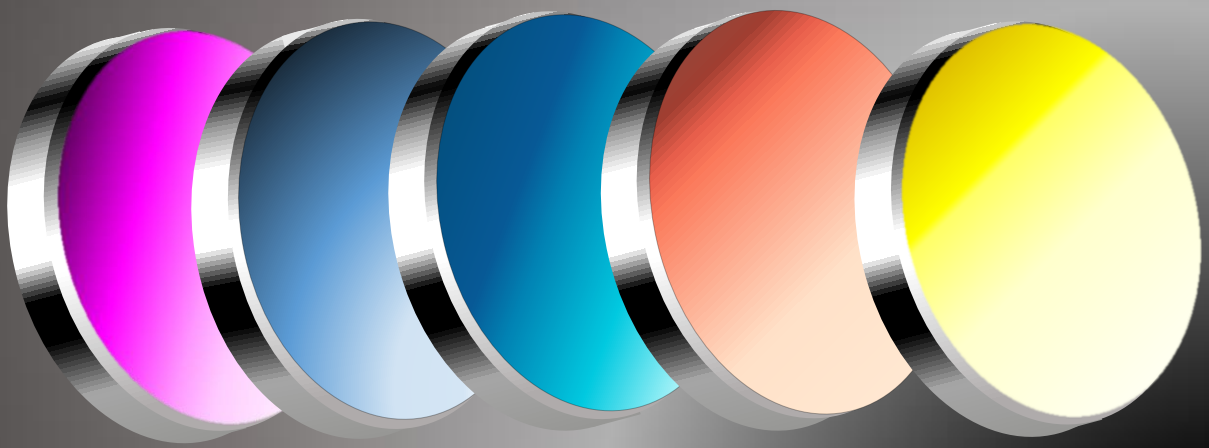
NTT AT

NTT-AT's Optics and Materials

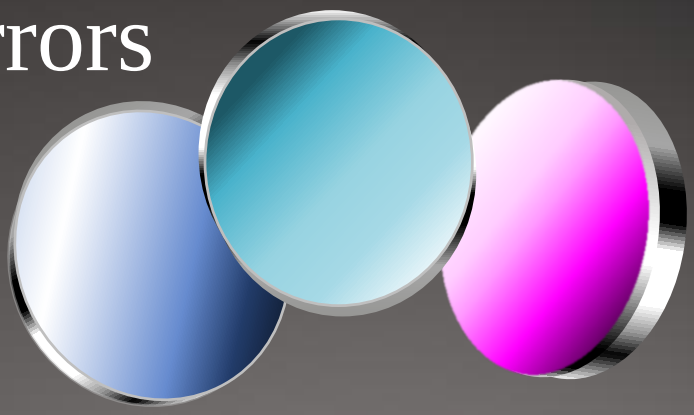


NTT Advanced Technology Corporation

NTT AT

Contents

Multilayer Mirrors

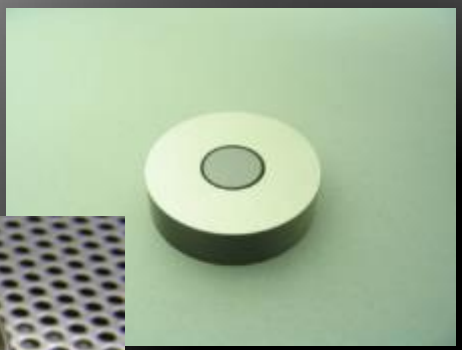


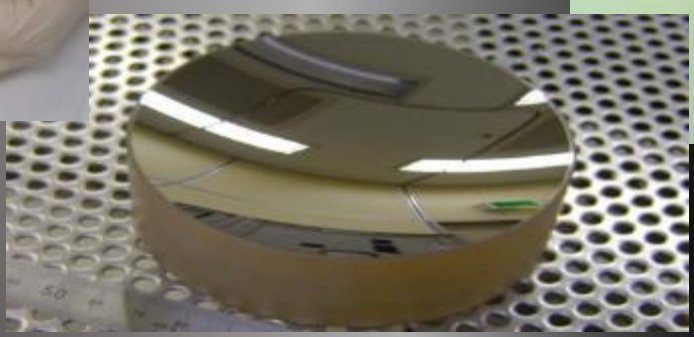
NTT-AT provides custom-made XUV multilayer mirrors for both academic fields and industrial fields. For high-quality mirror developments, not only fabrication techniques but also optical design know-how is necessary. We have been supplying kinds of mirrors corresponding to the customers' requirements, such as high reflectivity, broad-bandwidth, narrow-bandwidth, and high contrast.

Our technologies will support your research and developments.

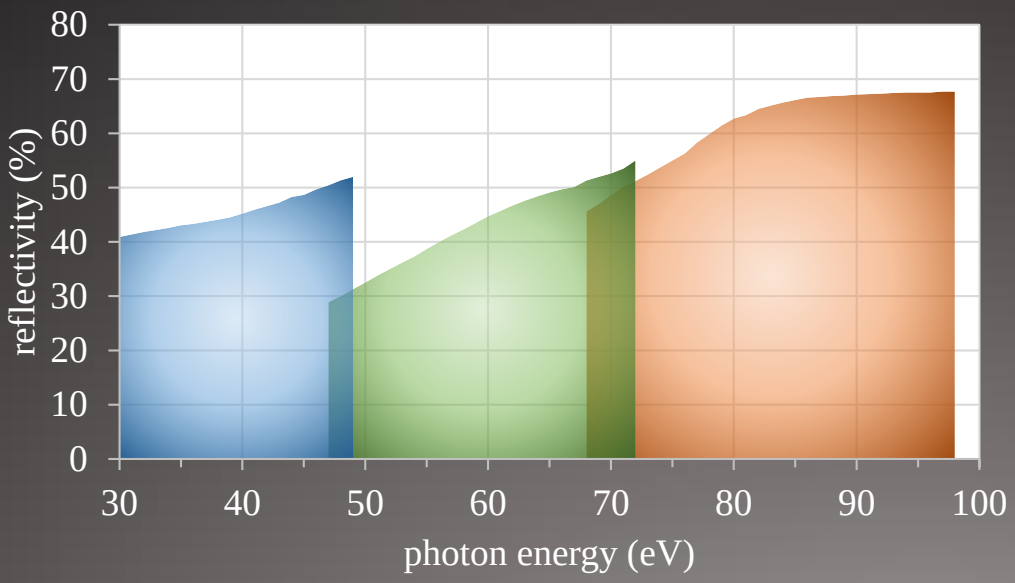
Please kindly find the detail information of our XUV mirrors for your experiments.

For more information, please contact:https://www.ntt-at.com/product/list_xuv_euv_x-ray_optics.html





XUV High Reflectivity Mirrors



No	design name	AOI	pol.	peak energy	wavelength	reflectivity	bandwidth (FWHM)	
1	HR-98-3.4	5 deg	s	98 eV	12.7 nm	67.7%	3.4 eV	(0.4 nm)
2	HR-95-3.8	5 deg	s	95 eV	13.1 nm	67.7%	3.8 eV	(0.5 nm)
3	HR-90-3.8	5 deg	s	90 eV	13.8 nm	68.0%	3.8 eV	(0.6 nm)
4	HR-85-4.0	5 deg	s	85 eV	14.6 nm	66.8%	4.0 eV	(0.7 nm)
5	HR-80-4.0	5 deg	s	80 eV	15.5 nm	63.3%	4.0 eV	(0.8 nm)
6	HR-75-4.6	5 deg	s	75 eV	16.5 nm	54.5%	4.6 eV	(1.0 nm)
7	HR-70-5.0	5 deg	s	70 eV	17.7 nm	47.5%	5 eV	(1.2 nm)
8	HR-70-2.6	5 deg	s	70 eV	17.7 nm	52.1%	2.6 eV	(0.7 nm)
9	HR-65-2.6	5 deg	s	65 eV	19.1 nm	48.5%	2.6 eV	(0.8 nm)
10	HR-60-2.8	5 deg	s	60 eV	20.7 nm	43.7%	2.8 eV	(1.0 nm)
11	HR-55-3.6	5 deg	s	55 eV	22.5 nm	37.3%	3.6 eV	(1.5 nm)
12	HR-50-4.2	5 deg	s	50 eV	24.8 nm	30.9%	4.2 eV	(2.1 nm)
13	HR-48-2.0	5 deg	s	48 eV	25.8 nm	50.6%	2.0 eV	(1.1 nm)
14	HR-45-2.4	5 deg	s	45 eV	27.6 nm	48.4%	2.4 eV	(1.4 nm)
15	HR-40-2.6	5 deg	s	40 eV	31.0 nm	44.8%	2.6 eV	(2.0 nm)
16	HR-35-2.6	5 deg	s	35 eV	35.4 nm	43.1%	2.6 eV	(2.6 nm)
17	HR-30-3.0	5 deg	s	30 eV	41.3 nm	41.2%	3.0 eV	(4.1 nm)
18	HR45-90-6.0	45 deg	s	90 eV	13.1 nm	66.1%	6.0 eV	(0.9 nm)
19	HR45-80-7.4	45 deg	s	80 eV	15.5 nm	60.0%	7.4 eV	(1.4 nm)
20	HR45-70-36.0	45 deg	s	70 eV	17.7 nm	49.0%	3.6 eV	(0.9 nm)
21	HR45-60-5.4	45 deg	s	60 eV	20.7 nm	40.8%	5.4 eV	(1.8 nm)
22	HR45-50-10.0	45 deg	s	50 eV	24.8 nm	30.0%	10.0 eV	(5.1 nm)
23	HR45-40-5.0	45 deg	s	40 eV	31.0 nm	44.4%	5.0 eV	(3.8 nm)
24	HR45-30-7.0	45 deg	s	30 eV	41.3 nm	42.5%	7.0 eV	(9.3 nm)

design name	HR-98-3.4
AOI	5 deg
polarization	s
peak energy	98 eV (12.7 nm)
peak reflectivity	67.7%
bandwidth (FWHM)	3.4 eV (0.4 nm)

design name	HR-95-3.8
AOI	5 deg
polarization	s
peak energy	95 eV (13.1 nm)
peak reflectivity	67.7%
bandwidth (FWHM)	3.8 eV (0.5 nm)

design name	HR-90-3.8
AOI	5 deg
polarization	s
peak energy	90 eV (13.8 nm)
peak reflectivity	68.0%
bandwidth (FWHM)	3.8 eV (0.6 nm)

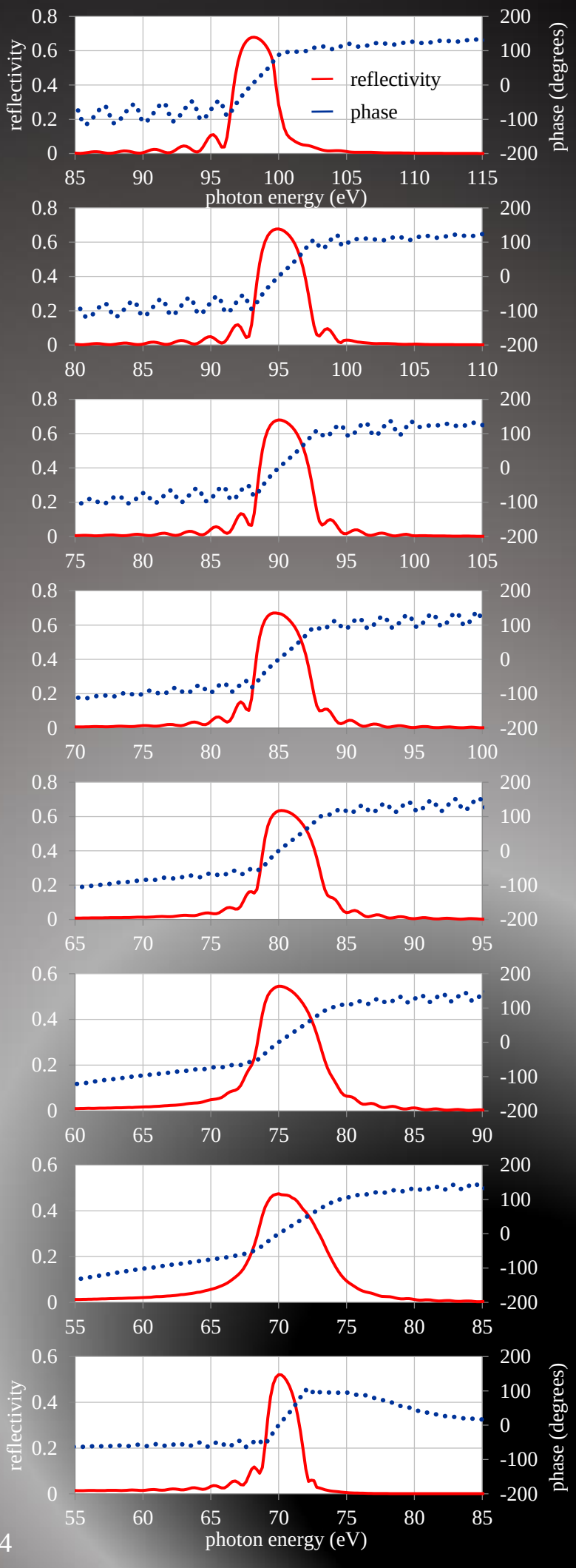
design name	HR-85-4.0
AOI	5 deg
polarization	s
peak energy	85 eV (14.6 nm)
peak reflectivity	66.8%
bandwidth (FWHM)	4.0 eV (0.7 nm)

design name	HR-80-4.0
AOI	5 deg
polarization	s
peak energy	80 eV (15.5 nm)
peak reflectivity	63.3%
bandwidth (FWHM)	4.0 eV (0.8 nm)

design name	HR-75-4.6
AOI	5 deg
polarization	s
peak energy	75 eV (16.5 nm)
peak reflectivity	54.5%
bandwidth (FWHM)	4.6 eV (1.0 nm)

design name	HR-70-5.0
AOI	5 deg
polarization	s
peak energy	70 eV (17.7 nm)
peak reflectivity	47.5%
bandwidth (FWHM)	5.0 eV (1.2 nm)

design name	HR-70-2.6
AOI	5 deg
polarization	s
peak energy	70 eV (17.7 nm)
peak reflectivity	52.1%
bandwidth (FWHM)	2.6 eV (0.7 nm)



design name	HR-65-2.6
AOI	5 deg
polarization	s
peak energy	65 eV (19.1 nm)
peak reflectivity	48.5%
bandwidth (FWHM)	2.6 eV (0.8 nm)

design name	HR-60-2.8
AOI	5 deg
polarization	s
peak energy	60 eV (20.7 nm)
peak reflectivity	43.7%
bandwidth (FWHM)	2.8 eV (1.0 nm)

design name	HR-55-3.6
AOI	5 deg
polarization	s
peak energy	55 eV (22.5 nm)
peak reflectivity	37.3%
bandwidth (FWHM)	3.6 eV (1.5 nm)

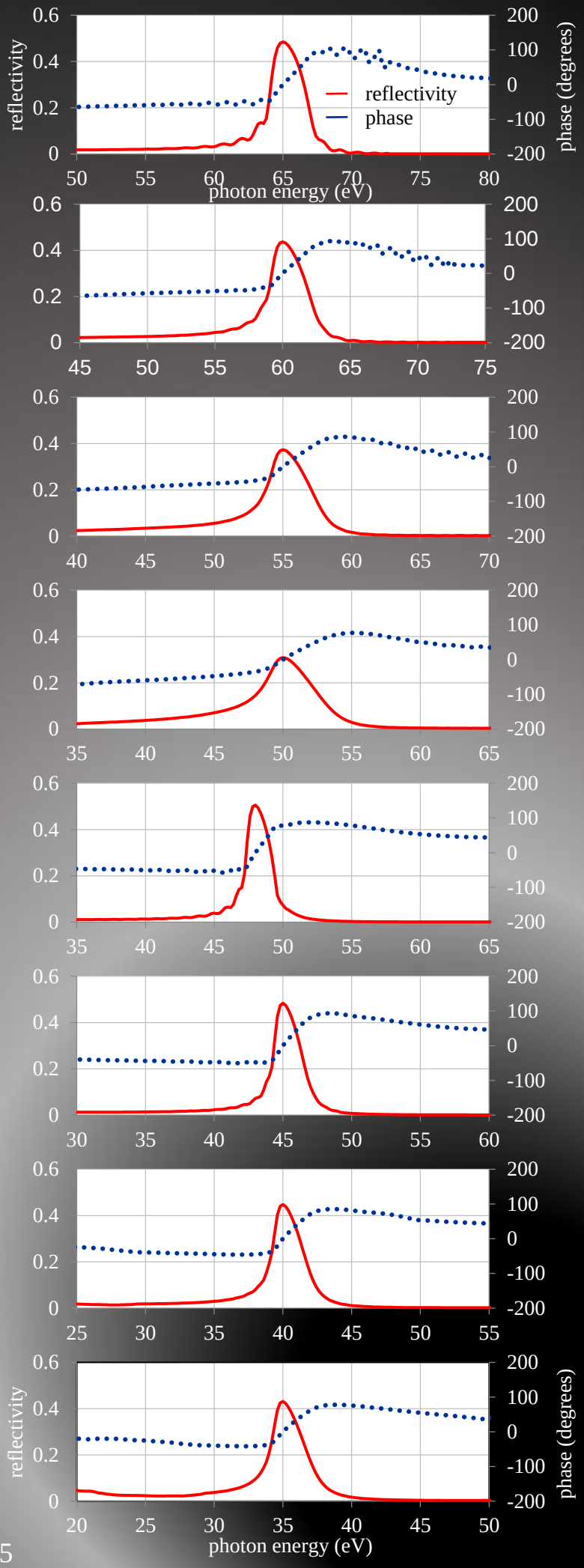
design name	HR-50-4.2
AOI	5 deg
polarization	s
peak energy	50 eV (24.8 nm)
peak reflectivity	30.9%
bandwidth (FWHM)	4.2 eV (2.1 nm)

design name	HR-48-2.0
AOI	5 deg
polarization	s
peak energy	48 eV (25.8 nm)
peak reflectivity	50.6%
bandwidth (FWHM)	2.0 eV (1.1 nm)

design name	HR-45-2.4
AOI	5 deg
polarization	s
peak energy	45 eV (27.6 nm)
peak reflectivity	48.4%
bandwidth (FWHM)	2.4 eV (1.4 nm)

design name	HR-40-2.6
AOI	5 deg
polarization	s
peak energy	40 eV (31 nm)
peak reflectivity	44.8%
bandwidth (FWHM)	2.6 eV (2.0 nm)

design name	HR-35-2.6
AOI	5 deg
polarization	s
peak energy	35 eV (35.4 nm)
peak reflectivity	43.1%
bandwidth (FWHM)	2.6 eV (2.6 nm)



design name	HR-30-3.0
AOI	5 deg
polarization	s
peak energy	30 eV (41.3 nm)
peak reflectivity	41.2%
bandwidth (FWHM)	3.0 eV (4.1 nm)

design name	HR45-90-6.0
AOI	45 deg
polarization	s
peak energy	90 eV (13.8 nm)
peak reflectivity	66.1%
bandwidth (FWHM)	6.0 eV (0.9 nm)

design name	HR45-80-7.4
AOI	45 deg
polarization	s
peak energy	80 eV (15.5 nm)
peak reflectivity	60.0%
bandwidth (FWHM)	7.4 eV (1.4 nm)

