The development of a bent Si crystal for X-ray imaging polarimetry

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1. Introduction : X-ray polarization

- 4 important quantities from celestial objects

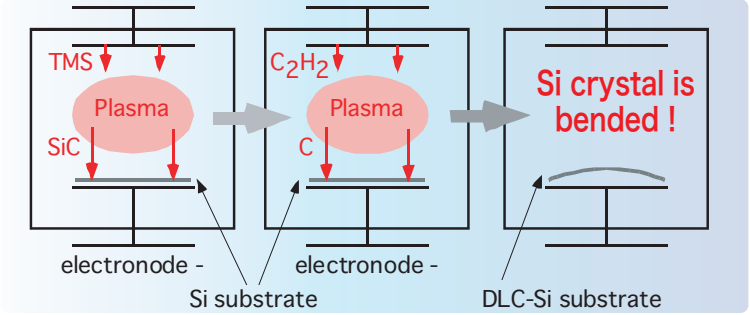
Celestial objects		Capabities of X-ray astronomy
	Images	Δθ ～ 0.5 arcsec
	Time variation	E/ΔE ～ 3000
	energy spectrum	Δt < 1 msec
	Polarization	Delayed development !!!

- Meathods to measure the X-ray polarization
  1. Thomson/Compton scattering
  2. Direction of a K-shell photoelectron in photoeletcric absorption
  3. Bragg reflection by crystals with 45° incident angle

- Our porpose for the measurement of X-ray polarization
  Measurement of X-ray polarization in wider energy band
  Development of a bend crystal for the element of optical system

2. Plasma CVD for DLC deposition

- DLC (Diamond-Like Carbon) deposition
  Pulsed DC plasma CVD machine (area 300Φmm × 300Hmm)
  Si crystal with DLC deposition is bended by the redidual stress.

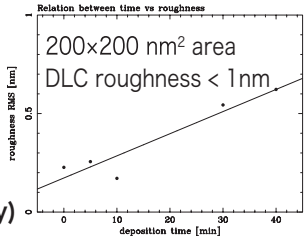


No.	Aim	Filled Gas	DC	Current	Gas Flow	Deposited Rate
1	Cleaning	Ar	4 kV	0.4 A	30 sccm	---
2	SiC deposition	TMS	5 kV	1.0 A	20 sscm	35 nm/min
3	DLC deposition	Acetylene	5 kV	0.8 A	30 sccm	20 nm/min

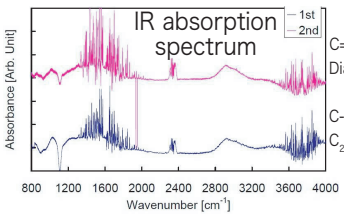
3. Property of diposited DLC on Si crystal

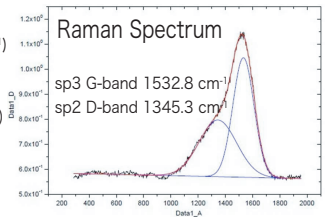
- DLC thickness (with laser profilometer)
  Deposited Rate : 20 nm/min, Distribution : < 2.4% within 300 mmΦ

- DLC roughness (with AFM)
  Increasing in deposition time
  Roughness <1 nm in 40 min deposition



- DLC Composition (IR spectroscopy)
- DLC Distortion (Raman spectroscopy)

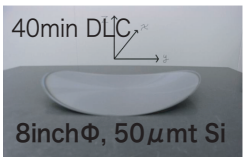


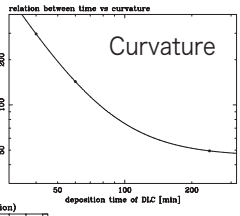


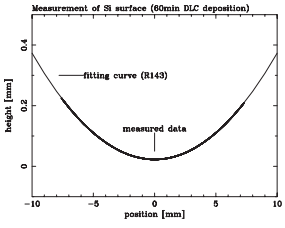
	Our DLC	Standard DLC	Diamond	Graphite
Configuration	Amorphous	Amorphous	Cubic	Hexagonal
Structure	sp3, sp2	sp3, sp2	sp3	sp2
Density [g/cm³]	1.66±0.99	1.2～3.3	3.52	2.27
Band Gap [eV]	0.1～1.1	0.8～3.0	5.47	0
Refractive index	2.22±0.44	2.0～2.8	2.41～2.44	2.0～2.2
H2 Content [%]	??	30～45	0	0

