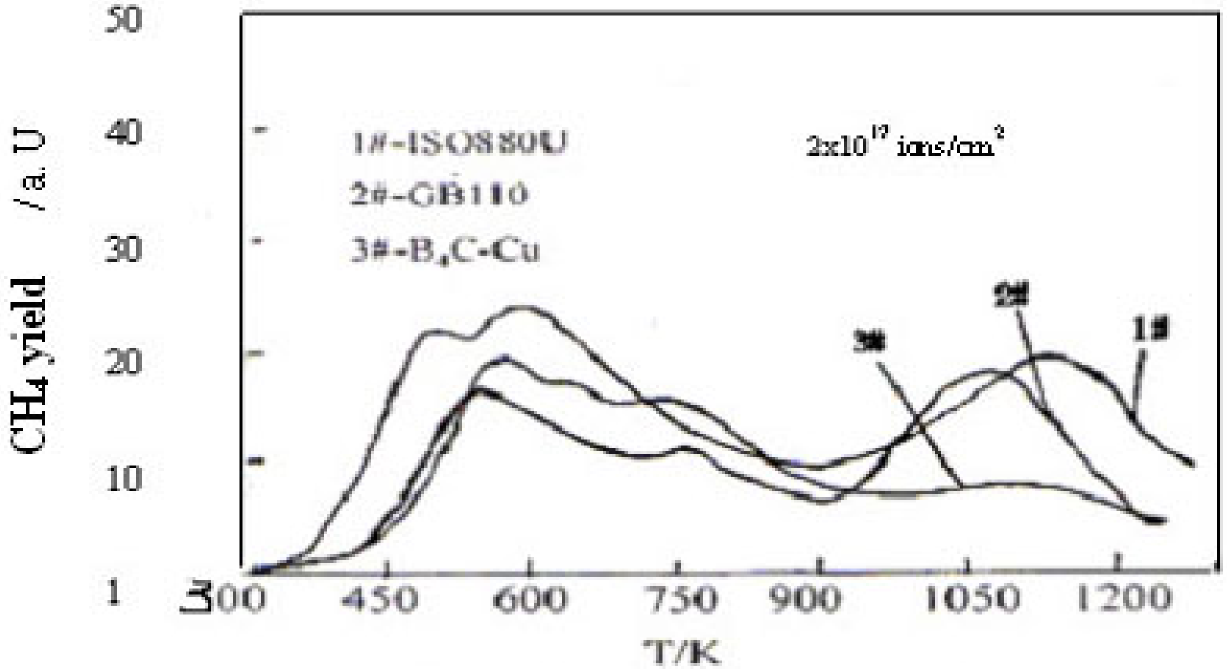


P.S. GB110÷GTB10610

TDS--experiments

Temperature Desorption Spectrum:
after using 2.5keV H^+ irradiated specimens and the fluence up $1.2x10^{17}$ H^+ ions cm^{-2} , rising temperature up and measured CH_4 gas partial pressure at the same time.