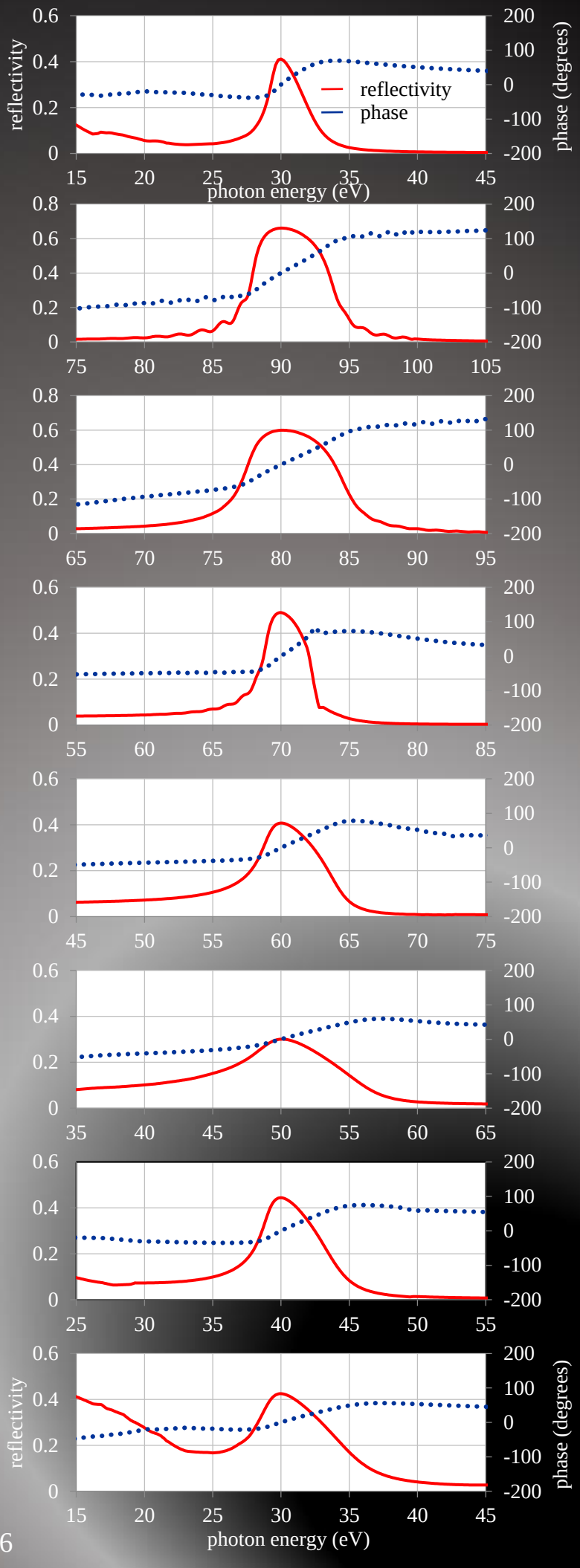
design name	HR45-70-3.6
AOI	45 deg
polarization	s
peak energy	70 eV (17.7 nm)
peak reflectivity	49.0%
bandwidth (FWHM)	3.6 eV (0.9 nm)

design name	HR45-60-5.4
AOI	45 deg
polarization	s
peak energy	60 eV (20.7 nm)
peak reflectivity	40.8%
bandwidth (FWHM)	5.4 eV (1.8 nm)

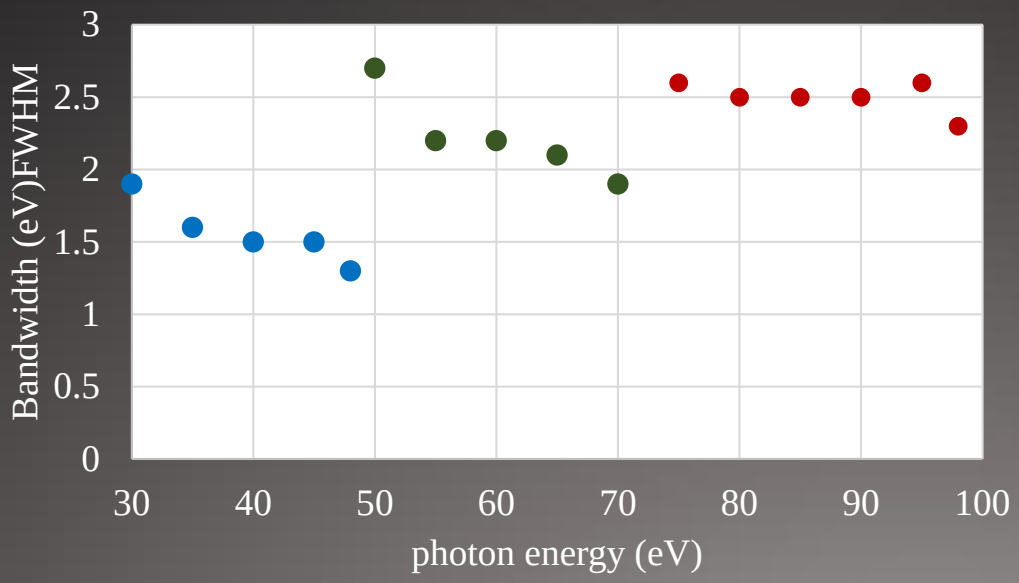
design name	HR45-50-10.0
AOI	45 deg
polarization	s
peak energy	50 eV (24.8 nm)
peak reflectivity	30.0%
bandwidth (FWHM)	10.0 eV (5.1 nm)

design name	HR45-40-5.0
AOI	45 deg
polarization	s
peak energy	40 eV (31 nm)
peak reflectivity	44.4%
bandwidth (FWHM)	5.0 eV (3.8 nm)

design name	HR45-30-7.0
AOI	45 deg
polarization	s
peak energy	30 eV (41.3 nm)
peak reflectivity	42.5%
bandwidth (FWHM)	7.0 eV (9.3 nm)



XUV Narrowband Mirrors



No	design name	AOI	pol.	peak energy	wavelength	reflectivity	bandwidth (FWHM)	
1	NBR-98-2.3	5 deg	s	98 eV	12.7 nm	39.5%	2.3 eV	(0.3 nm)
2	NBR-95-2.6	5 deg	s	95 eV	13.1 nm	40.7%	2.6 eV	(0.4 nm)
3	NBR-90-2.5	5 deg	s	90 eV	13.8 nm	44.5%	2.5 eV	(0.4 nm)
4	NBR-85-2.5	5 deg	s	85 eV	14.6 nm	48.5%	2.5 eV	(0.4 nm)
5	NBR-80-2.5	5 deg	s	80 eV	15.5 nm	50.1%	2.5 eV	(0.5 nm)
6	NBR-75-2.6	5 deg	s	75 eV	16.5 nm	46.0%	2.6 eV	(0.6 nm)
7	NBR-70-1.9	5 deg	s	70 eV	17.7 nm	43.7%	1.9 eV	(0.5 nm)
8	NBR-65-2.1	5 deg	s	65 eV	19.1 nm	43.5%	2.1 eV	(0.6 nm)
9	NBR-60-2.2	5 deg	s	60 eV	20.7 nm	42.2%	2.2 eV	(0.8 nm)
10	NBR-55-2.2	5 deg	s	55 eV	22.5 nm	38.4%	2.2 eV	(1.0 nm)
11	NBR-50-2.7	5 deg	s	50 eV	24.8 nm	33.5%	2.7 eV	(1.3 nm)
12	NBR-48-1.3	5 deg	s	48 eV	25.8 nm	49.2%	1.3 eV	(0.7 nm)
13	NBR-45-1.5	5 deg	s	45 eV	27.6 nm	47.6%	1.5 eV	(0.9 nm)
14	NBR-40-1.5	5 deg	s	40 eV	31.0 nm	44.8%	1.5 eV	(1.1 nm)
15	NBR-35-1.6	5 deg	s	35 eV	35.4 nm	43.7%	1.6 eV	(1.6 nm)
16	NBR-30-1.9	5 deg	s	30 eV	41.3 nm	42.0%	1.9 eV	(2.6 nm)
17	NBR45-90-3.1	45 deg	s	90 eV	12.7 nm	53.2%	3.1 eV	(0.5 nm)
18	NBR45-80-3.6	45 feg	s	80 eV	15.5 nm	52.3%	3.6 eV	(0.7 nm)
19	NBR45-70-2.6	45 feg	s	70 eV	17.7 nm	45.6%	2.6 eV	(0.7 nm)
20	NBR45-60-3.7	45 feg	s	60 eV	20.7 nm	41.1%	3.7 eV	(1.3 nm)
21	NBR45-50-5.5	45 feg	s	50 eV	24.8 nm	32.2%	5.5 eV	(2.7 nm)
22	NBR45-40-2.9	45 feg	s	40 eV	31.0 nm	46.5%	2.9 eV	(2.2 nm)
23	NBR45-30-3.8	45 feg	s	30 eV	41.3 nm	44.1%	3.8 eV	(5.1 nm)

design name	NRB-98-2.3
AOI	5 deg
polarization	s
peak energy	98 eV (12.7 nm)
peak reflectivity	39.5%
bandwidth (FWHM)	2.3 eV (0.3 nm)

design name	NNR-95-2.6
AOI	5 deg
polarization	s
peak energy	95 eV (13.1 nm)
peak reflectivity	40.7%
bandwidth (FWHM)	2.6 eV (0.4 nm)

design name	NRB-90-2.5
AOI	5 deg
polarization	s
peak energy	90 eV (13.8 nm)
peak reflectivity	44.5%
bandwidth (FWHM)	2.5 eV (0.4 nm)

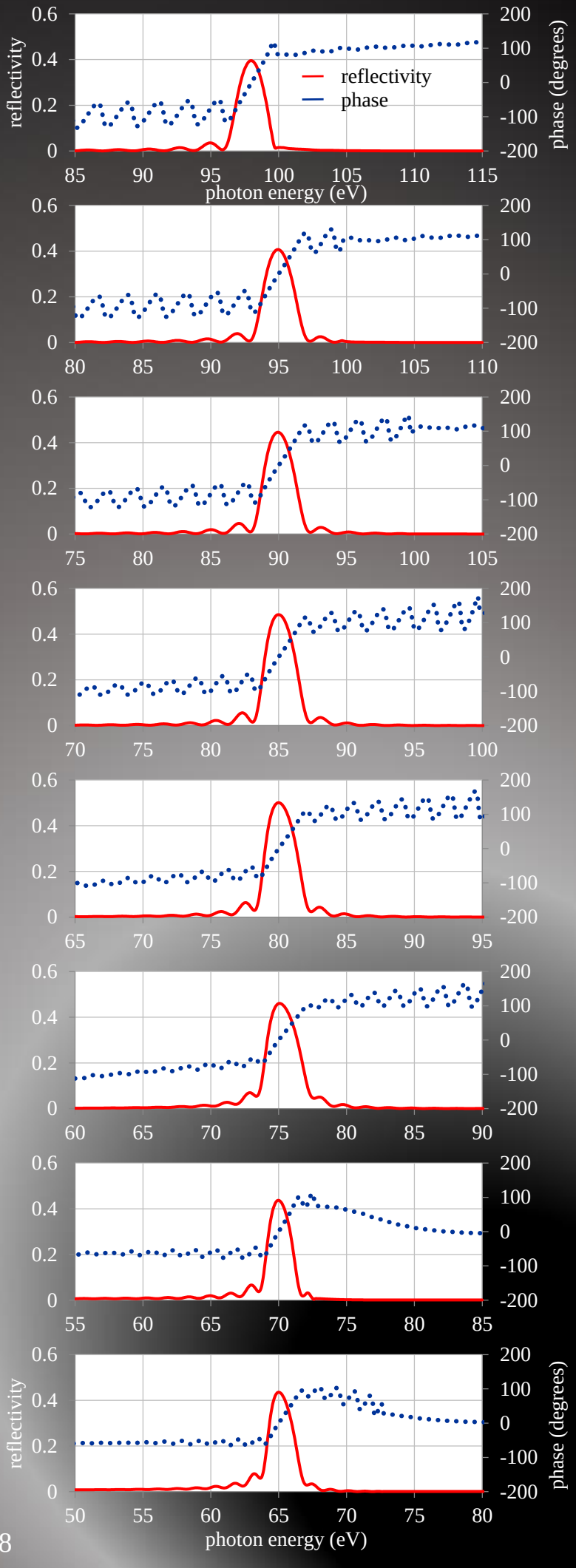
design name	NNR-85-2.5
AOI	5 deg
polarization	s
peak energy	85 eV (14.6 nm)
peak reflectivity	48.5%
bandwidth (FWHM)	2.5 eV (0.4 nm)

design name	NRB-80-2.5
AOI	5 deg
polarization	s
peak energy	80 eV (15.5 nm)
peak reflectivity	50.1%
bandwidth (FWHM)	2.5 eV (0.5 nm)

design name	NNR-75-2.6
AOI	5 deg
polarization	s
peak energy	75 eV (16.5 nm)
peak reflectivity	46.0%
bandwidth (FWHM)	2.6 eV (0.6 nm)

design name	NRB-70-1.9
AOI	5 deg
polarization	s
peak energy	70 eV (17.7 nm)
peak reflectivity	43.7%
bandwidth (FWHM)	1.9 eV (0.5 nm)

design name	NNR-65-2.1
AOI	5 deg
polarization	s
peak energy	65 eV (19.1 nm)
peak reflectivity	43.5%
bandwidth (FWHM)	2.1 eV (0.6 nm)



design name	NRB-60-2.2
AOI	5 deg
Polarization	s
peak energy	60 eV (20.7 nm)
peak reflectivity	42.2%
bandwidth (FWHM)	2.2 eV (0.8 nm)

design name	NNR-55-2.4
AOI	5 deg
polarization	s
peak energy	55 eV (22.5 nm)
peak reflectivity	38.4%
bandwidth (FWHM)	2.4 eV (1 nm)

design name	NRB-50-2.7
AOI	5 deg
polarization	s
peak energy	50 eV (24.8 nm)
peak reflectivity	33.5%
bandwidth (FWHM)	2.7 eV (1.3 nm)

