Characteristics of co-deposited carbon layers on tungsten nano-structure

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1 Introduction

Background

Carbon (C) and tungsten (W) are used for 1st set of divertor of ITER.
C can be easily sputtered and form co-deposition layer with hydrogen isotopes (H,D,T).
W nanostructure (fuzz) enhanced C deposition on the W observed in TEXTOR tokamak [1].
No systematic studies for deposition conditions, structure of deposition layers, and behaviour of hydrogen isotopes by precisely controlled experiments.

Purpose

To investigate the effects of fuzz on the structure of C deposition layers.

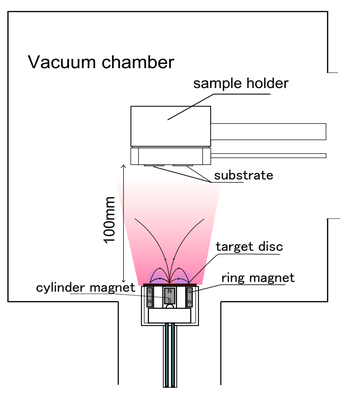
[1] Y. Ueda et al, J. Nucl. Mater. in print (2011), presented at 19th PSI (2010).

2 Conclusion

- Fuzz affected the structure of the C deposition layer on W.
- Features of C layer on Fuzz compared with normal C deposition layer :
  - hexagonal bonds (from I(D)/I(G)) increased,
  - three dimensional disorder (from FWHMG) decreased,
  - sp3 bonds (from posG) decreased.
- The parameters on above indicated bigger two dimensional clusters.
- Decrease in internal stress of C deposition layer on fuzz surface (compared with flat surface) due to porous structure could relate to these differences.

3 Experimental

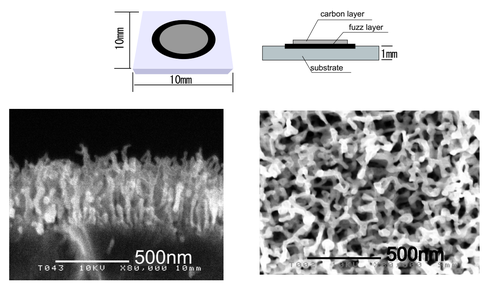
Magnetron sputtering device



experimental condition

target - isotropic graphite
(ToyoTanso Ltd:IG-110)
discharge voltage : DC450V
discharge current : 200mA
power : 60W
gas : Ar D2
flow : Ar= D2= 5 sccm
pressure : 20mTorr
temperature : ~350K

Fuzz samples

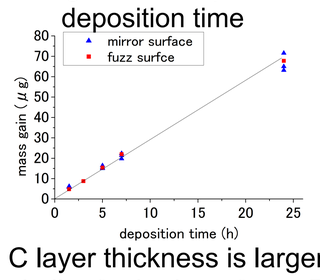


fuzz production condition
irradiation He ion energy : 150eV
substrate temperature : 1300K~

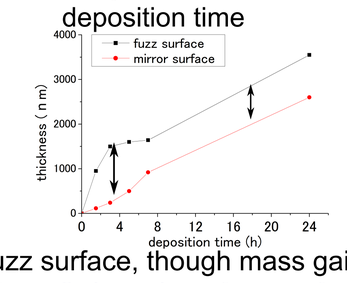
4 Growth properties

layer growth

mass gain of C deposit vs. deposition time

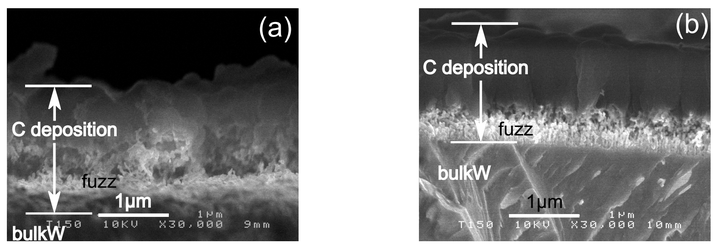


C layer thickness vs. deposition time



- C layer thickness is larger on fuzz surface, though mass gain is similar for both surfaces.Therefore, C deposit on fuzz surface has lower density (could have porous structure)

