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MoSi Coating Performance on EUVL Optics for Imaging Systems

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Overview

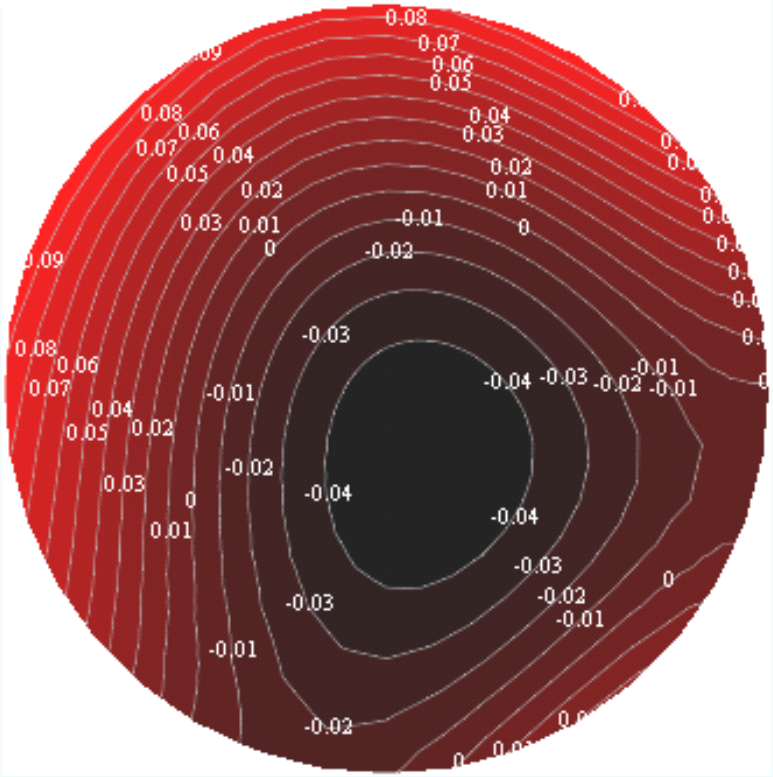
Osmic has recently completed the coatings for two imaging systems. The first was a pair of six-optic RIM condenser/imager systems, described previously (M. Booth et. al., Proc SPIE vol 5751, p. 78-89). Each optic design is uniform angle-of-incidence (γ) & multilayer period (Λ); one optic is glancing-incidence Ru. Each optic is of different curvature, size and γ.

The second two-optic system was a larger set with a complex non-radial 2D gradient of γ & Λ, different for each. They also required B4C/Ru cap layers. An overview of the results of peak-position control and reflectivity performance is given.

In the course of calibration & design, Osmic also utilized ray-tracing methodology (in collaboration with I. Wallhead of Exitech Ltd) to examine the impact of peak-position distributions on the illumination levels and variability. These results are also included & discussed.

Matched Set of Silicon Optics

- **Design**: ~20deg nominal 2D gradient (non-radial symmetry)
- ~200mm diameter ~300mm curvature
- B4C/Ru Cap Layer
- Masking + Velocity Control ±0.15nm overall
- Peak Refl variation highly variable due to surface polish (best results 65-67% Rp)