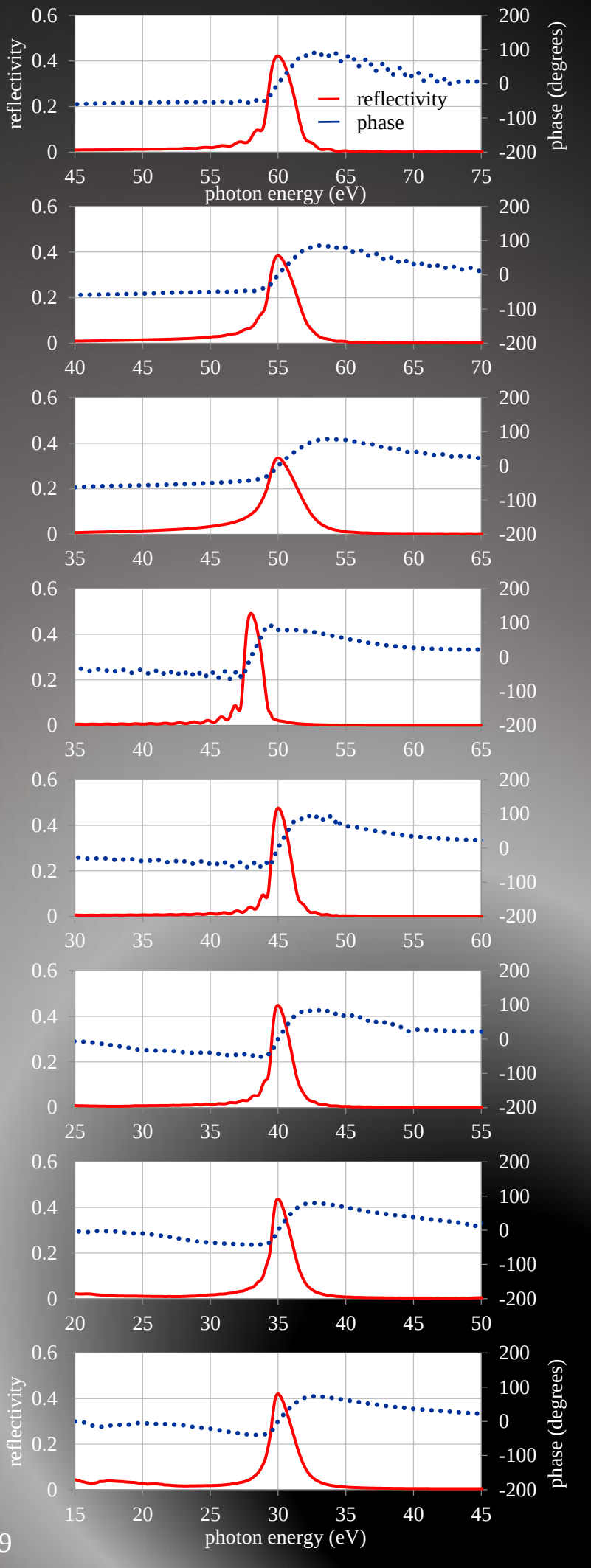
design name	NNR-48-1.3
AOI	5 deg
polarization	s
peak energy	48 eV (25.8 nm)
peak reflectivity	49.2%
bandwidth (FWHM)	1.3 eV (0.7 nm)

design name	NRB-45-1.5
AOI	5 deg
polarization	s
peak energy	45 eV (27.6 nm)
peak reflectivity	47.6%
bandwidth (FWHM)	1.5 eV (0.9 nm)

design name	NNR-40-1.5
AOI	5 deg
polarization	s
peak energy	40 eV (31 nm)
peak reflectivity	44.8%
bandwidth (FWHM)	1.5 eV (1.1 nm)

design name	NRB-35-1.6
AOI	5 deg
polarization	s
peak energy	35 eV (35.4 nm)
peak reflectivity	43.7%
bandwidth (FWHM)	1.6 eV (1.6 nm)

design name	NNR-30-1.9
AOI	5 deg
polarization	s
peak energy	30 eV (41.3 nm)
peak reflectivity	42.0%
bandwidth (FWHM)	1.9 eV (2.6 nm)



design name	NRB45-90-3.1
AOI	45 deg
polarization	s
peak energy	90 eV (13.8 nm)
peak reflectivity	53.2%
bandwidth (FWHM)	3.1 eV (0.5 nm)

design name	NRB45-80-3.6
AOI	45 deg
polarization	s
peak energy	80 eV (15.5 nm)
peak reflectivity	52.3%
bandwidth (FWHM)	3.6 eV (0.7 nm)

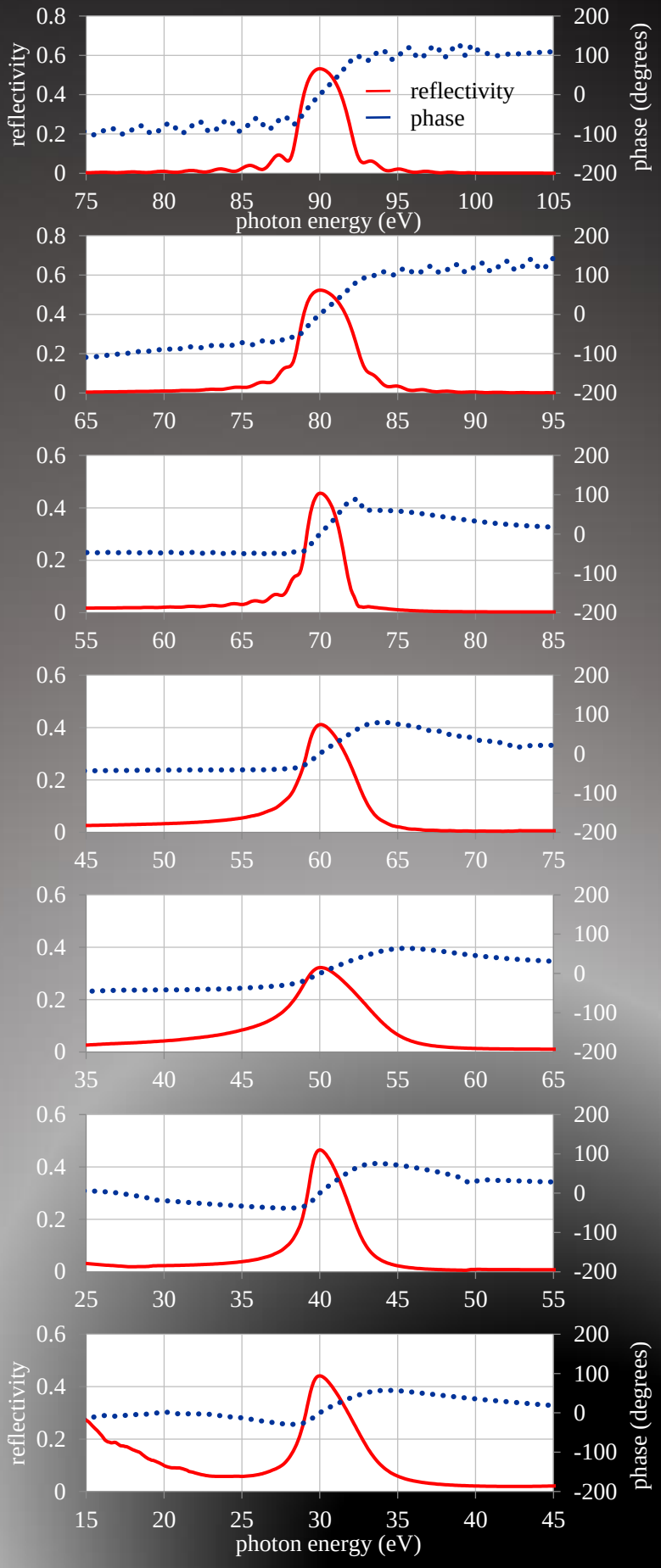
design name	NNR45-70-2.6
AOI	45 deg
polarization	s
peak energy	70 eV (17.7 nm)
peak reflectivity	45.6%
bandwidth (FWHM)	2.6 eV (0.7 nm)

design name	NRB45-60-3.7
AOI	45 deg
polarization	s
peak energy	60 eV (20.7 nm)
peak reflectivity	41.1%
bandwidth (FWHM)	3.7 eV (1.3 nm)

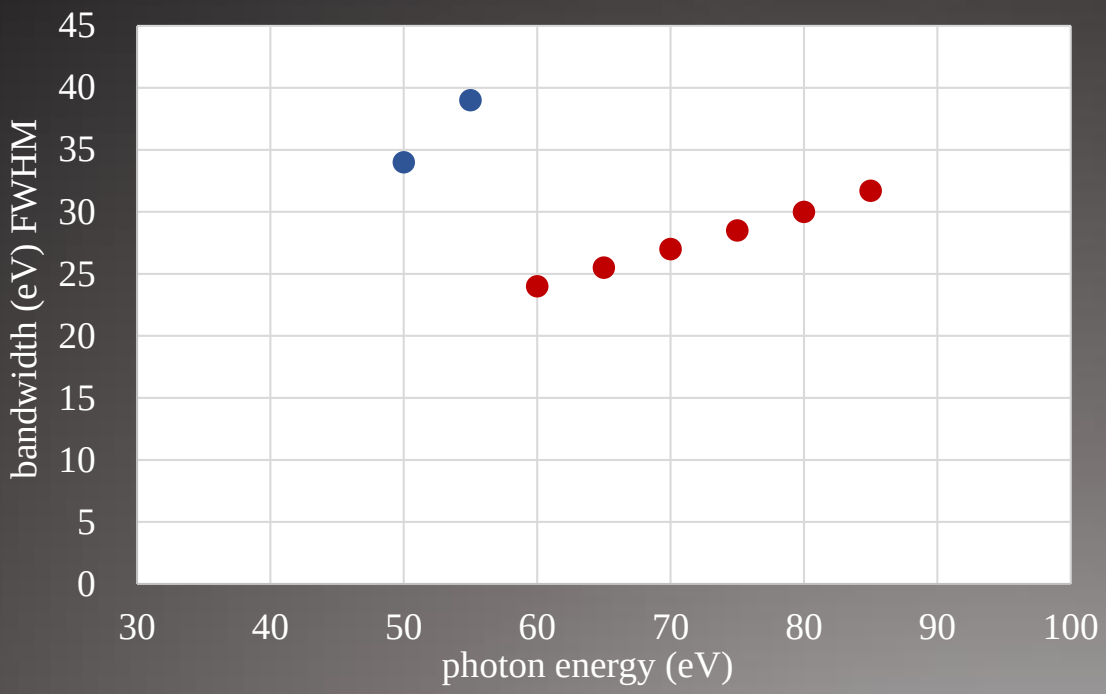
design name	NRB45-50-5.5
AOI	45 deg
polarization	s
peak energy	50 eV (24.8 nm)
peak reflectivity	32.2%
bandwidth (FWHM)	5.5 eV (2.7 nm)

design name	NRB45-40-2.9
AOI	45 deg
polarization	s
peak energy	40 eV (31.0 nm)
peak reflectivity	46.5%
bandwidth (FWHM)	2.9 eV (2.2 nm)

design name	NRB45-30-3.8
AOI	45 deg
polarization	s
peak energy	30 eV (41.3 nm)
peak reflectivity	44.1%
bandwidth (FWHM)	3.8 eV (5.1 nm)



XUV Broadband Mirrors



No	design name	AOI	pol.	peak energy	wavelength	reflectivity	bandwidth (FWHM)	
1	BBR-85.31.7	5 deg	s	85 eV	14.6 nm	3.8%	31.7 eV	(5.7nm)
2	BBR-80-30	5 deg	s	80 eV	15.5 nm	5.1%	30 eV	(6.1 nm)
3	BBR-75-28.5	5 deg	s	75 eV	13.8 nm	6.6%	28.5 eV	(6.6 nm)
4	BBR-70-27	5 deg	s	70 eV	17.7 nm	8.1%	27 eV	(7.3 nm)
5	BBR-65-25.5	5 deg	s	65 eV	19.1 nm	9.3%	25.5 eV	(8 nm)
6	BBR-60-24	5 deg	s	60 eV	20.7 nm	9.8%	24 eV	(8.6 nm)
7	UBBR-55-39	5 deg	s	55 eV	22.5 nm	6.8%	39 eV	(16.3 nm)
8	UBBR-50-34	5 deg	s	50 eV	24.8 nm	6.7%	34 eV	(18.6 nm)

design name	BR-85-31.7
AOI	5 deg
polrization	s
peak energy	85 eV (14.6 nm)
peak reflectivity	3.8%
bandwidth (FWHM)	31.7 eV (5.7 nm)

design name	BBR-80-30
AOI	5 deg
polarization	s
peak energy	80 eV (15.5 nm)
peak reflectivity	5.1%
bandwidth (FWHM)	30 eV (6.1 nm)

design name	BBR-75-28.5
AOI	5 deg
polarization	s
peak energy	75eV (16.5 nm)
peak reflectivity	6.6%
bandwidth (FWHM)	28.5eV (6.6 nm)

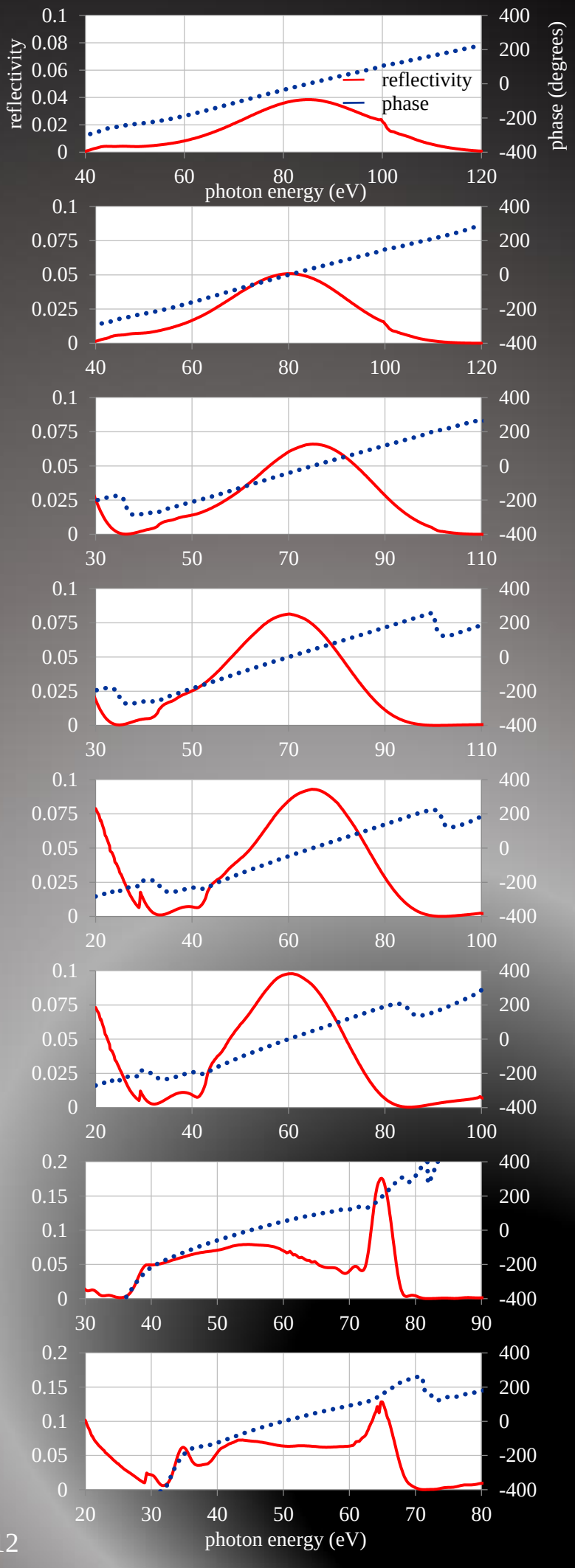
design name	BBR-70-27
AOI	5 deg
polarization	s
peak energy	70 eV (17.7 nm)
peak reflectivity	8.1%
bandwidth (FWHM)	27 eV (7.3 nm)

design name	BBR-65-25.5
AOI	5 deg
polarization	s
peak energy	65eV (19.1 nm)
peak reflectivity	9.3%
bandwidth (FWHM)	25.5eV (8nm)

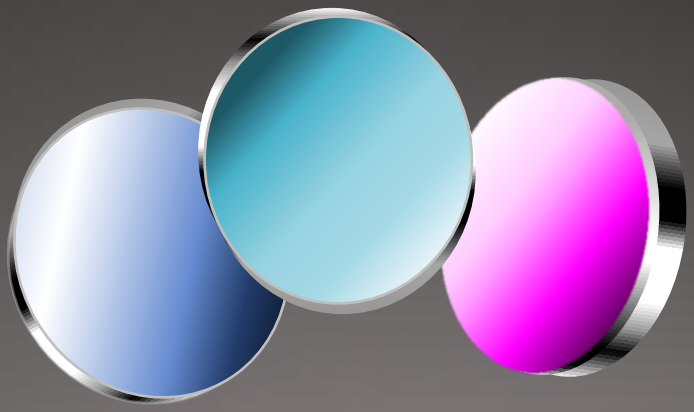
design name	BBR-60-24
AOI	5 deg
polarization	s
peak energy	60 eV (20.7 nm)
peak reflectivity	9.8%
bandwidth (FWHM)	24 eV (8.6 nm)

design name	UBBR-55-39
AOI	5 deg
polarization	s
peak energy	55 eV (22.5 nm)
peak reflectivity	6.8%
bandwidth (FWHM)	39 eV (16.3 nm)

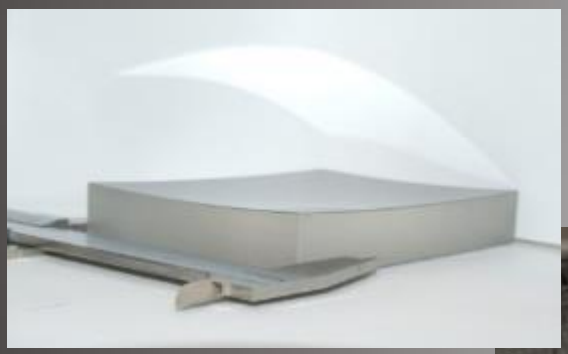
design name	UBBR-50-34
AOI	5 deg
polarization	s
peak energy	50 eV (24.8 nm)
peak reflectivity	6.7%
bandwidth (FWHM)	34 eV (18.6 nm)

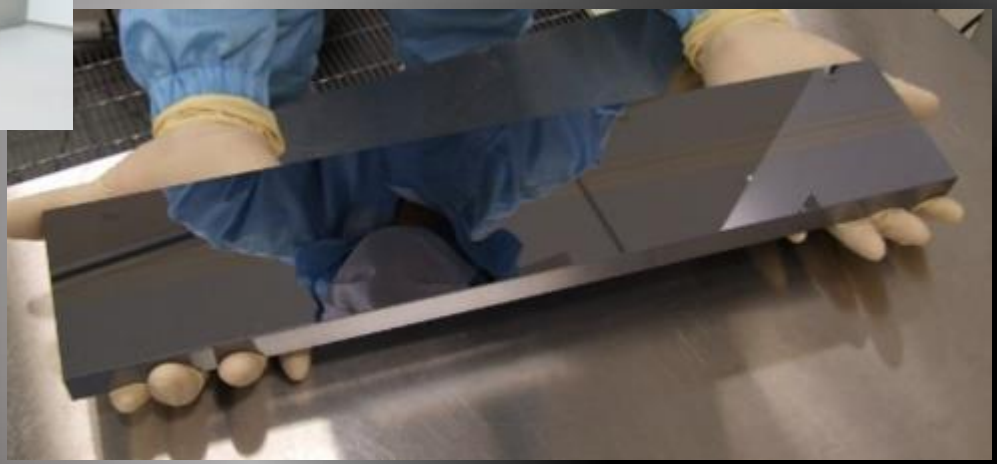


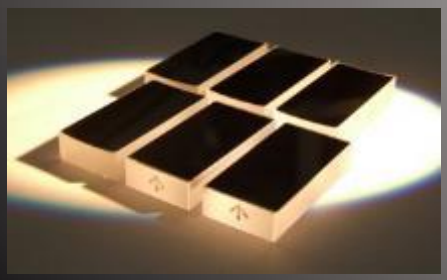
XUV Grazing Incidence Mirrors



NTT-AT supplies grazing incidence mirrors for steering and focusing in high-energy x-ray and broadband XUV light. Custom-made ellipsoidal mirrors and toroidal mirrors work for your attosecond spectroscopy, imaging, and other XUV applications. Grazing incident multilayer mirrors are used for x-ray monochrometers.