TDS--results



1#-Purity G   2#-Boron Doped G

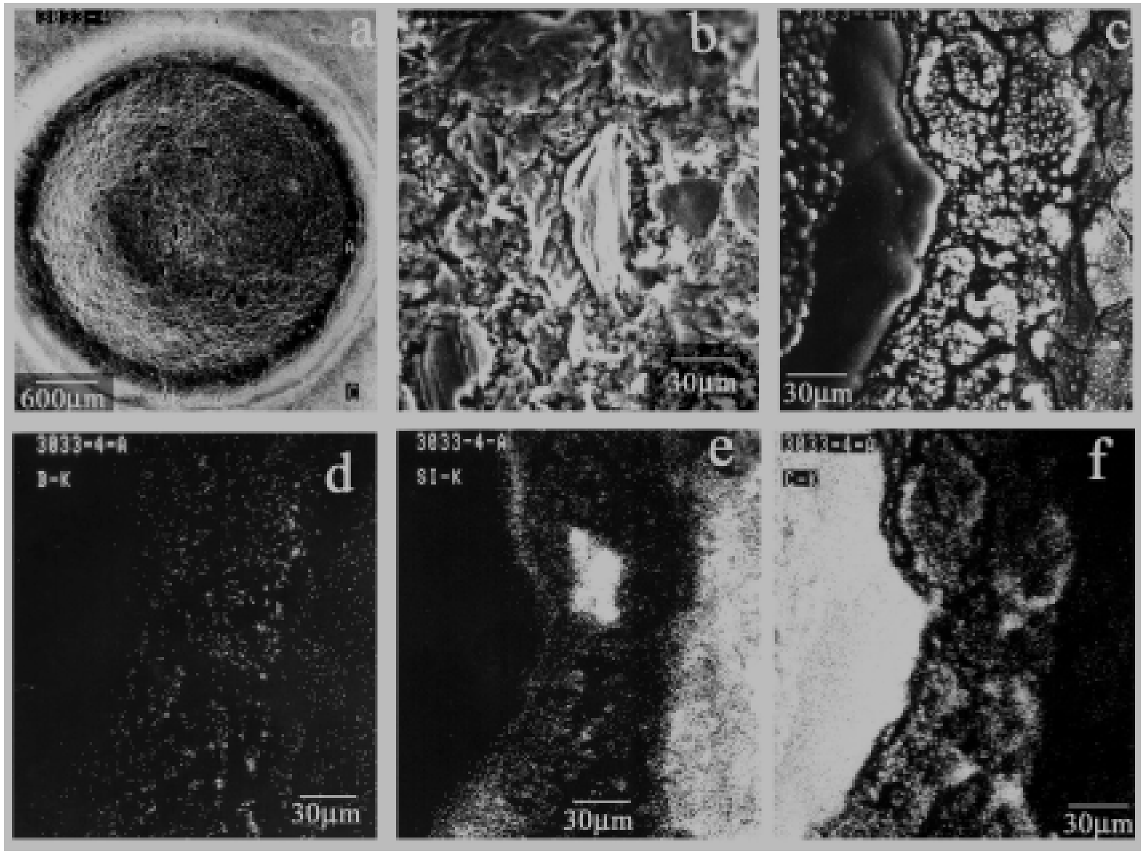
3#--B4C-Cu GFM

Thermal Shock -- experiments

Thermal Shock:

using Laser beam, beam size 4mm and 7.2mm in diameter, duration 4ms, frequency 10Hz, average power 200W, total irradiation time 5 to 30s, or, power density on surface of specimens is 122.9MWm^{-2} and 398.1MWm^{-2}, and thermal shock strength is 0.78 $KJ\ cm^{-2}.S^{-1/2}$ and 2.52 $KJ\ cm^{-2}.S^{-1/2}$.