Cross section of C deposition on fuzz surface (a) and mirror surface (b)

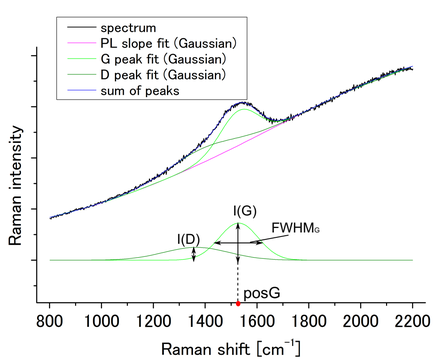


- Sample with 3h of C deposition and 7h sample have the same thickness of fuzz on the W surface.
- Together with the mass gain result, these indicate that 3h sample is more porous.

5 Analysis of structure by Raman spectroscopy

5-1 Raman spectroscopy

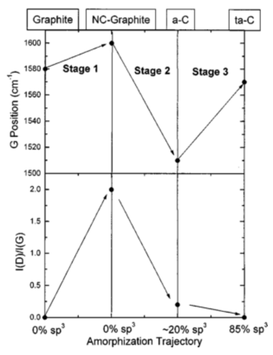
Typical Raman spectrum



Ar gas laser (514.5nm)
analysis depth ~1.0μm
(estimated by absorption coefficient of a-C:H[2])

Parameters

FWHMG: (full width at half maximun of the G peak)
mainly corresponds to three dimensional disorder
I(D)/I(G) : (ratio of intensity D peak to G peak)
only corresponds to hexagonal ring bond
posG : (position of G peak)
corresponds to sp3 bond



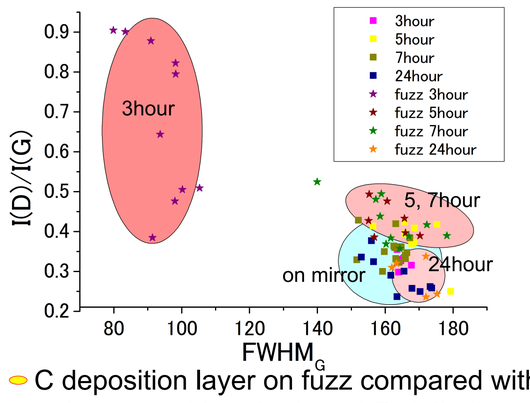
- Change of Raman parameters on carbon materials.
- Increase in sp3 bonds prevents the construction of hexagonal bonds.

Three stage model [3]

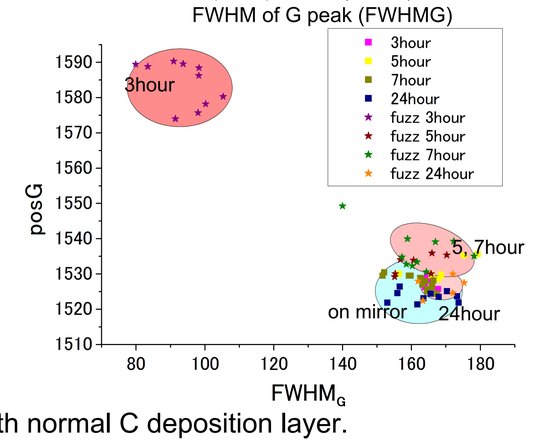
[2] B. Dischler, Appl Phys Let 42 (1983) 636.
[3] A. Ferrari, J. Robertson, Phys Rev B 61 (2000) 14095-14107.