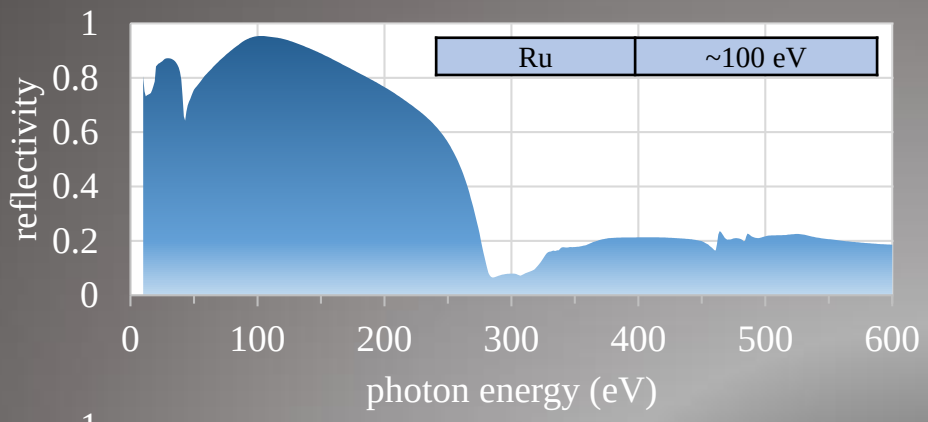


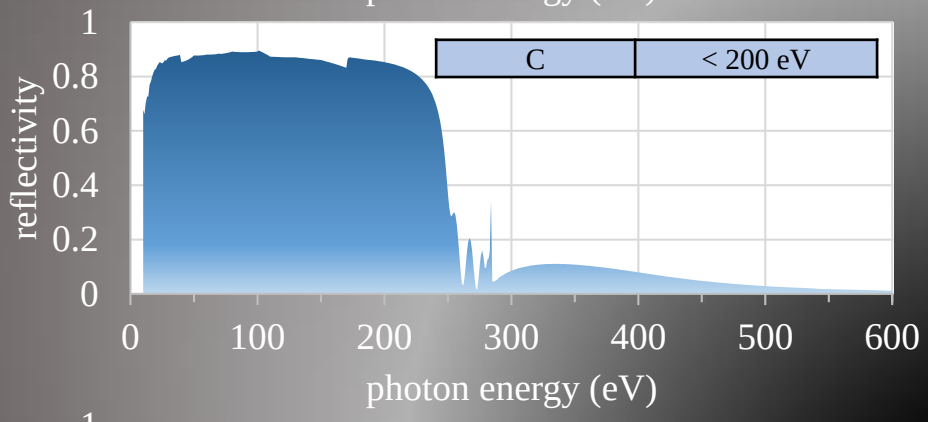


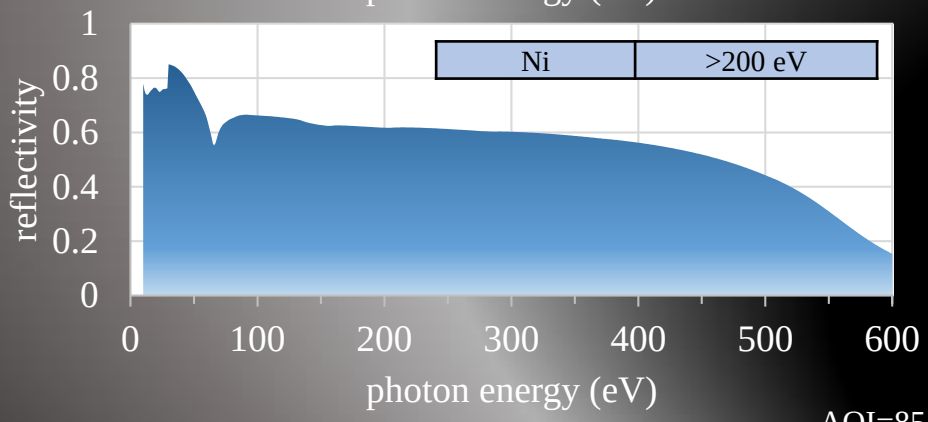
Substrate capability

Material	Fused Silica, Low Expansion Glass
Shape	Ellipsoidal, Toroidal, Cylindrical, Flat
Roughness	<0.5 nm rms
Max size	Flat: 1000 mm Curved: 300 mm

Coating examples

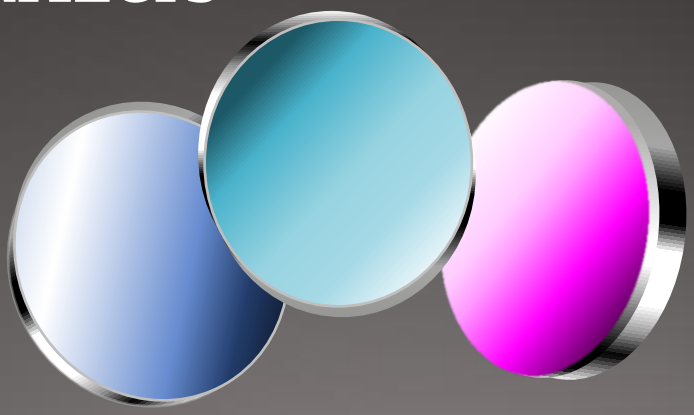






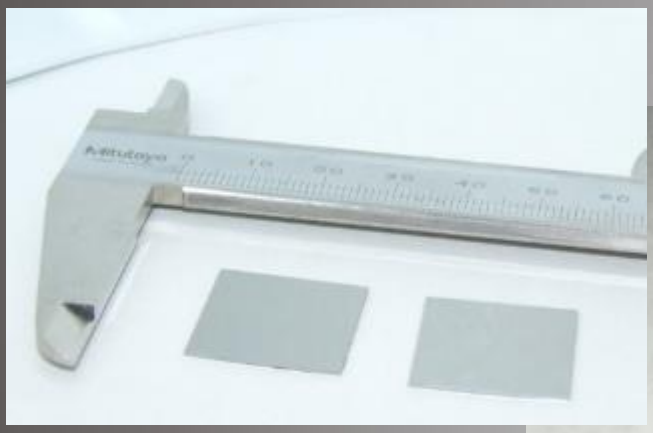
AOI=85 deg.

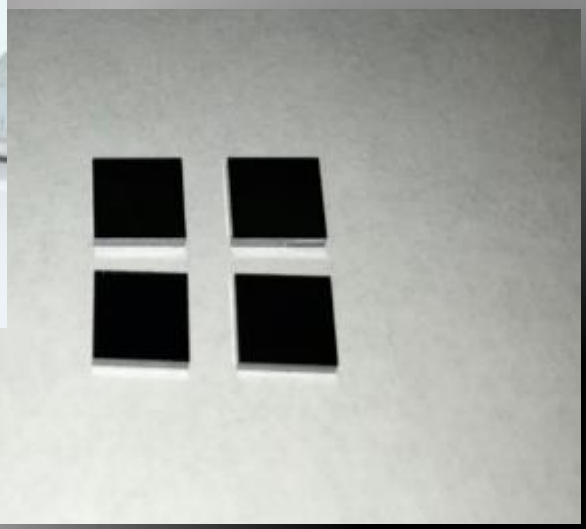
Multilayer Polarizers

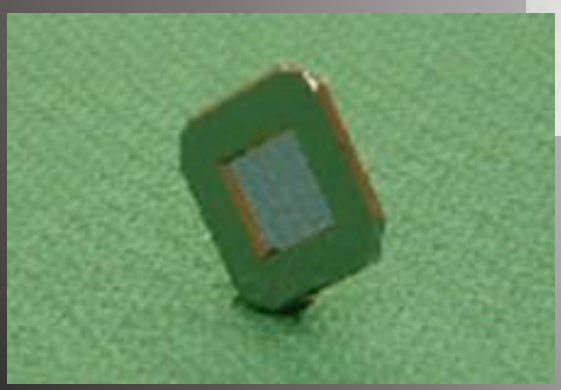


In XUV and soft x-ray regions, Brewster angle of multilayer mirrors around 45 degrees, thus, in synchrotron science. Multilayer are used as polarizers.

NTT-AT provides both reflective type and transmissive type multilayer polarizers corresponding to your required material bandgap.







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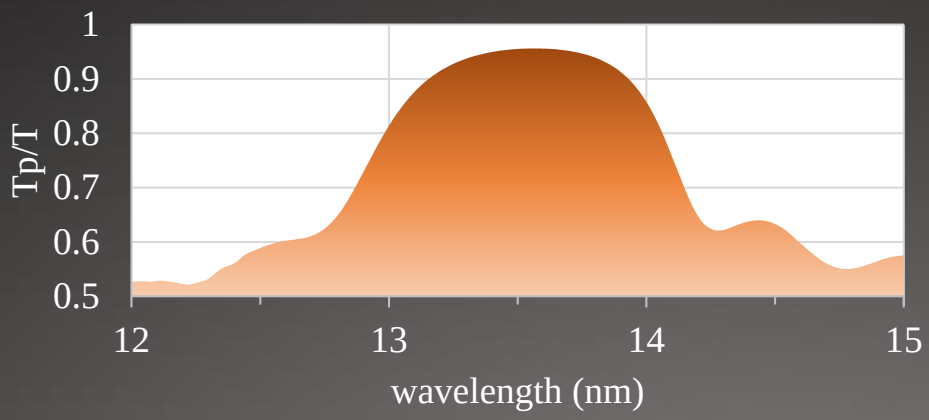
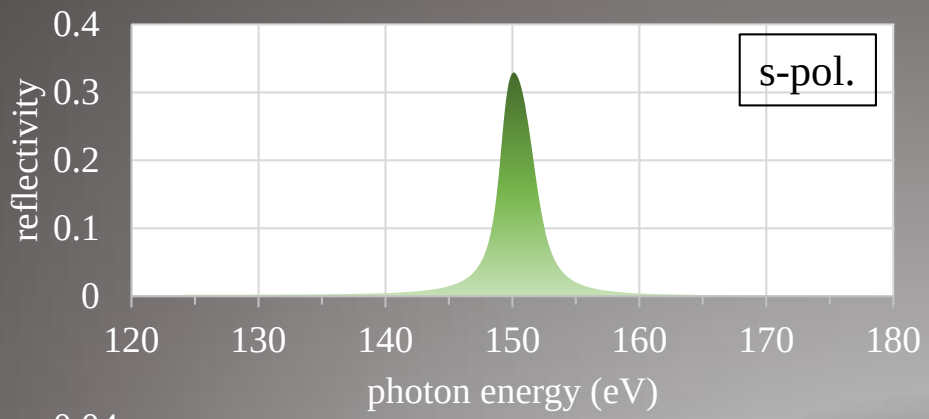
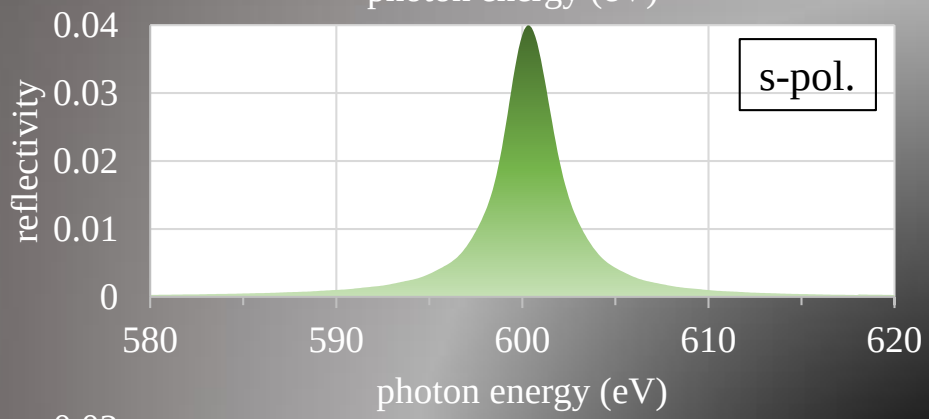
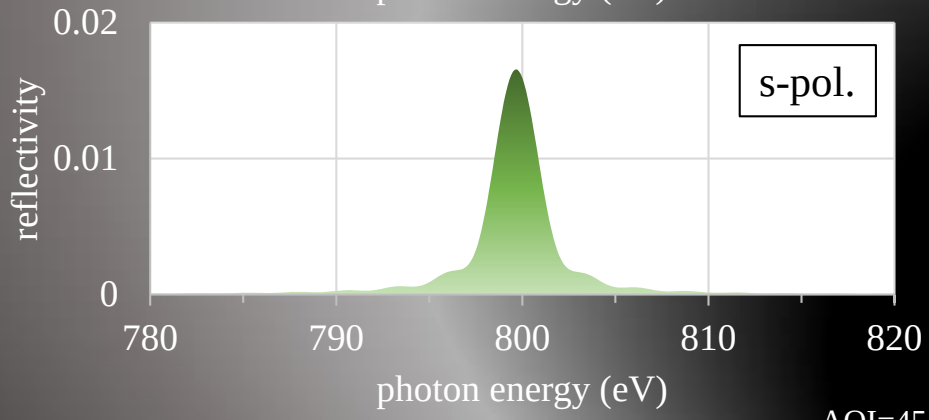
Transmission type examples



Reflective type examples





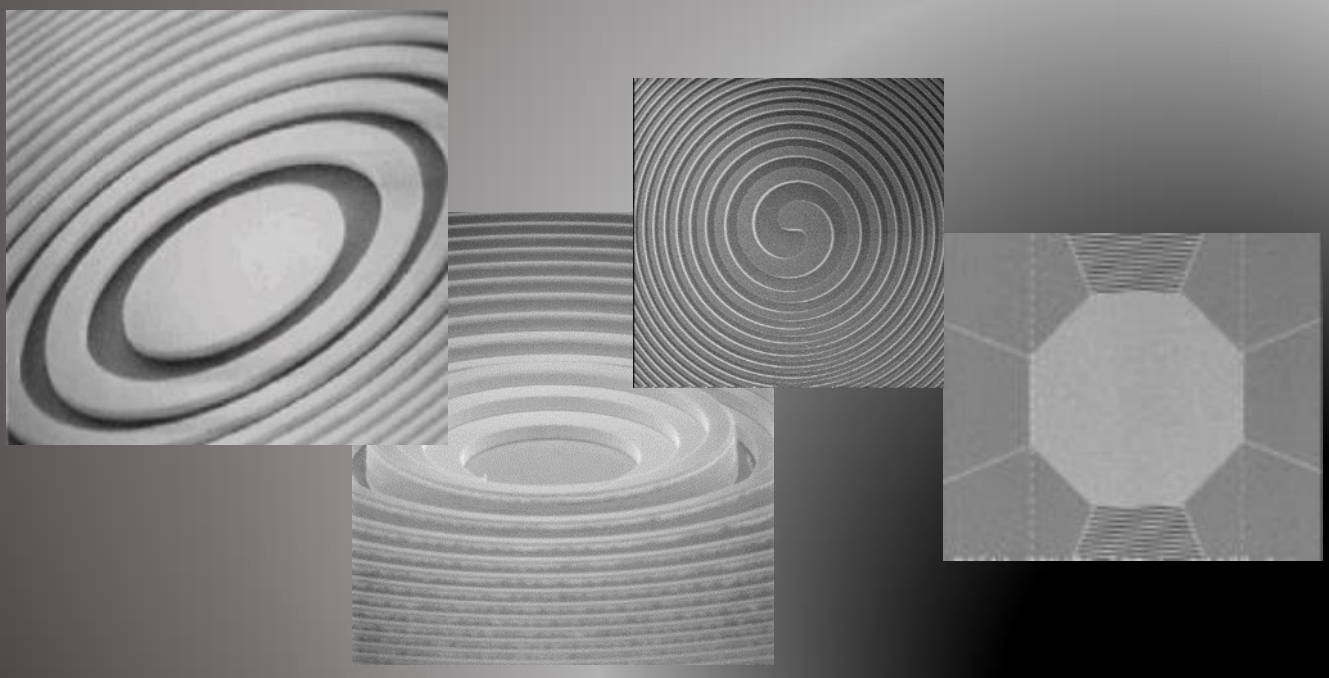


AOI=45 deg.