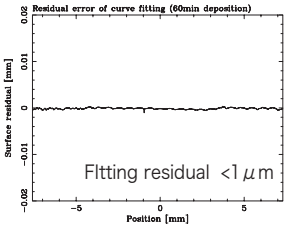
4. Shape of bent Si crystals

- Curvature





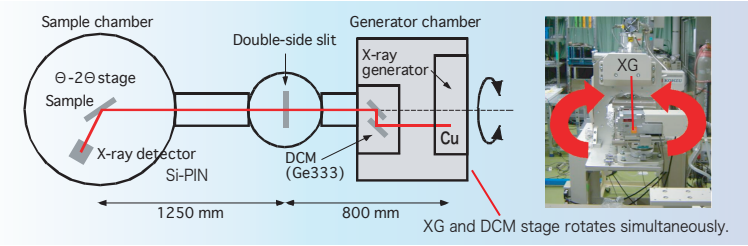




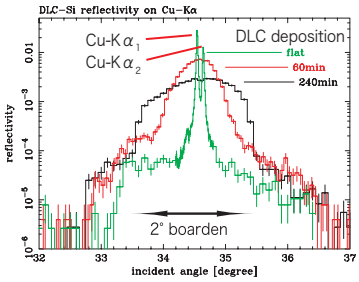
The bending looks like only in one direction. The surface is very smooth. The fitting residual is less than 1μm.

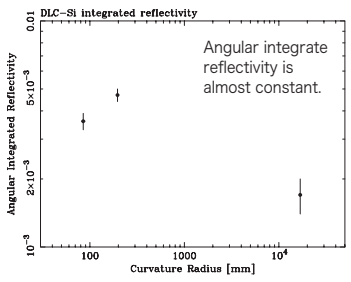
5. X-ray measurement

- Instrument : Simplified polarized X-ray generator and beamline



- X-ray reflectivity (non-polarized Cu-Kα filtered with Ni-filter)





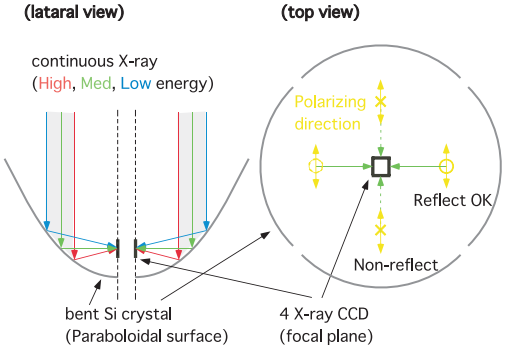
- X-ray polarization (Ge DCM polarized Cu-Kα)
  Modulation Factor is measured rotated with XG.

P = R/M
R = $(N_{90}-N_0)/(N_{90}+N_0)$
P : Polarization degree
M : Modulation factor
N_{90} : Count at XG 90°
N_0 : Count at XG 0°

Monochromator	Energy	$R=(N_{90}-N_0)/(N_{90}+N_0)$ flat Si	bent Si
Nothing	Cu-Kα	2.3 ± 0.3 %	-3.2 ± 0.3 %
Nothing	Cu-Kβ	5.5 ± 0.3 %	-2.5 ± 0.3 %
Ge DCM	Cu-Kα	---	96 ± 1 %

Modulation factor of the bended Si crystal is M>90%.

6. Disucussion : Proposed new optical system



If Si(400) is bent to the shape of paraboloid ...
↓
Fe-K line 6.4～6.9 keV
45° Reflect & Focus
↓
High modulation factor and small S/N ratio

Proposed new optical system with the bent Si crystal
→ wider energy band, higher modulation factor, smaller S/N, larger EA