Thermal Shock--results



Si、B rich at boundary of Laser Spot

Graphite in center area

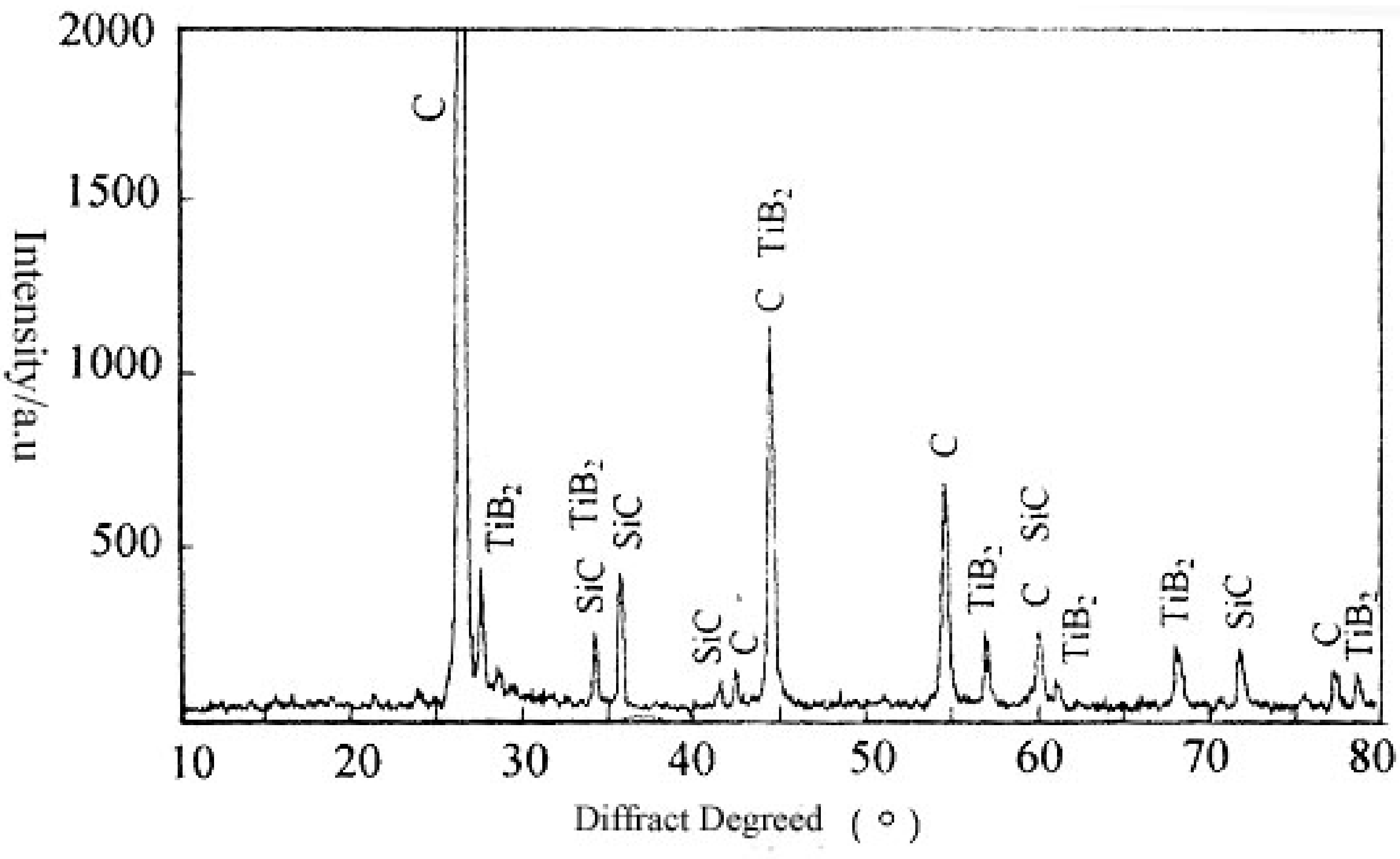
SiC melt point 2100°C

B_4C - 2450°C

Graphite - 3500°C

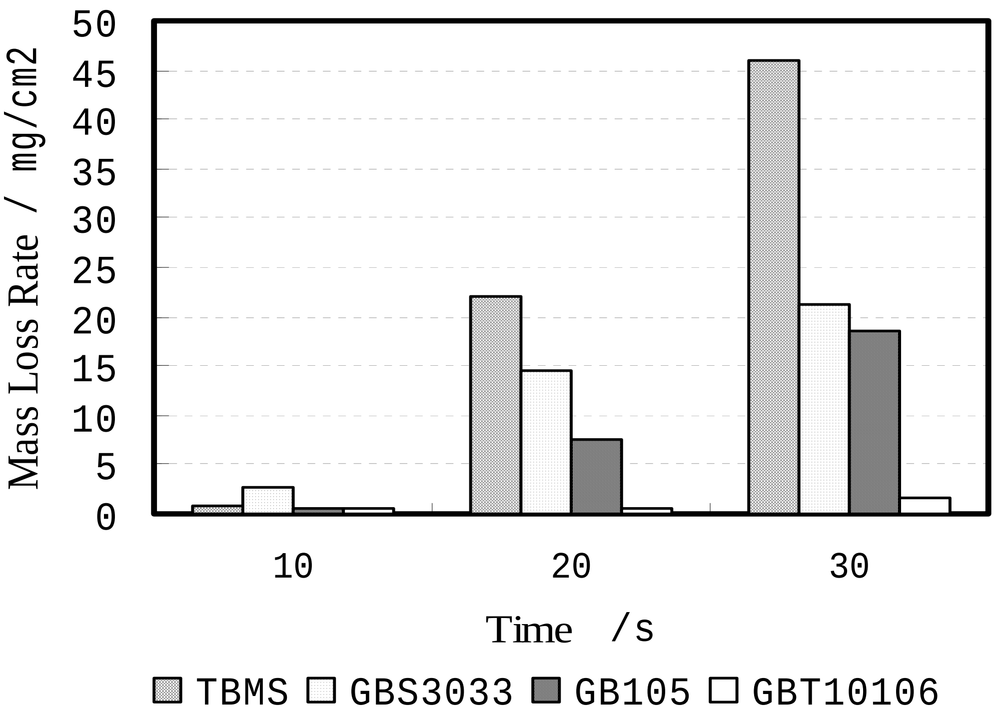
GBS33 SEM photos after thermal shock (GBS3033 ÷ GBS33