X-ray Fresnel Zone Plate

NTT-AT provides custom-made Fresnel Zone Plate (FZP) for soft x-ray as well as XUV region. Only NTT-AT provides the SiC membrane supported FZPs, which has high an outstandingly high x-ray irradiation durability. And our Ta absorber FZPs is high pattern sharpness, low side-wall roughness, and high spatial uniformity.

Our FZPs are used for x-ray applications such as x-ray microscopy, x-ray micro-beam irradiation, and x-ray imaging. You will obtain ideal focusibility and spatial resolution.



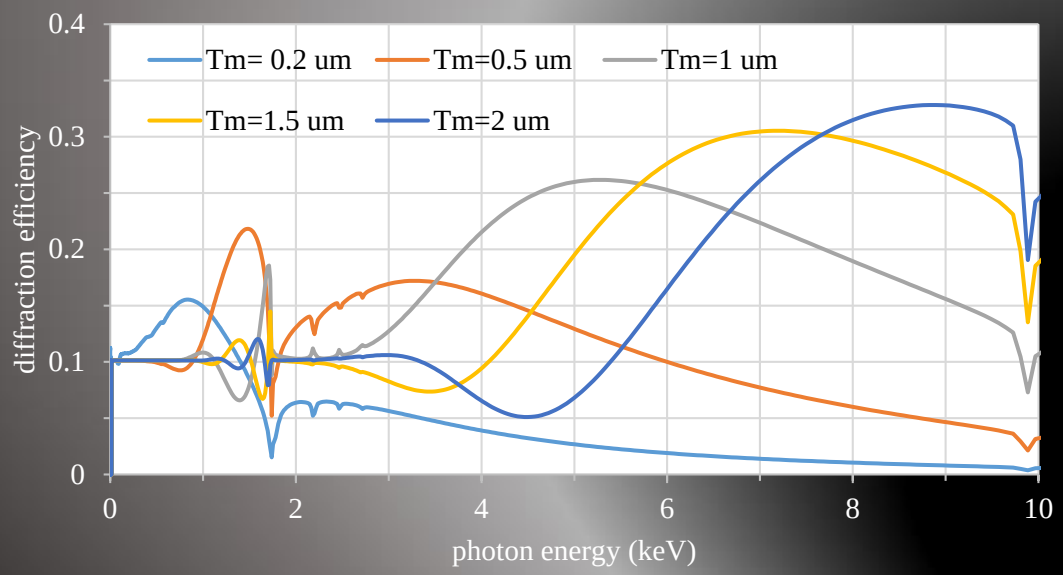
NTT AT

Standard FZPs

Part Name	Membrane Material	Outermost Zone Width (nm)	Diameter (μm)	Total Zone	Ta thickness (nm)
FZP-S38/84	SiN	38	84	550	160
FZP-S40/155	SiN	40	155	968	200
FZP-S50/80	SiN	50	80	400	250
FZP-S50/330	SiN	50	330	1,650	400
FZP-S86/416	SiN	86	416	1,200	700
FZP-100/155	SiN	100	155	388	800
FZP-173/208	SiN	173	208	300	1000
FZP-200/206	SiN	200	206	255	1600
FZP-C234/2500	SiC	234	2500	2670	150

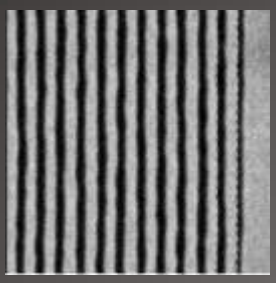
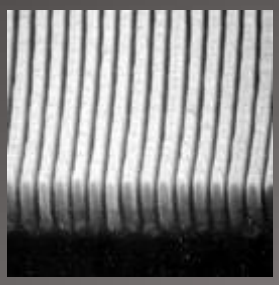
Custom-made FZPs

Minimum zone width (outer most zone)	25 nm
Maximum diameter	5 mm
Membrane material	SiN, SiC
Membrane thickness	0.2-2 μm
Absorber material	Ta
Absorber thickness	0.1-2 μm
Si flame shape	10 mm square
Si flame thickness	1 mm, 0.625 mm



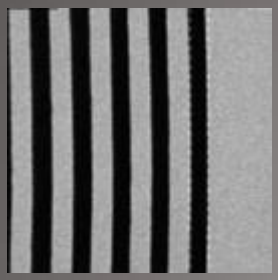
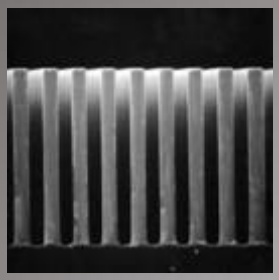
Custom made FZP examples

■ Ultra fine pattern

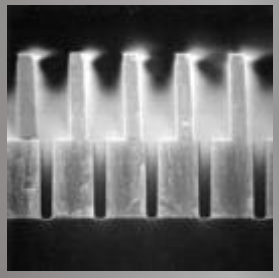
Diameter : 250μm
Ta thickness : 125nm
Outermost zone width : 25nm
Membrane : SiC, 2.0μm

■ High aspect ratio

Diameter : 100μm
Ta thickness : 2.5μm
Outermost zone width : 250nm
Membrane : SiN, 2.0μm

■ Step (Kinoform) type

Diameter : 100μm
Ta thickness : 4.0μm
Outermost zone width : 400nm
Membrane : SiC, 2.0μm

UV Focusing Lenses

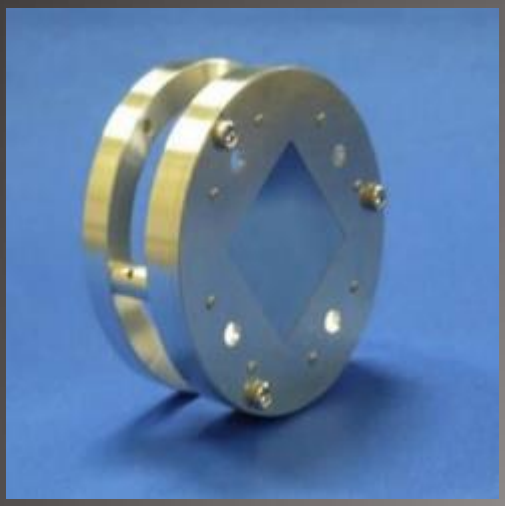
NTT-AT provides focusing relay lenses for UV and VUV photoelectron spectroscopy application. Both standard models and custom-made models will help your sub-5 μm ARPES experiments.

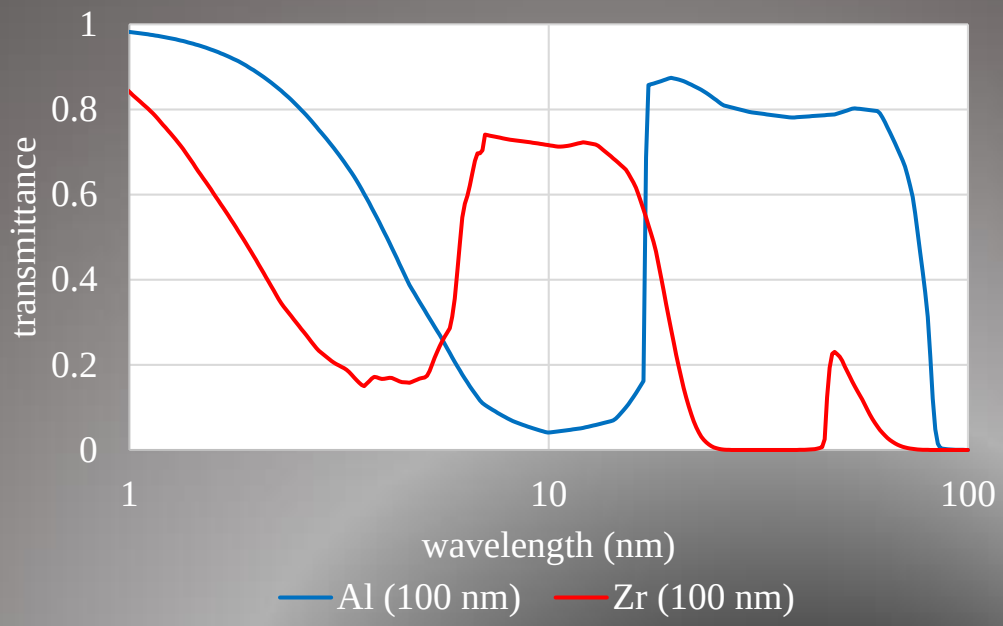
Standard Models

	AUL-250-190	AUL-320-177
Lens Material	Fused Silica	CaF2
Lens Coating	AR	AR
Wavelength	190 – 210 nm	177 nm
Incidence beam, dia.	1.7 mm	1.7 mm
Working Distance	250 mm @ 190 nm 310 mm @ 210 nm	320 mm @ 177 nm
Length	~145 mm	~250 mm
Throughput	91% @ 190 nm	93% @ 177 nm
Focusability	< 5 μm	~5 um

XUV filter

NTT-AT provides free-standing, pinhole-less, stable, and long-lifetime XUV filters for high-order harmonics application, EUV lithography and related applications, and plasma (x-ray) experiments.

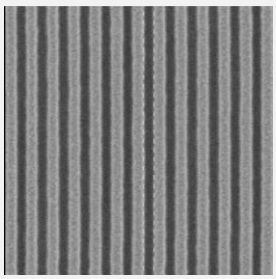


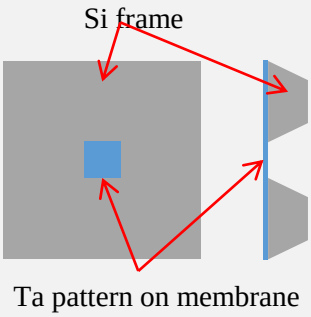


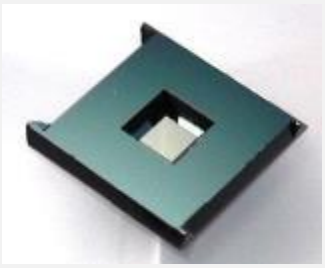
Standard Specifications	
Filter size	6 mm × 6 mm
Filter thickness	100 nm, 200 nm, 500 nm
Holder size	17 mm dia. × 1.5 mm thick
Material	Target wavelength
Zr	10 – 20 nm
Al	20 – 50 nm
Customization is available upon request.	

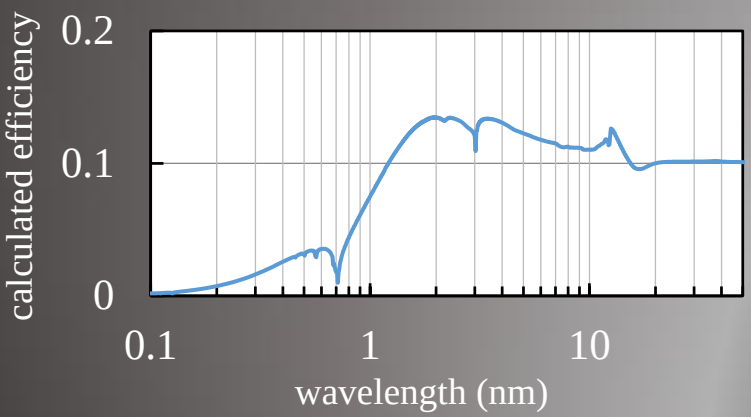
XUV Transmission Grating

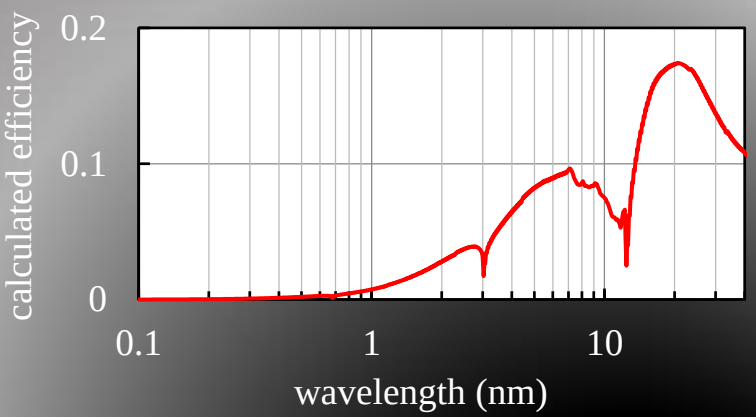
NTT-AT provides custom-made XUV transmission grating for spectroscopy, beam monitor, and beam separator. This free-standing Ta/SiN bilayer or SiN single-layer grating with low side-wall roughness and high-sharpness realizes ideal XUV diffraction.









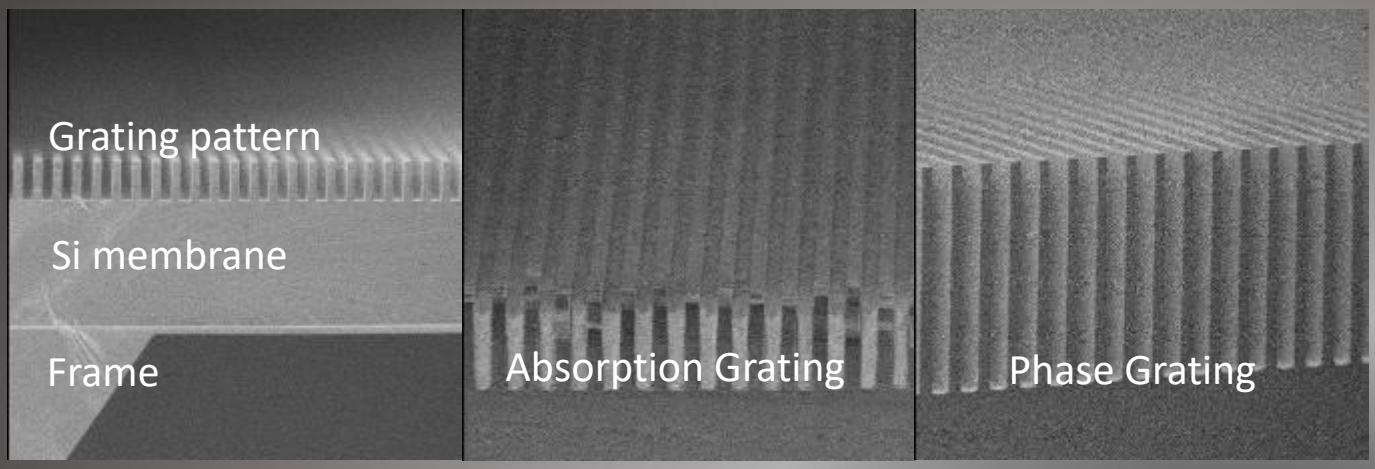


	Ta/SiN type	SiN type
Grating area	2 × 2 mm	
Grooves	100 – 1200 lines/mm	
Support bar	500 nm width, 50 μm pitch	
Material	Ta (100 nm) and SiN (100 nm)	SiN (100 nm)
Flame	10 × 10 × 0.625 mm Si	

Grating for X-ray Talbot-Lau Interferometry

NTT-AT's high-contrast and high-sharpness gratings are optimized for x-ray Talbot imaging.

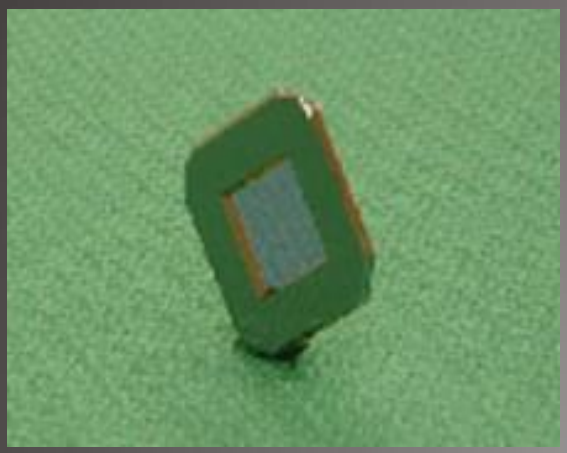
- Low side-wall roughness
- High edge sharpness

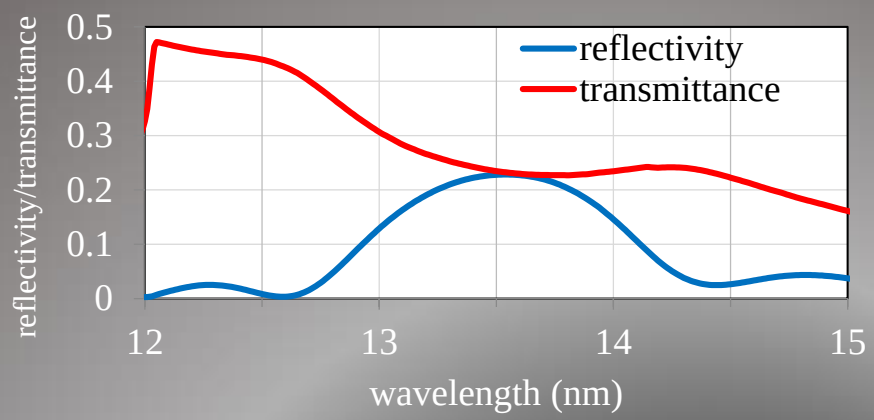


Specification	Absorption Grating	Phase Grating
Material	Au	Si
Membrane	Si, 50 μm thick	Si, 50 μm thick
Pitch/height	3 μm / 10 μm	2 μm / 20 μm
Max. area	10 mm sq.	40 mm sq.
Customization is available upon request.		

