A novel multi-collimator for high energy X-rays and application to CCDs

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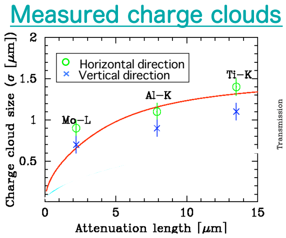
Abstract

:Charge-coupled devices (CCDs) are widely used in X-ray astronomy as a focal plane detector up to 10keV. For future X-ray space missions, thick CCDs are being developed to improve the detection efficiency of high energy X-rays.A mesh experiment has been, so far, the only practical technique to study CCD response with subpixel resolution. The mesh technique has revealed the X-ray response within a pixel for various types of CCDs the final charge cloud shape. However the mesh experiment is never valid for X-rays not more than 7keV because the mesh becomes transparent for higher X-rays. This fact has prevented us to %measure the charge cloud shape for higher energy X-rays.We have proposed a new method to produce a novel multi-collimator using a barium phosphate glass, BP-1, which was originally developed as a solid state track detector. The BP-1 collimator has a capability to realize small through-holes of several hundred nanometers in radius. The initial production of BP-1 collimator revealed that unprecedented high aspect-ratio of through holes with perfect circular shape. We found that BP-1 collimator functions well up to 20keV. This unique technique can be employed to investigate subpixel response of X-ray CCDs beyond 10keV.

1. Charge clouds in X-ray CCDs

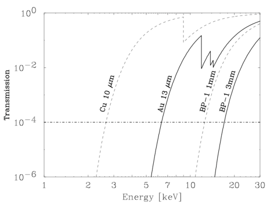
Charge cloud produced could be a prove to investigate signal charge dynamics inside CCDs.
(electric field, charge diffugion, electrostatic repulsion etc.)

Measured charge clouds



The mesh-experiment enable us to directrly measured charge cloud shapes of various X-ray energies by (Hiraga 2002)

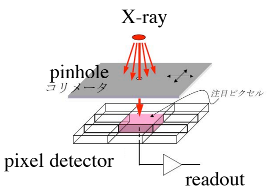
Transmission of X-ray



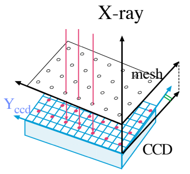
However, limited up to 6keV.
Mesh metal is transparent!
Need another methods?
Need another materials?

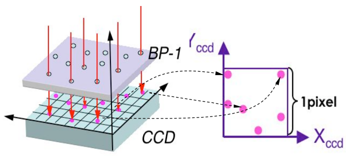
2. mono v.s. multi collimators beyond 10keV

mono-collimator with scan



multi-collimator withoutscan





	pinhole	mesh	BP-1
pinhole number	1 ×	10^5◎	10^4○
X-Y stage	need ×	no ◎	no ◎
Thickness	◎	×	◎

BP-1 glass is introduced to produce multi-collimaror beyond 10keV.

3. A novel fine-collimator using BP-1 glass

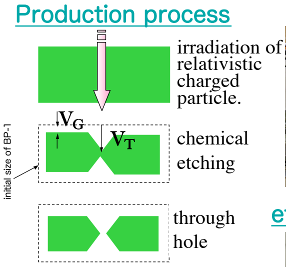
Construction of BP-1[wt%]

S.C. Wang et al NIMB (1988)

O	Na	Si	P	Ca	Sr	Ba	total
42.2	1.39	1.06	29.0	0.003	0.045	26.3	100

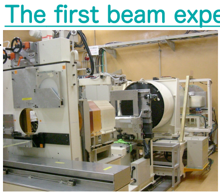
Barium Phosphate glass, BP-1, has originally developed as the most sensitive solid state nuclear track etch detector.
High-Z material, Ba--> low transmission for high energy X-ray

Production process



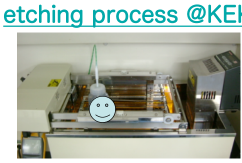
High sensitivity(s=Vt/Vg) cone-shaped etchpit with chemical etching through-hole would be produced.

The first beam experiment@HIMAC



Beam: Xe
Energy:80-100MeV/u
size: 15x15x1.3mm
density:2x10^4 holes/cm^2

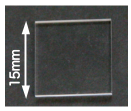
etching process @KEK



etchant: HBF4:49%
Temp.:50 ℃
Duration : 60-100 hours

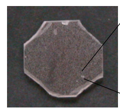
The first prototype

before



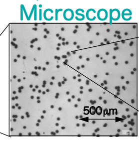
Transparent glass

after



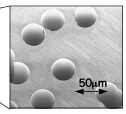
smoked due to tiny pinholes

Optical Microscope



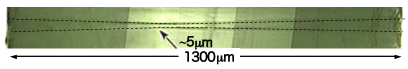
pinholes are romdomely distributed

SEM



perfect circuler shape

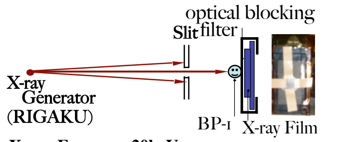
cross sectioin



high aspect ratio with micron-order pinhole were carried out
surface:30um
inner:5um

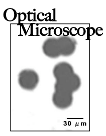
4. Validity for high energy X-rays up to 20keV

X-ray photo with parallel beam@ISAS

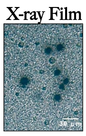


X-ray Energy :~20keV
Beam length:36m
Film resolution:0.4μm

Optical Microscope



X-ray Film



- **same pattern**
- **X-ray photo:~6μmφ**

Our first prototype function well up to 20keV as a collimator.

5. Summary and feature prospects

- ✓ Novel multi-collimator using BP-1 glass are proposed.
- ✓ The first prototype of the BP-1 collimator was produced and realized unprecedented high-aspect ratio.
- ✓ The first performance with X-ray films verify that BP-1 collimator functions up to 20keV.
- ✓ CCD detection test with Fe55 is on going.
- ✓ Applications to CCDs using parallel X-ray beam are planed.

references

Junko Hiraga ph.D thesis 2002

S.C. Wang et al. NIM B (1988)

J. S. Hiraga et al NIM A (2006) to bu published