Thermal Shock--results



XRD spectrums for doped graphite (GBS33) after thermal shock

Thermal Shock --the mass loss rate



The major mass loss is due to the thermal emission of large particle of mass, and large particle of mass is produced by thermal stress fracture, so, for doped materials, during and after thermal shock, SiC and B_4C was melt in the first (melt points are 2100°C, 2450°C and 3500° for SiC, B_4C and graphite, respectively), and the thermal stress was released

The mass loss rate of new type multi-doped graphite and purity graphite after Laser beam bombarded. (TBMS –purity graphite, GBS3033 ÷ GBS33 , GBT10106 ÷GTB10610)

RES--experiments

Radiation Enhance Sublimation:

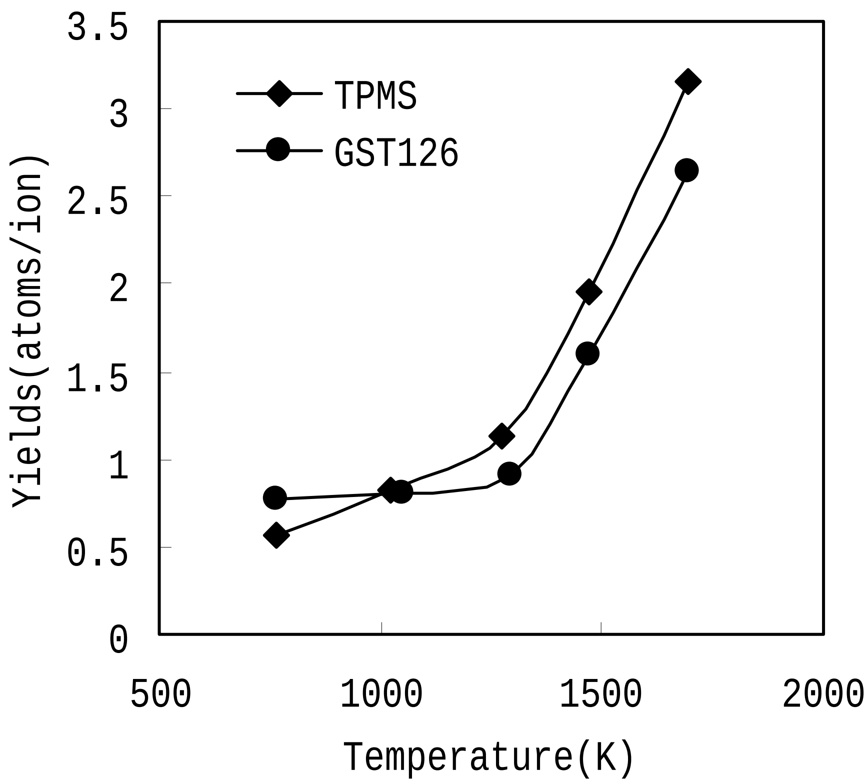
2.5keV H^+ 5 mA **irradiated**

2×10^{18} H^+ ions cm^{-2}

(at different temperatures)

measured the specimens weight changed before and after irradiation.

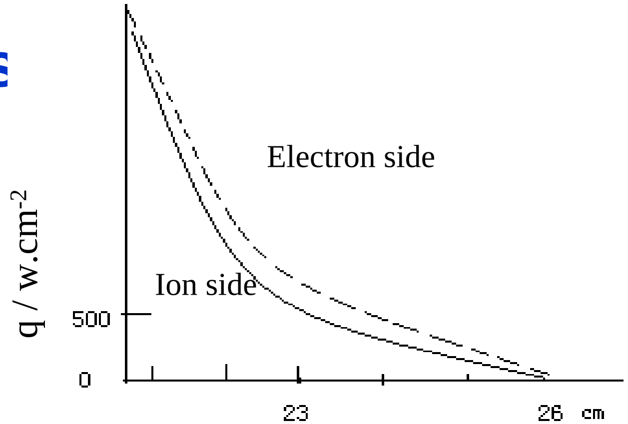
RES--results



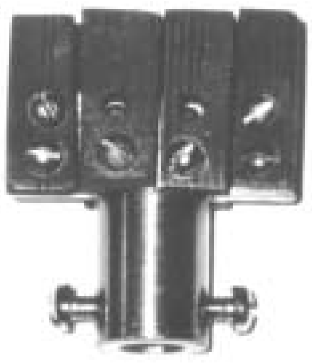
Radiation enhance sublimation yield of purity graphite (TMPS) and Si and Ti doped graphite.