Multilayer type Half Mirrors

NTT-AT's multilayer type half mirror, also known as a XUV beam splitter, realizes interferometric experiments operating in a similar way to those for the visible region. This free-standing Mo/Si multilayer is applied to various applications in the XUV field such as interferometry, astronomical telescopy, pump-probe experiments and beam monitor systems.

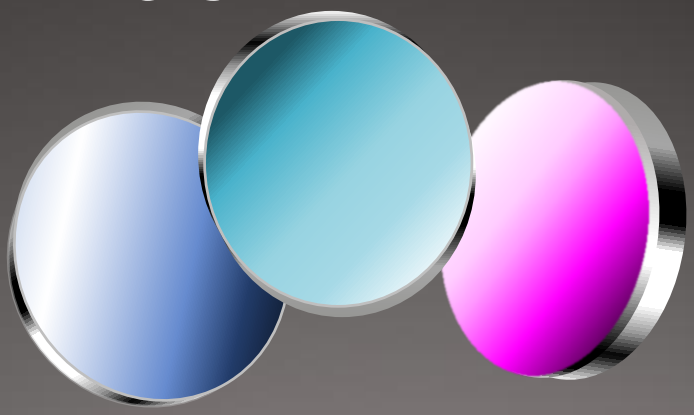




AOI=45 deg.

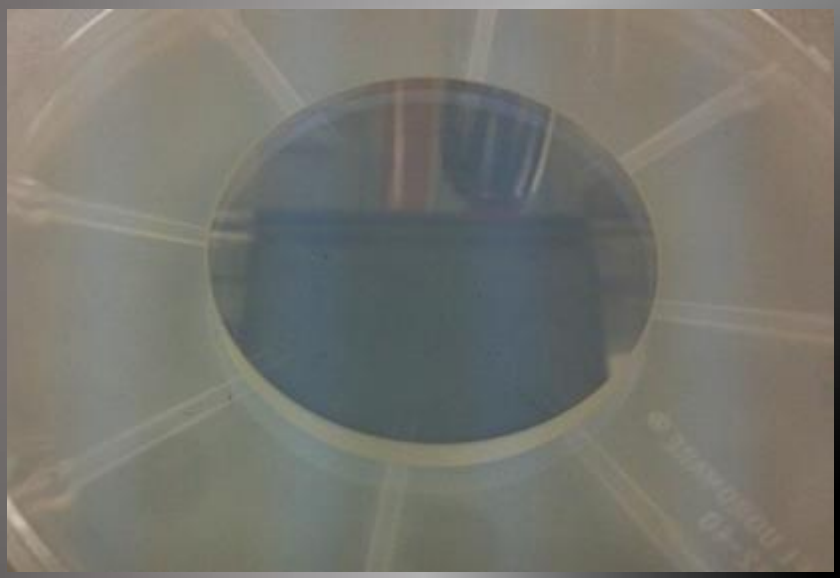
Typical specifications	
Holder diameter	25.4 mm
Half mirror area	10 mm × 10 mm
Incident angle:	between 0 degrees and 45 degrees
Center wavelength:	13.5 nm and 13.9 nm
Customization is available upon request.	

XUV Dichroic Mirrors



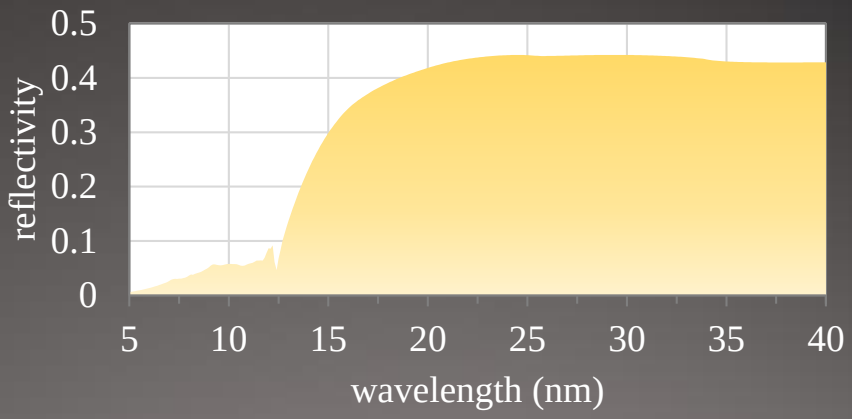
For high-order harmonics experiments, beam separation technology between XUV and NIR with high-efficiency, high-damage threshold, and broad bandwidth is required. NTT-AT provides standard and custom-made XUV dichroic mirror (DM) corresponding to your target energies.

The dielectric multilayer AR coating based DM has higher damage threshold than that of Brewster angle type beam separator and thin film XUV filter. In addition, this mirror can be used for beam combiner between XUV and NIR.

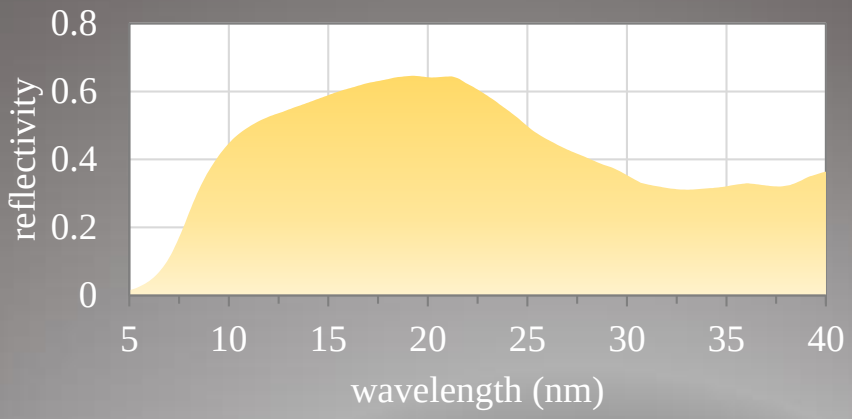


Standard DMs

Design Name	DM-30/800-2010
AOI	78 deg
polarization	p
NIR reflectivity	~2% @800 nm+/- 50 nm
XUV reflectivity	~45% @30 nm
Coating	Dielectric AR
Substrate material	Fused silica
Size	2” dia., 10 mm thick



Design Name	DM-20/800-2010
AOI	78 deg
polarization	p
NIR reflectivity	~2% @800 nm+/- 50 nm
XUV reflectivity	~60% @20 nm
Coating	Dielectric AR
Substrate material	Fused silica
Size	2” dia., 10 mm thick



Custom made DMs

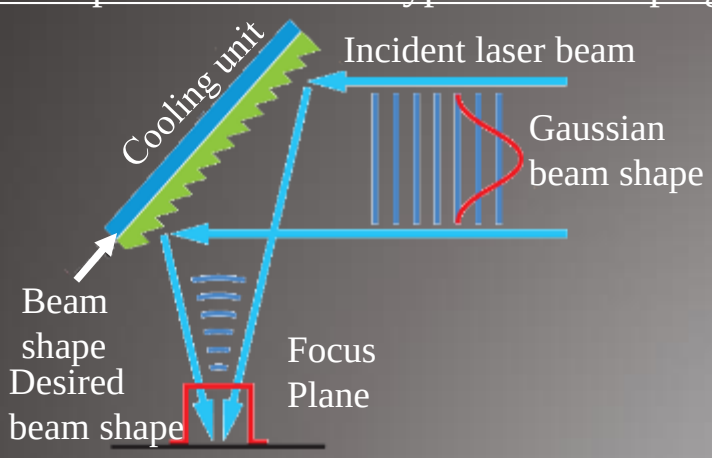
AOI	75 deg. – 87 deg.
Polarization	s, p
AR wavelength	400 nm, 800 nm, 1000 nm, etc.
HR wavelength	3-5 nm, 13 nm, 30 nm, 60 nm, etc.
Substrate material	Fused silica
Substrate size	1” dia. – 4” dia.

Reflectivity is depended on incident angle, target wavelength and polarization.

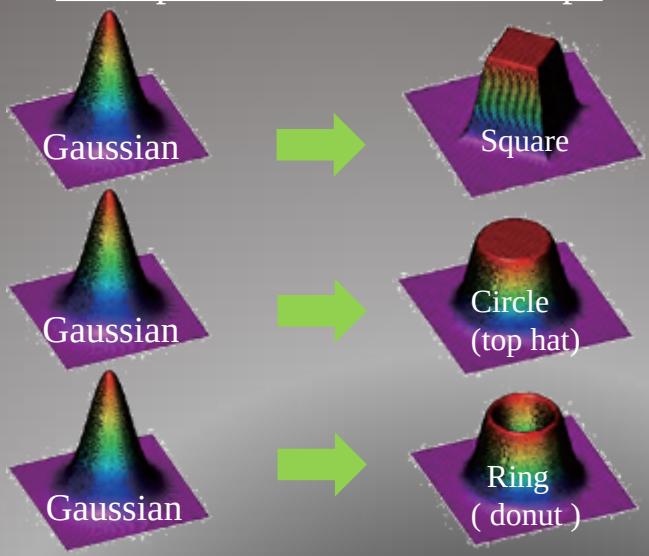
Beam Shaper

NTT-AT provides custom-made beam shaper for laser machining (cutting, ablation, drilling, welding, 3D printing, Laser marking, Annealing and etc.) The beam shaper can transform the Gaussian beam to various arbitrarily beam shape. Direct cooling system allows NTT-AT's reflection type beam shaper used with the high power laser (Conventional beam shaper may face the deformation due to the heat generated by the high power laser)

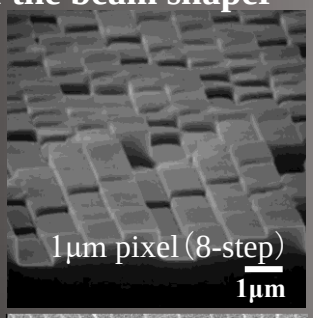
Principal of Reflection type Beam Shaping

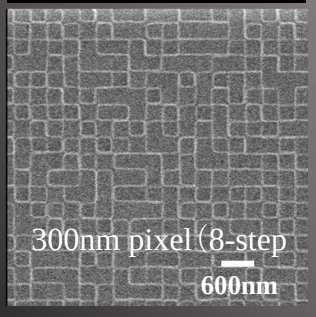


Example of various beam shape



Optical microscope image of the beam shaper





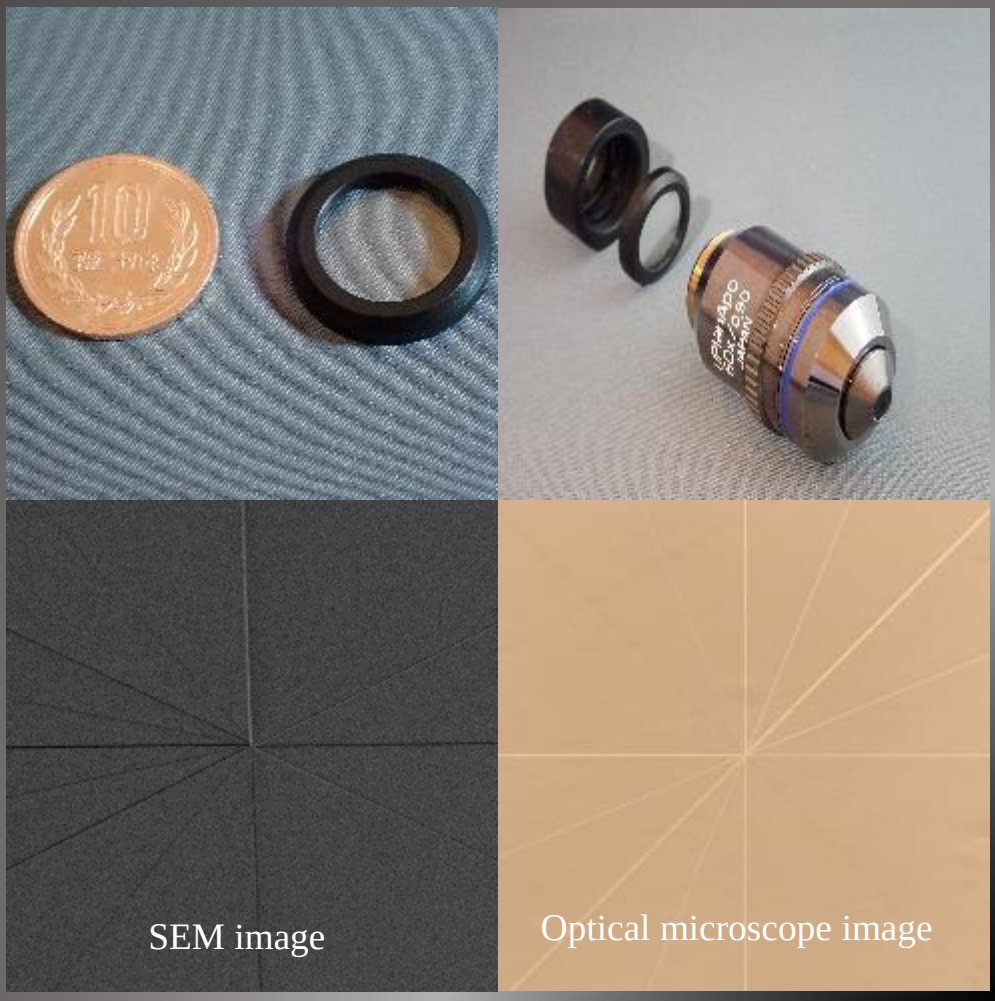
Spec. Example

Item	Specifications
Beam shape	Gaussian to Top hat (Square shape)
Wavelength	1064 nm
Laser power	～10 kW
Beam diameter	30 mmφ
Incident angle	45 degrees
Cooling capacitance （100mm square）	300 W
Size	40 mm x 40 mm x 0.5 mm
Material	Si, SiC, Sapphire

* The above spec. is typical example.
* Customized parameters are available.

Optical phase modulation element

NTT-AT provides custom-made optical phase modulation element for making light vortex and using for super-resolution microscopy imaging. This SiO2 element is edged with high accuracy and high performance. It is processed with extremely high accuracy using the technology cultivated by NTT-AT.

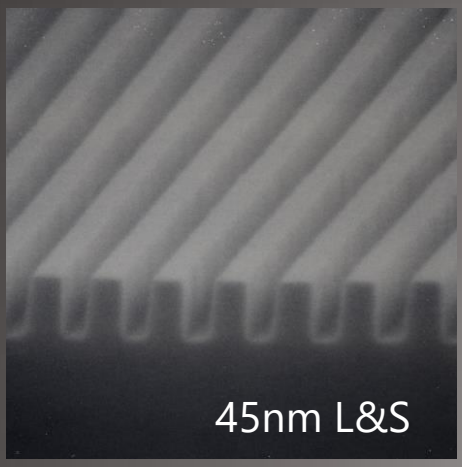


Standard Specifications	
Material	SiO2
Type	4, 8 or 16 divisions
Size	5 – 30mm Φ
Thickness	1mm
Customization is available upon request.	

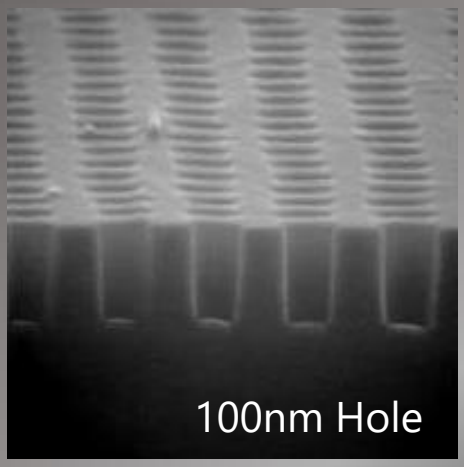
Nanoimprint Test Mold

NTT-AT's NIM-PH serious are high resolution test mold for nanoimprinting start-up and tool inspection. We will deliver quartz test molds for UV curing imprinting and Si test molds for hot embossing imprinting.
We will also provide customized molds for several applications.