variation of peak-position 0.01nm contours

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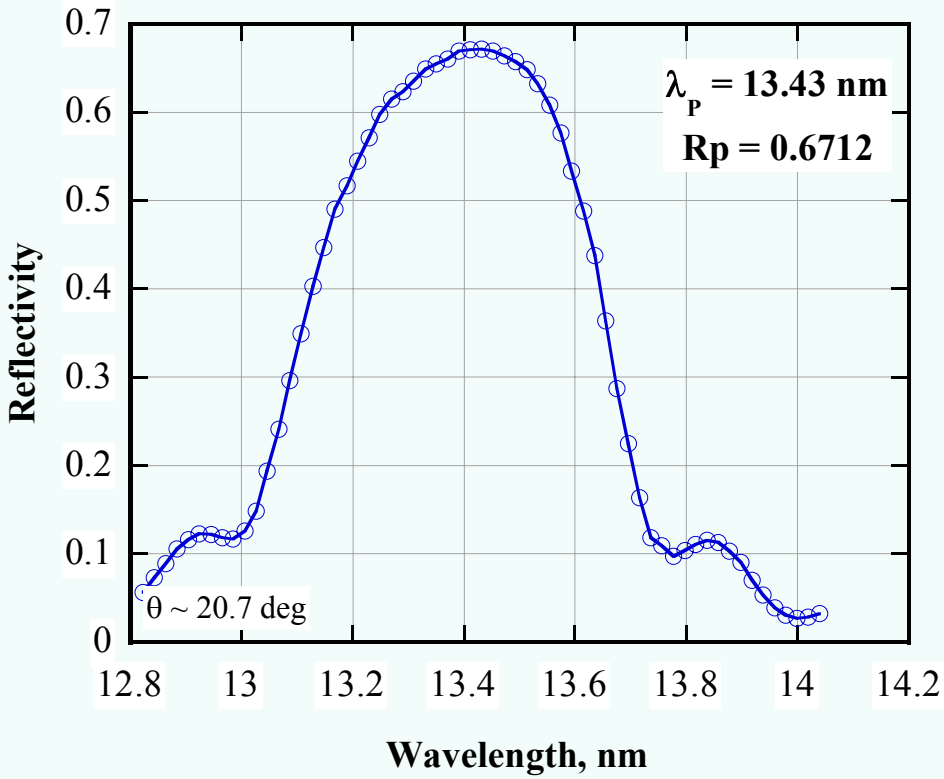
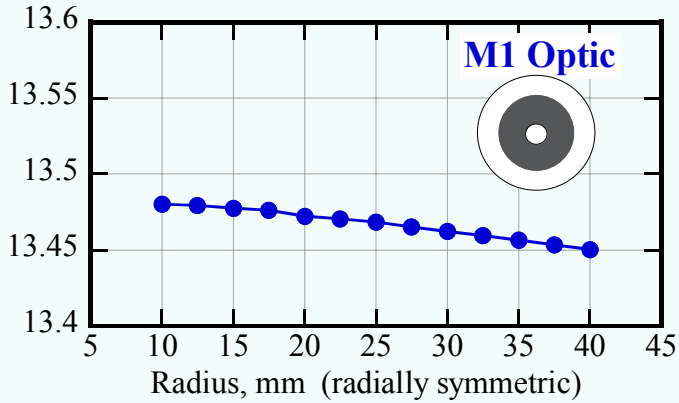
B_4C/Ru Cap Layers on Silicon Optic

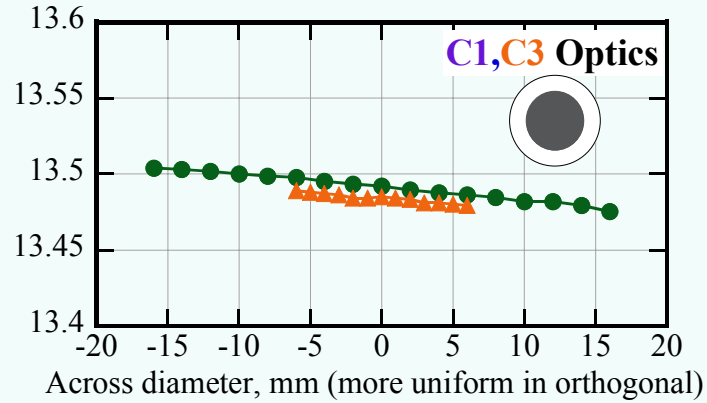


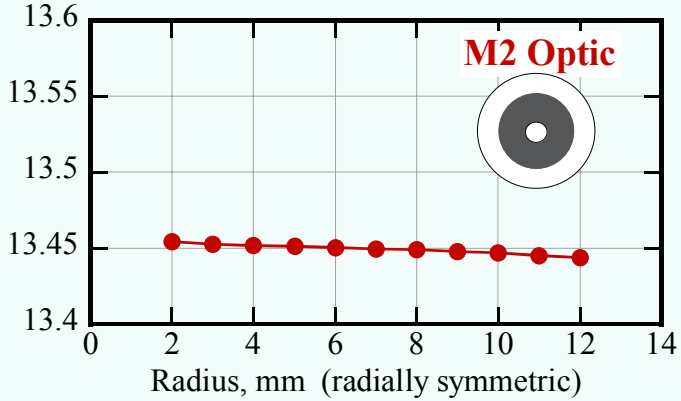
Maintain periodicity of final spacer layer