Exposing to plasma--experiments

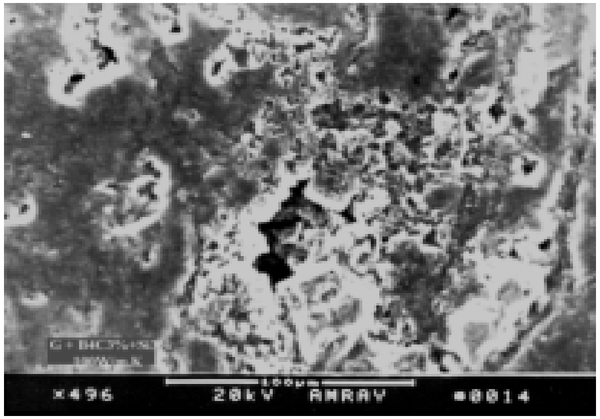
Exposing to plasma: locating specimens in HL-1M Tokamak, where is 1cm closer to main plasma than that of limiter. During exposure specimens were turn over for the specimen surface keeping to electron side and to ions side in half a total time. After about 100 times charged, specimens were taken off to analyze. surface energy density from 110 wcm^{-2} to 570 wcm^{-2}.



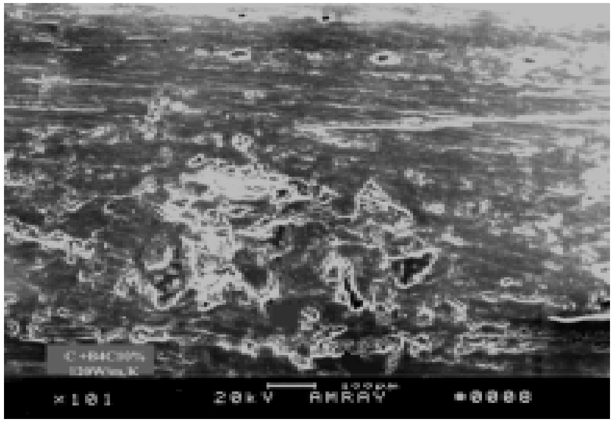
Specimens located at R=22cm (Limiter at R=23cm 575W.cm^{-2}, HL-1M total power 2MW)



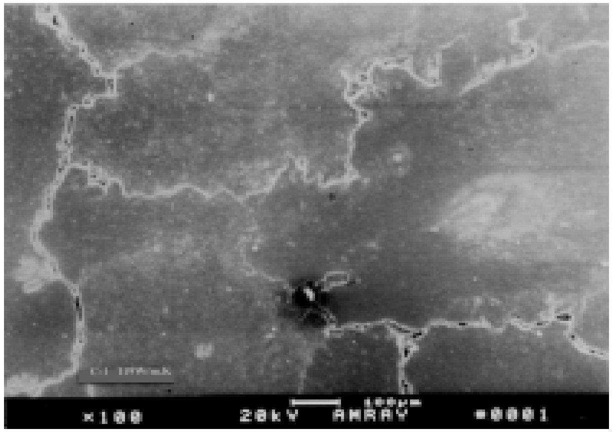
Exposing to plasma--results



(a). G + B_4C3% + Si3%



(b). C/C+B_4C10%



(C). Purity C/C composites

SEM photograph of multi-elements doped and non-doped carbon-base materials after exposed to HL-1M Tokamak (Plasma charged No：6070# - 6164#)(surface energy density from 110 wcm^{-2} to 570 wcm^{-2}.)

☛ Summary

The best composition of Multi-element doped for chemical sputtering are：

B_4C-3 ~ 5%， T_i –6 ~ 8%， S_i~6%

for RES is S_i>12%

The chemical sputtering yield is lower about one order magnitude, TDS and RES rates are lower about 20% for new type multi-elements doped than the purity materials.

Exposing specimens to plasma about 100 times charges, not significant cracking was observed for new type multi-elements doped but there were many net cracking for the purity materials materials,