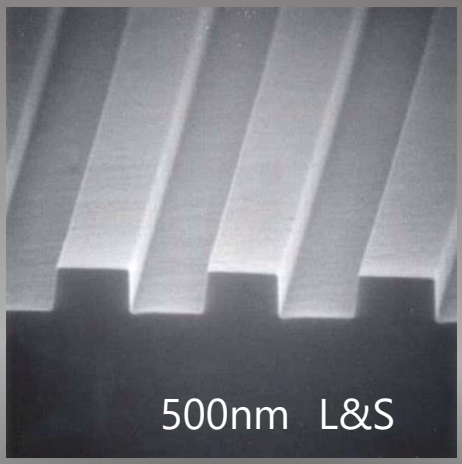
NIM-PHL45



NIM-PHH100



NIM-PH350

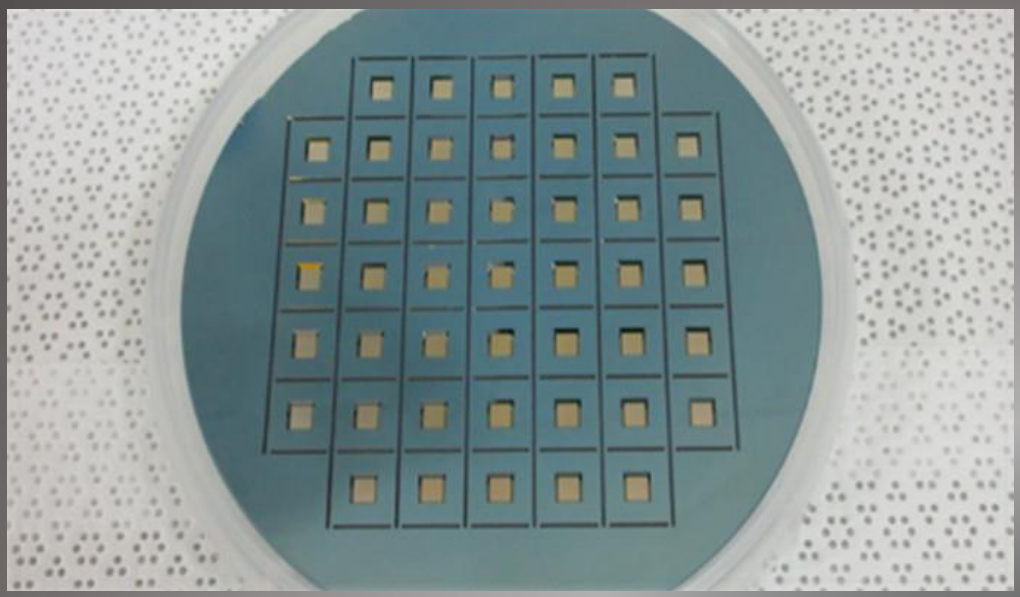


Model	Material	Pattern type	Pattern size (min, max)	Height / Depth	Chip size Pattern area
NIM-PHL45	quartz	Line & Space	45 nm, 100 nm	100 nm	10×10 mm ～ 2×3 mm
NIM-PHL80	quartz	Line & Space	80 nm, 3 μm	200 nm	10×10 mm 9×9 mm
NIM-PHH100	quartz	Hole	100 nm, 3μm	200 nm	10×10 mm 9×9 mm
NIM-PH350	quartz	LS, Hole, Dot	350 nm, 10 μm	350 nm	10×10 mm 9×9 mm

SiN membrane, SiC membrane

Only NTT-AT provides SiC membranes. This SiC poly-crystalline thin film has a higher durability for x-ray irradiation and e-beam irradiation comparing that of SiN membrane.

Our SiC membranes and SiN membranes are used as sample holders, liquid cells and vacuum window in both basic research fields and industrial fields.



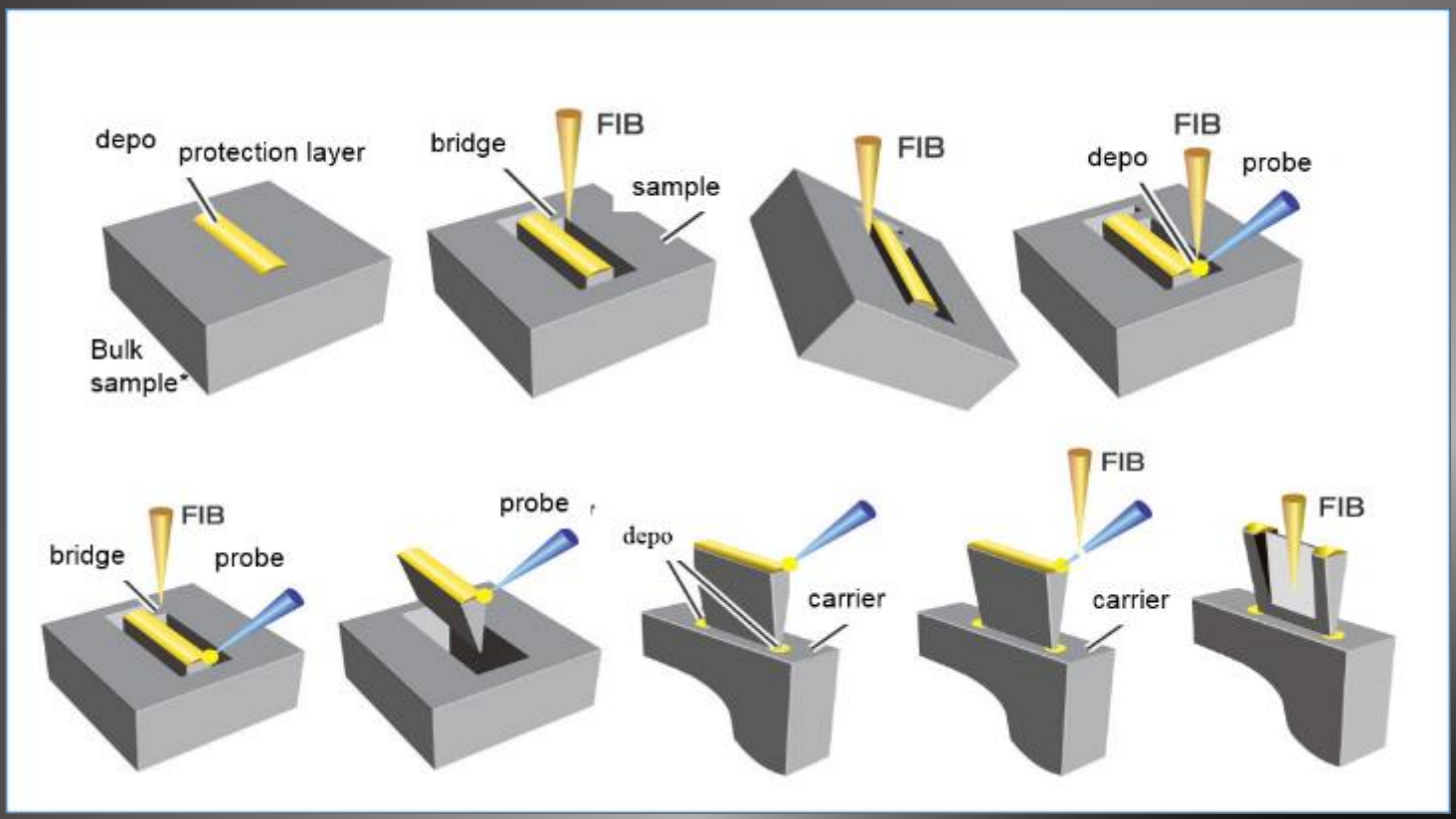
Standard membranes

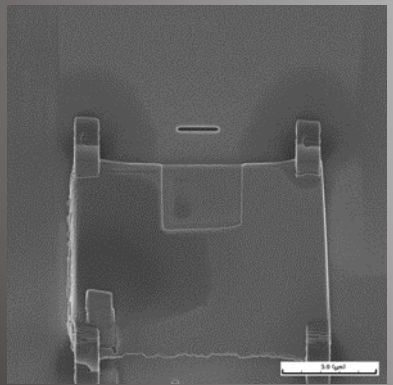
Material	Model	Chip Size(mm)	Thickness (mm)	Membrane Size(mm)	Thickness (nm)
SiN	MEM-N03001/7.5M	7.5 × 7.5	0.625	3 × 3	100
SiN	MEM-N02001/10M	10 × 10	0.625	2 × 2	100
SiN	MEM-N03002/7.5M	7.5 × 7.5	0.625	3 × 3	200
SiN	MEM-N03002/10M	10 × 10	0.625	3 × 3	200
SiN	MEM-N020027/10M	10 × 10	0.625	2 × 2	270
SiN	MEM-N0302/10M	10 × 10	0.625	3 × 3	2,000
SiN	MEM-N0301/10M	10 × 10	0.625	3 × 3	1,000
SiC	MEM-C03003/10M	10 × 10	0.625	3 × 3	300
SiC	MEM-C0301/10M	10 × 10	0.625	3 × 3	1,000

FIB Micro Sampling

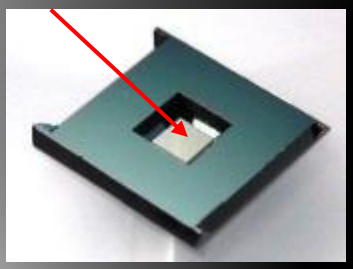
NTT-AT fabricates <1 μm free-standing samples by using FIB techniques for microscopy, spectroscopy and imaging.

- Material: crystal, metal, magnetics, organics and ceramics
- Holding option : mesh, membrane, pinhole and slit
- Evaluate option: SEM, TEM





Holding on Membrane

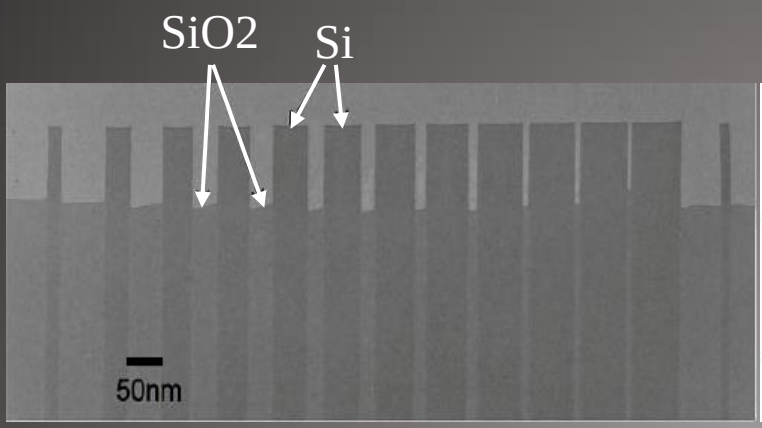


Si/SiO2 standard sample

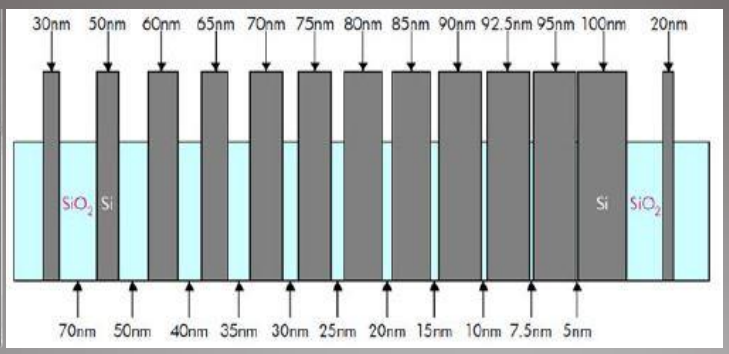
NTT-AT provides Si/SiO2 standard sample, which contains the sub-10nm resolution pattern.

This standard sample is available for various use including AFM tip characterizer as well as inspection purpose.

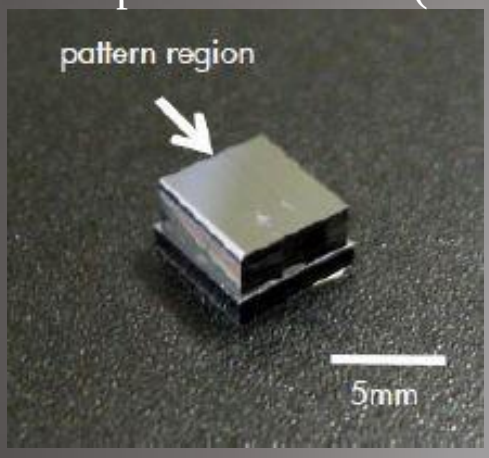
TEM cross sectional image



Schematic diagram



AFM tip characterizer (example)



Example of AFM tip characterizer

Advanced features

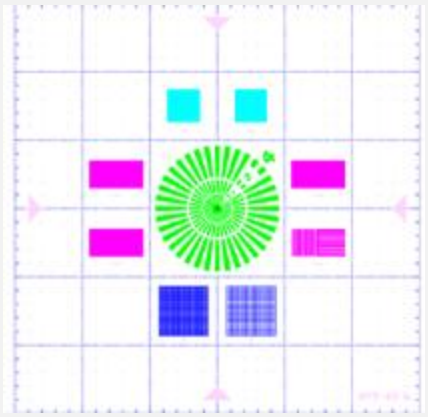
- Sub-10 nm resolution
- High aspect ratio
- Without contaminations for Si nano-device field
- Safety in use (nontoxic)

Patent number : JP 2007-078679

Reference : H. Ichimuraet. al., J. Phys. Conf. Series159, 012001, (2009).
: H. Takenakaet. al., J. Surf. Anal. 17, 264, (2011).

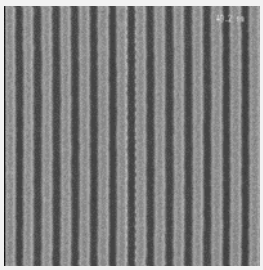
X-ray Resolution Test Chart

NTT-AT's x-ray resolution test charts are applied to several x-ray analyses, which require ultra-fine resolution, such as x-ray microscopy and x-ray inspection. Our Ta absorber resolution test charts are used as de facto standards in world wide customers.

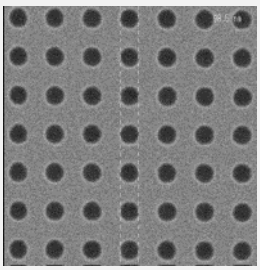


Pattern layout overview

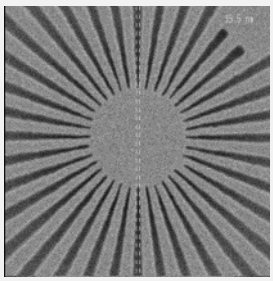
50 nm L&S



100 nm hole



20 nm radial pattern

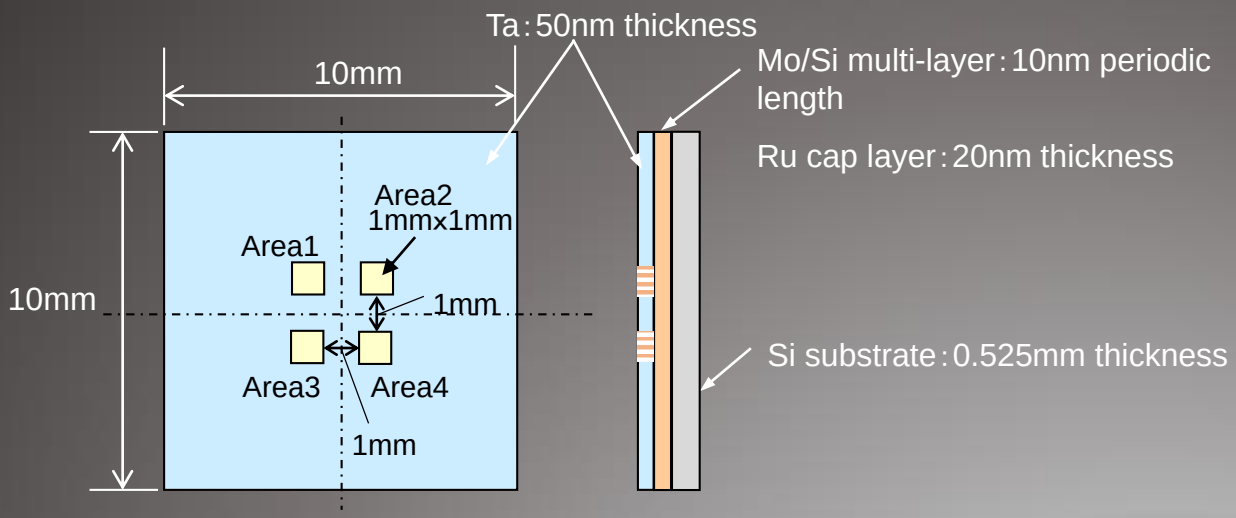


XRESO Series Specifications		XRESO-100	XRESO-50HC	XRESO-20
Substrate	Material / Size	Si 10mm square		
	Thickness	1mm	1mm	0.625mm
Membrane	Material /Thickness	Ru 20nm SiN 2μm	Ru 20nm SiN 50nm SiC 200nm	Ru 20nm SiN 50nm SiC 200nm
	Size	1mm square	1mm square	1mm square
Pattern	Absorber	Ta 1μm	Ta 500nm	Ta 100nm
	Minimum pattern size	100 nm	50 nm	20 nm at Radial Pattern
	Patterned area	250μm × 350μm	300μm square	300μm square
Customization is available upon request.				