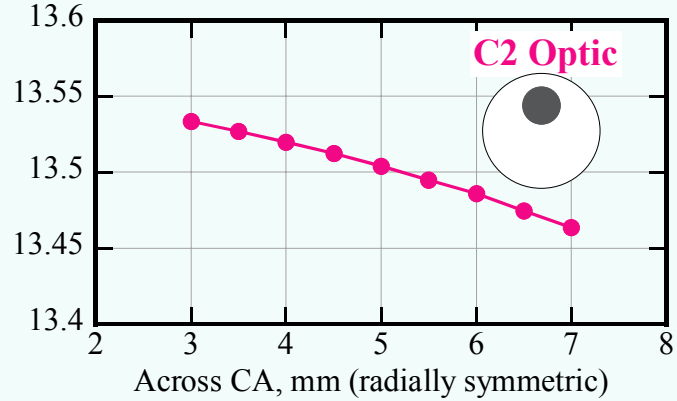
This is about
1% gain due to
Angle of meas

ML Peak Variation on RIM Optics









	Shape	Curvature	Diameter	CA Radii	$\Delta\lambda_C$ (PV)	Δthick (PV)	Δthick (rms)
M1	Concave	moderate	155mm	10-45mm	±0.018nm	±0.38nm	0.23nm
M2	Convex	moderate	78mm	3-12mm	±0.005nm	±0.10nm	0.04nm
C1	Concave	moderate	42mm	0-16mm	±0.013nm	±0.26nm	0.20nm
C2	Convex	very curved	18mm	3-7mm	±0.022nm	±0.45nm	0.37nm
C3	Concave	flat	25mm	0-6mm	±0.004nm	±0.10nm	0.08nm
C4	Flat	-n/a-	40mm	0-18mm	-n/a-	±0.30nm	-n/a-

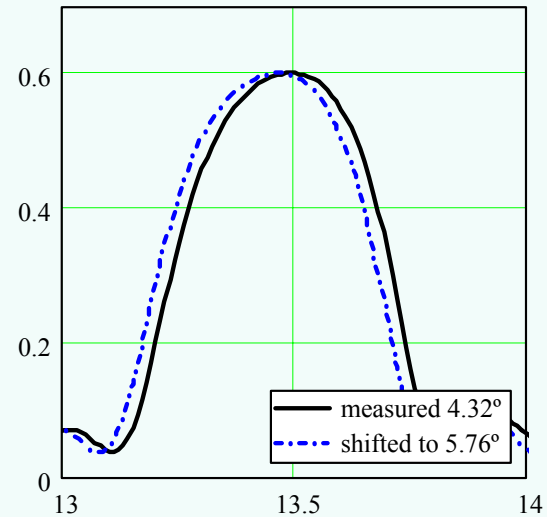
Ray-tracing investigation of ML impact to illumination at reticle/detector

- Source has spectrum $I_O(\lambda)$
- Multiple beams (N) exit from each position, x_S, on the source
- Each position of the source illuminates the entire width of the reticle/detector image; it images a subset of positions, x_M, across the clear-aperture on each optic (M optics).
- The variation of the reflectivity spectra, $R(\lambda)$, on each optic is known. Functionalize the variation in peak wavelength with position ($\Delta\lambda_P$ vs x)
- Each ray has a different angle-of-incidence, γ, on each optic. This value is different from the measurement angle, γ_m, of the multilayer. The peak is shifted $\Delta\lambda_\gamma$ from the γ_m to γ.

$$\Delta\lambda_\gamma = f\left(\cos(\gamma) \big/ \cos(\gamma_m)\right)$$

- The source spectrum and the optic reflectivity spectra are multiplied and integrated in the bandwidth for each beam. The multiple N beams arriving at each reticle/detector position are then summed.

$$I(x) = \sum_N \left[\int_{\lambda_1}^{\lambda_2} I_o(\lambda) \cdot R_M(x_M, \lambda[\Delta\lambda_{mfg}, \Delta\lambda_{\gamma\ vs\ \gamma_m}]) \right]$$