5-2 Properties of structure

Ratio of the D and G peaks (I(D)/I(G)) vs FWHM of G peak (FWHMG)



G peak position (Pos G) vs FWHM of G peak (FWHMG)

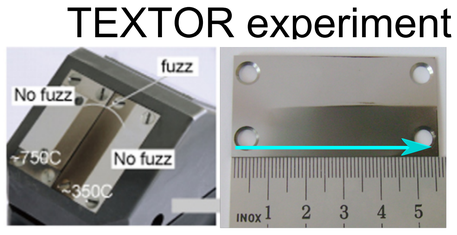


- C deposition layer on fuzz compared with normal C deposition layer.
  - hexagonal bonds (from I(D)/I(G)) increase
  - three dimensional disorder (from FWHMG) decrease
  - sp3 bonds (from posG) decrease
- The parameters on above indicated bigger two dimensional clusters.
- These changes were slimiler to the changes observed when stress in the film become smaller [4].
- Effects of fuzz disappeared for thick C deposition layer.

[4] J. Schwan, et al, Journal Of Appl Phys 80 (1996) 440.

5-3 Comparison with C deposit of the other experiments

TEXTOR experiment

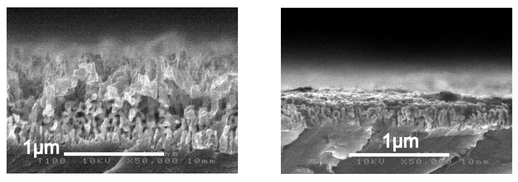


- Samples with fuzz surface and mirror surface on TEXTOR Test limiter, and were exposed to the edge plasma (D discharge, 623K~) [2].
- Erosion area (the most fuzz is sputtered) and thick deposition area(the most fuzz remained).

Ion beam irradiation experiment

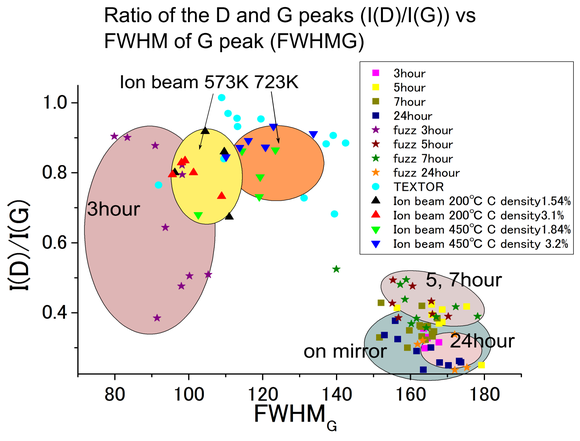
- C and D mixed ion beam irradiation experiment with High Flux Irradiation Test device(HiFIT)

irradiation energy : 150eV
temperature : 473K, 623K
fluence : $1.4 \times 10^{24}/m^2$

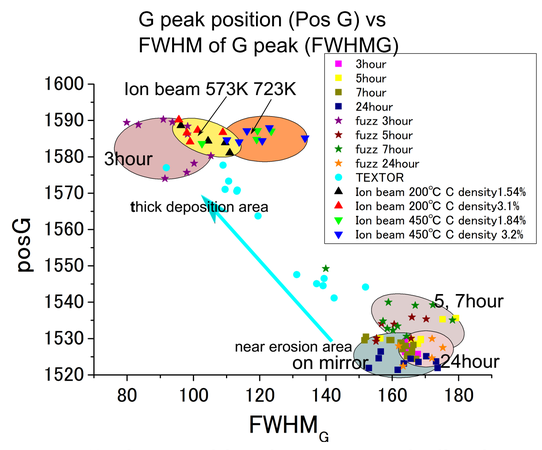


(a) 473K, C concentration 3.1% (b) 723K, C concentration 3.2%

Ratio of the D and G peaks (I(D)/I(G)) vs FWHM of G peak (FWHMG)



G peak position (Pos G) vs FWHM of G peak (FWHMG)



- C deposition characteristics on fuzz by magnetron sputtering and ion beam are similar in I(D)/I(G) and posG.
- FWHMG varied with the substrate temperature.
- PosG of the erosion area on TEXTOR sample was close to that of the mirror surface samples by magnetron sputtering.
- These results indicate that the existence of fuzz has more significant effect on the structure of C deposition layers, as compared to temperature and incident ion energy.