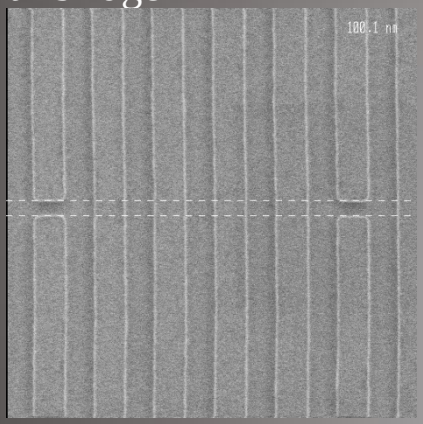
EUV Test Pattern

NTT-AT provides “Reflective” type test pattern (which size is down to ~80nm L&S*). “Bridge” pattern and “Thin isolation line” pattern are available.

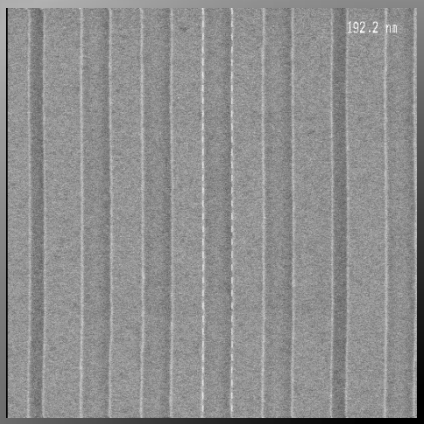
Overview (example)



SEM image of the test pattern with bridge



SEM image of L&S with isolation thin line width



Advanced features

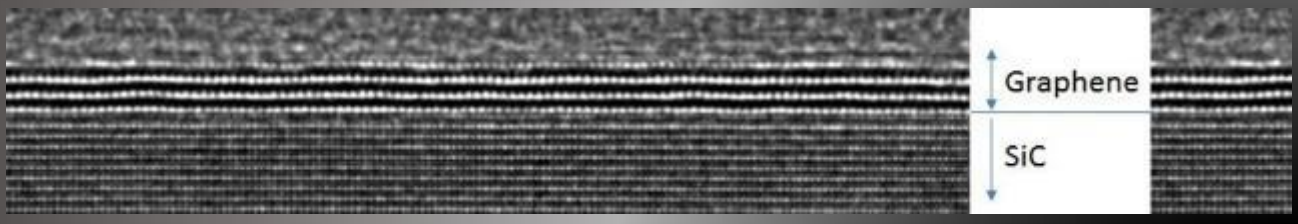
- Reflective type patterns for EUV
- ~80nm* L&S patterns
- Fine patterns fabricated on Multilayer Coated substrate

(*: Depending on other parameters, minimum L&S pattern feature may change from 80nm.)

NTT-AT also provides test pattern sample for XUV application.

Analysis

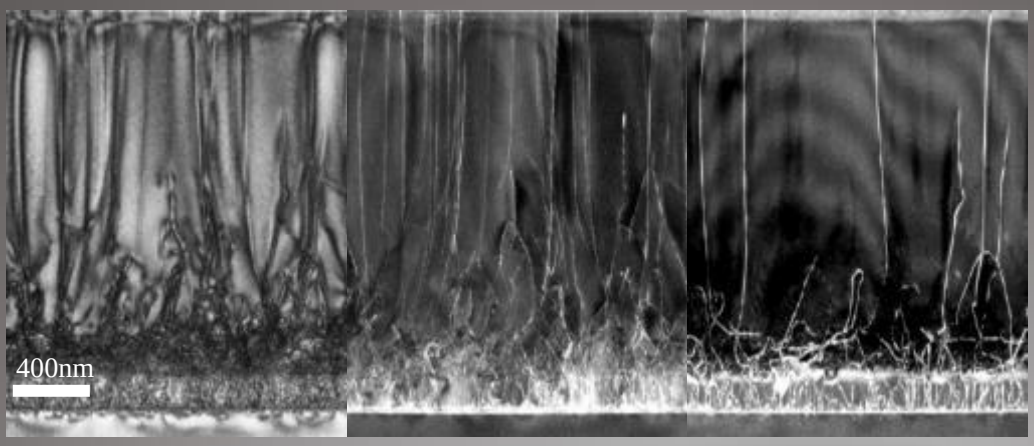
We provide most advanced material analysis services. Even atomic level observations are available. We have supported NTT's leading telecom services directly or indirectly through NTT Laboratories' R&D. Our technologies come from reputed NTT Laboratories, which have been publishing outstanding analytical data and images on top academic and technical journals. We can cater to corporate R&D, quality assessments and trouble shooting as well as academic research with track records over 30 years. Technical areas extend across semiconductor, nano-technologies, material science, optics, electronics, and others. Combined with those analytical services, we can offer micro-fabrication services to meet your various demands and requests.



TEM analysis

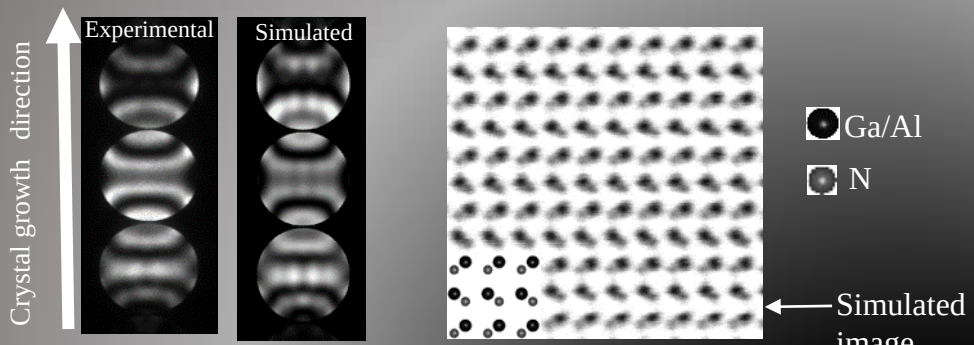
NTT-AT provides TEM solutions for material science, opto-electro science, and the other wide fields. We also support TEM related simulations for better understanding of microscopic material properties.

Dislocations



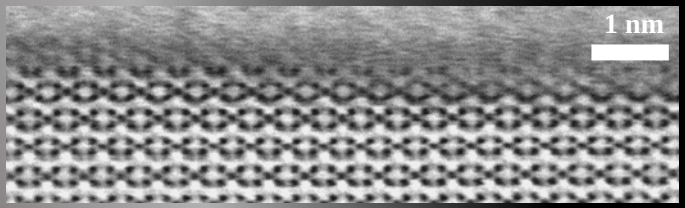
Blight field　　Dark field (g=1120)　　Dark field (g=0002)

Polarity



CBED　　STEM

Substrate

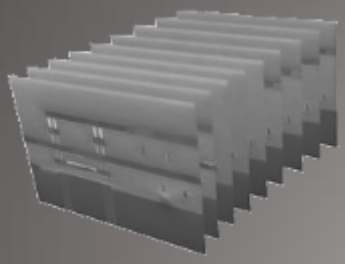


STEM image of sapphire substrate surface (R-plane)

FIB-SEM 3D Imaging

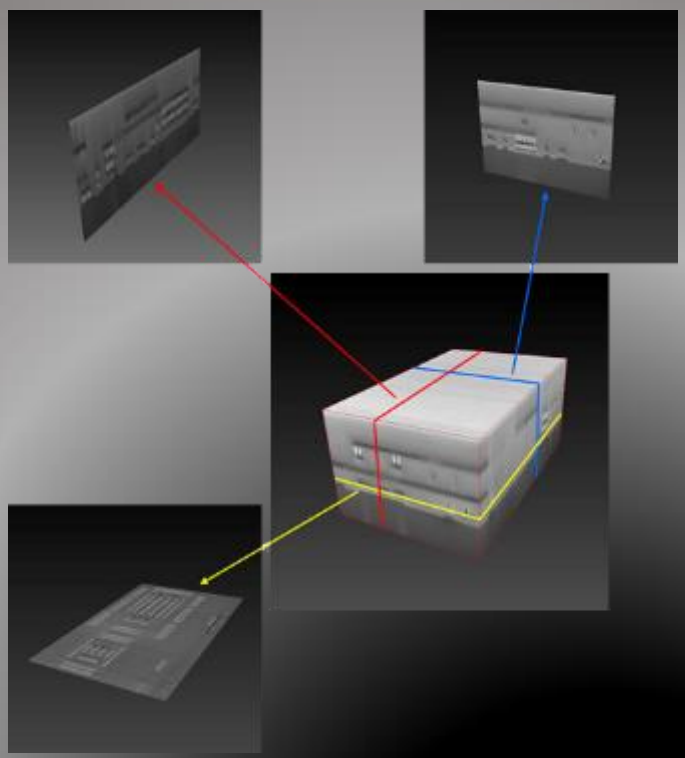
NTT-AT provides 3D reconstructed SEM images to observe various materials from a three-dimensional viewpoint, and analyzes their structures, defects, and vacancies. 3D FIB-SEM can analyze the structure in three dimensions by repeatedly processing and observing the sample. 3D FIB-SEM can grasp the structure from various directions by extracting and visualizing arbitrary cross sections.

Example of FIB-SEM 3D Imaging



Step1 FIB slightly process and observe the exposed cross section with SEM

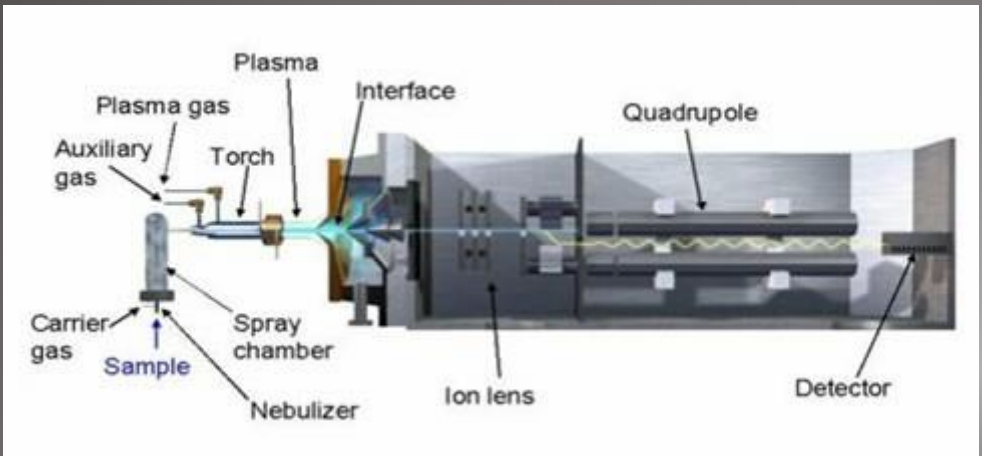
Step2 The acquired SEM images are reconstructed into 3D software



Step3 Extract and visualize any cross section

ICP Mass Spectroscopy

NTT-AT provides high-sensitivity an high-precision ICP mass spectroscopy (ICP MS) solutions for both basic research fields and industrial fields. Our ICP MS sensitivity reach to sub parts per trillion level.

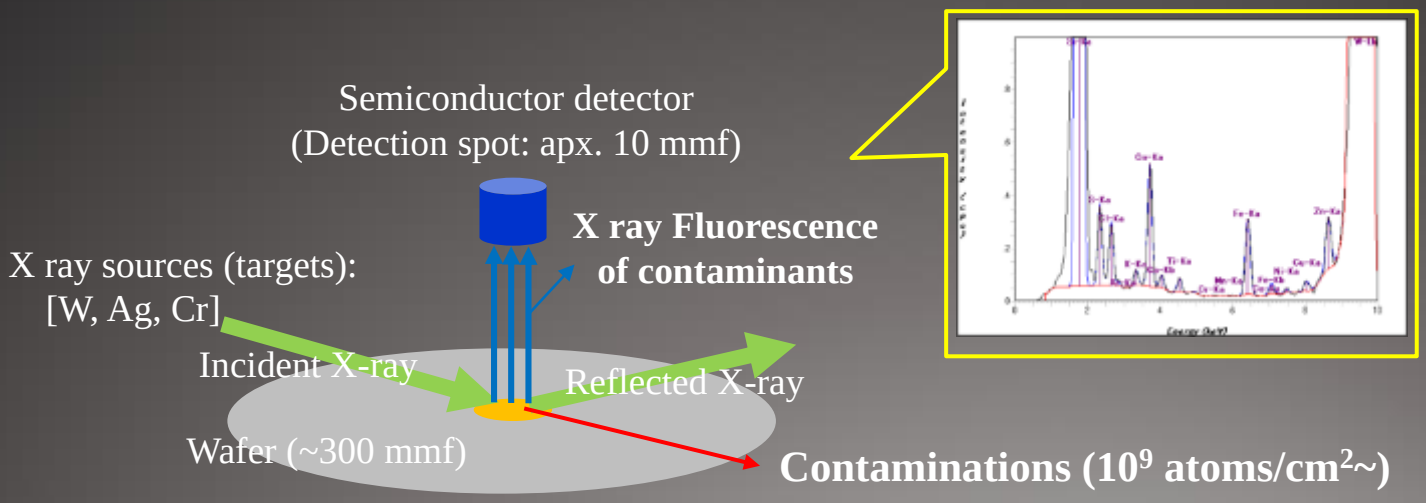


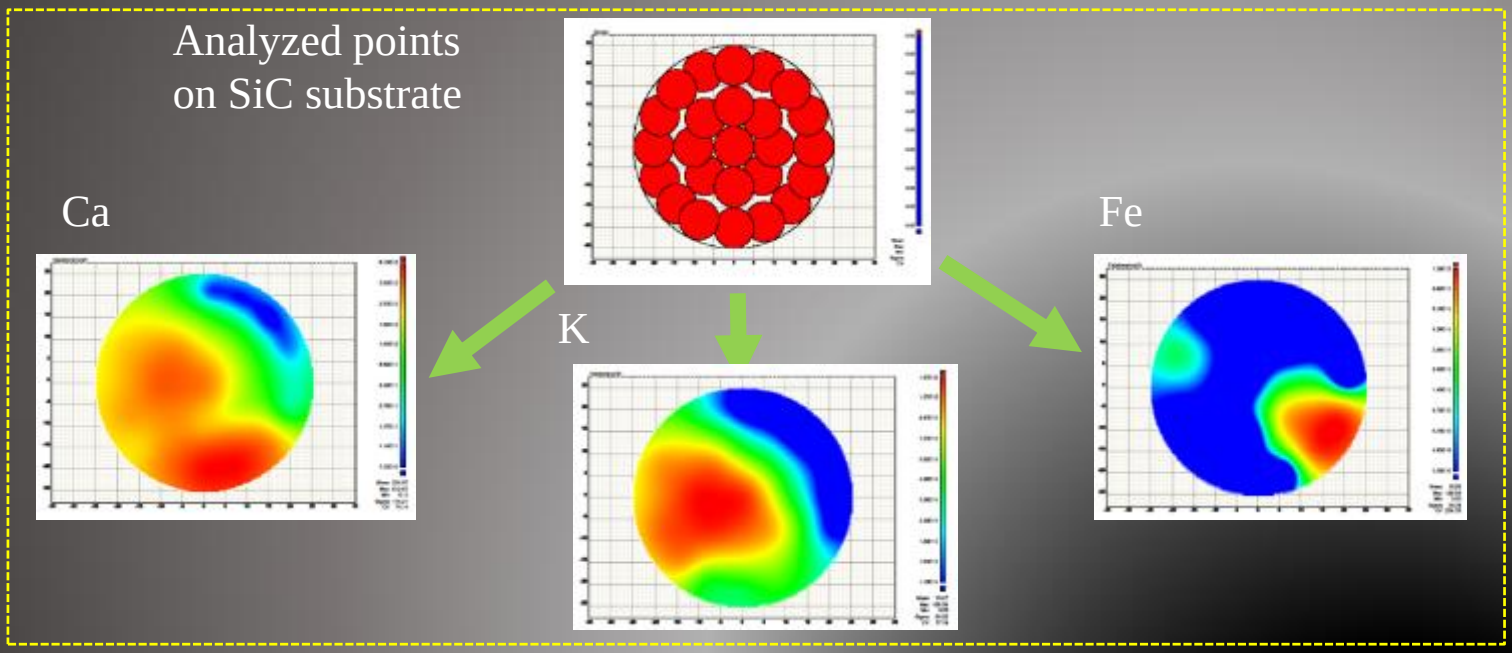
Provided by Agilent Technologies

Example

- Wafer surface metal contamination
  Applicable size 4 inches to 12 inches
- Impurity in bulk
- Pure water, impurities in reagents
- Dissolution amount of metal component from parts
- Thin film composition and impurity analysis
- Environmental analysis of river water

TXRF





- Various substrates: Si, sapphire, GaAs, Glass, thin films (metal, organic inorganic), others which wet analyses can not handle.
- High sensitivity: 10^9atoms/cm^2~
- Simultaneous multiple elements analyses (Na ~ U)
- Quick, non-destructive, non-contact (without pretreatment), highly-reproducible

Fabrication and Evaluation Tools

Multilayer deposition

- Magnetron-sputtering multilayer deposition

Thin film deposition

- LP-CVD, ECR-CVD, Plasma-CVD, E-beam evaporation

Lithography

- E-beam lithography system, i-line stepper, Mask aligner

Dry etching

- ECR etching, RIE, deep-RIE

Evaluation

- TEM, SEM, AFM, Optical microscope
- XRD
- ICP-mass, TXRF

Multilayer deposition system

XRD

For more information, please contact : https://www.ntt-at.com/product/list_xuv_euv_x-ray_optics.html