Shift effect at use angle g versus measurement γm

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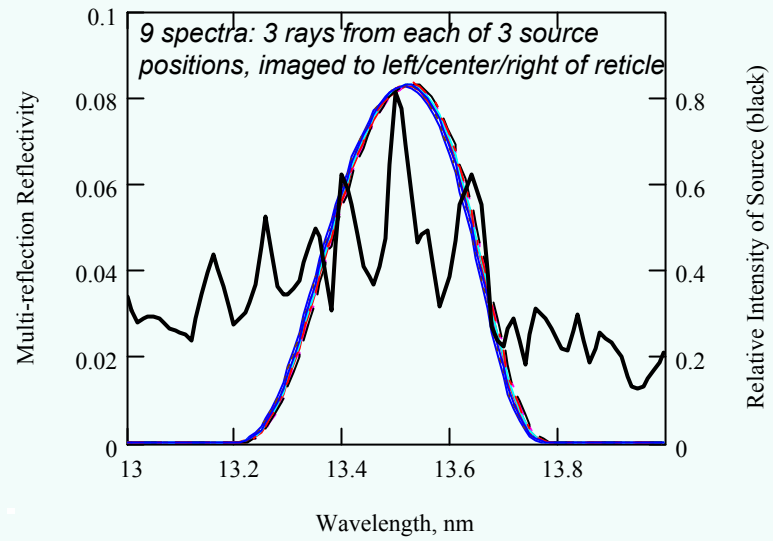
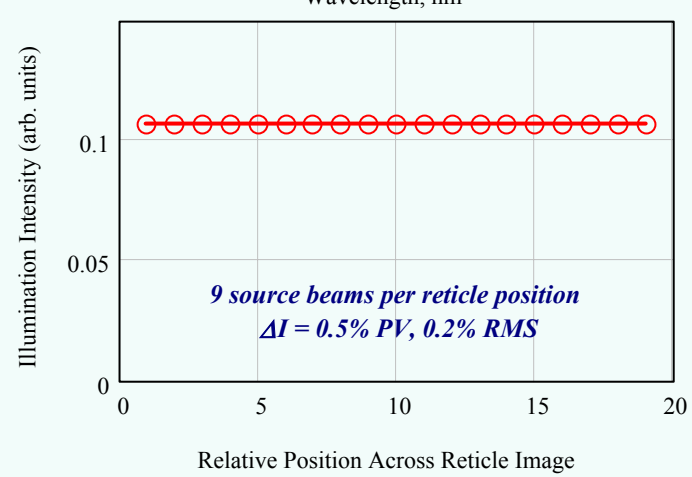
Ray-tracing results

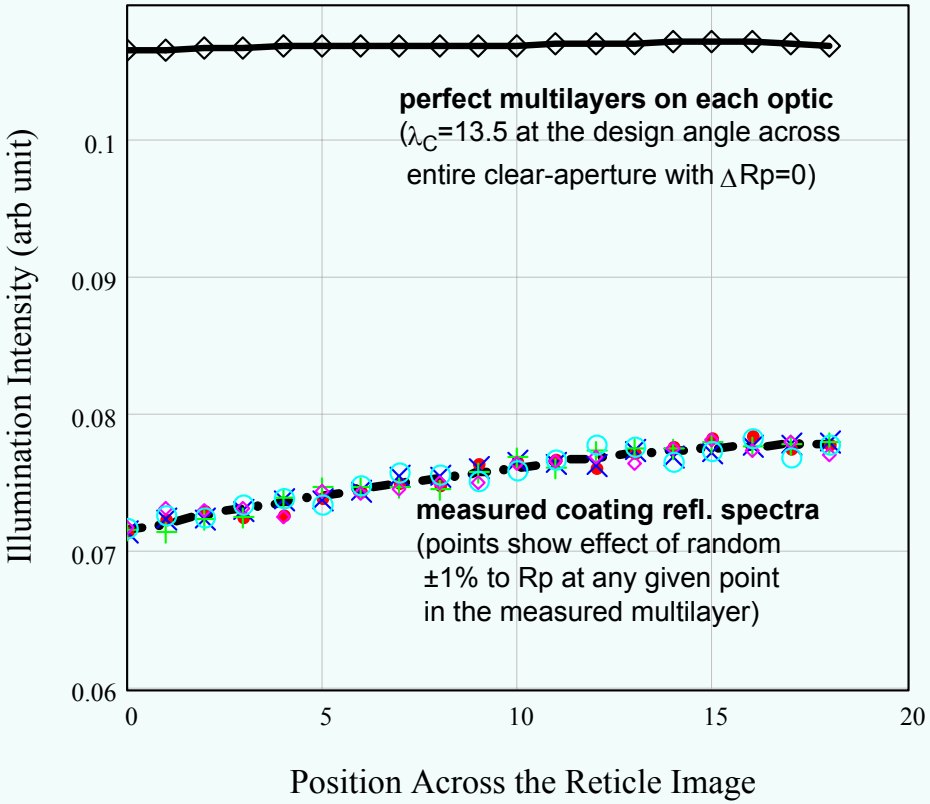
- Can investigate the following issues:
- How does illumination vary across reticle/detector?
- How does I(x) change from assumption of perfect coatings (identical & perfect uniform R(λ)) with actual measured spectra?
- Is there an effect of the actual source spectrum $I_o(\lambda)$ from some idealized constant value?
- What are individual effects of Δλ & ΔRp variations in the ML coatings?
- What are the relative contributions to I(x) of each optic?
- With known expectations or prior results of coatings, can you make tradeoffs in total illumination (I_{avg}) vs illumination variation (ΔI) by changing the targeted specifications of individual optic-coatings?

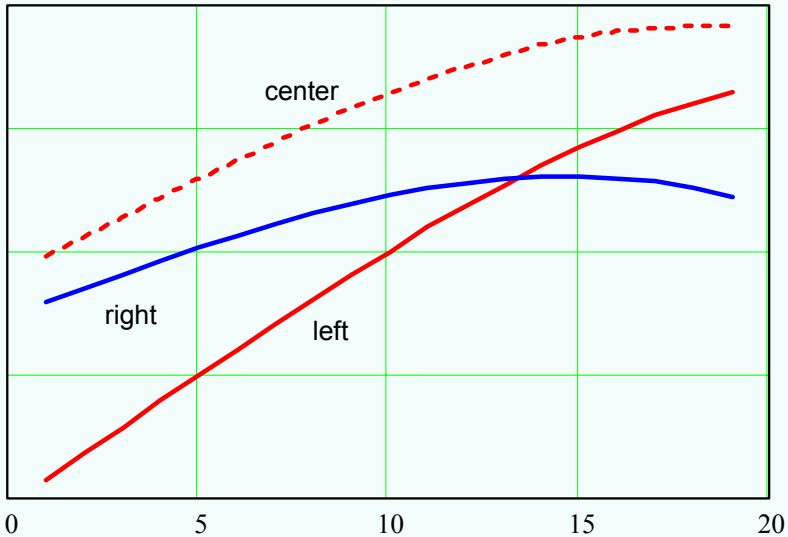
Intrinsic Design Performance
(coatings with zero variation in Rp or peak position)





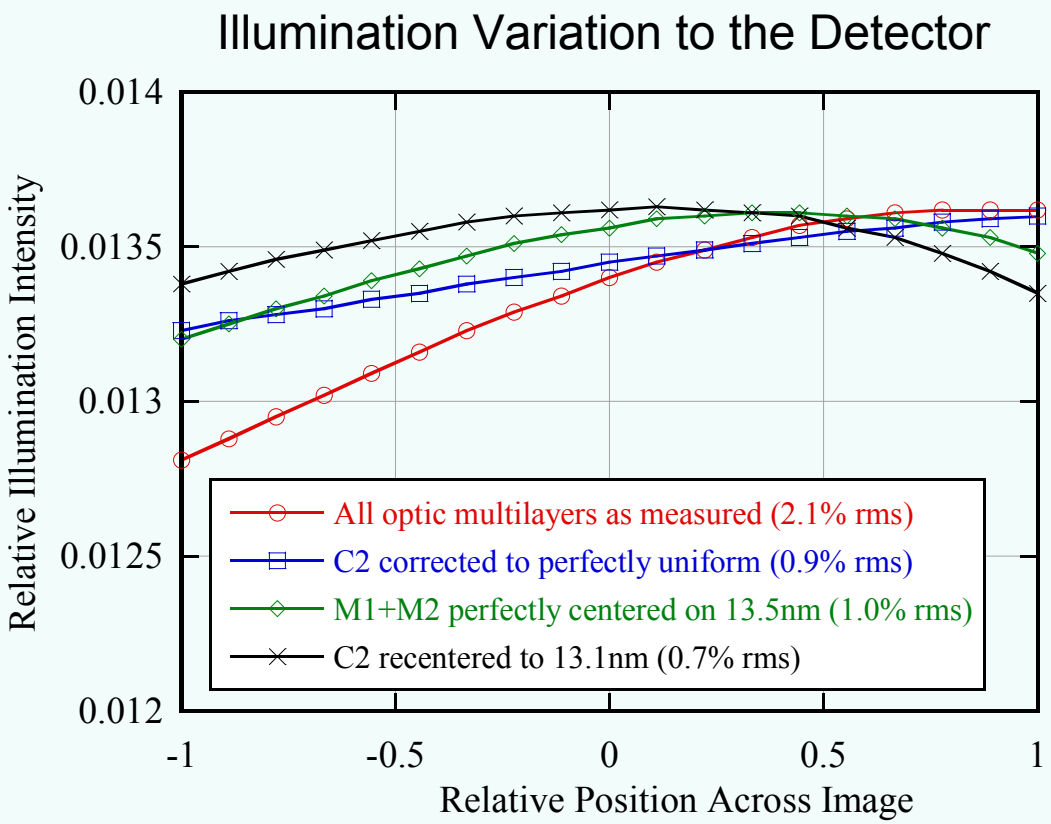
Ray-Tracing Investigations





The image of the left side of source produces majority of Illumination variation

Ray-Tracing: What-if?



As produced, both M1 & M2 optics' ML coatings were below 13.5nm; correcting both to perfectly centered improves the illumination variation by a factor of 2.

C2 was centered, but had large variation in peak position. Making it perfectly uniform also improves illumination variation by a factor of 2.

However, the simplest correction is to shift the average of the C2 distribution away from the target 13.5nm, to an offcenter value of 13.1nm. This improves illumination variation by a factor of 3.

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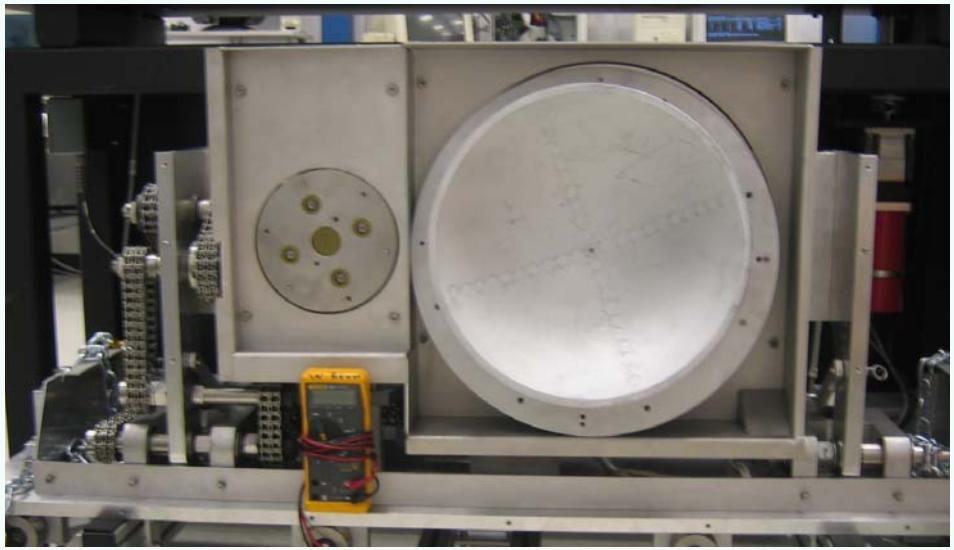
Upgrade: Dual-Optic Spinners

- Osmic has upgraded it Inline deposition machine with a dual-spinner substrate carrier
- Spinner #1: 450mm diam x 100mm thick
  Spinner #2: 175mm diam x 35mm thick



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