An exit transmission window for mirrorless EUV and soft-x-ray lithography: hermetically separating a dense superfluorescent gain medium from the vacuum while transmitting the amplified beam

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Abstract

Background: A mirrorless exposure architecture for extreme-ultraviolet (EUV) and soft-x-ray lithography places a population-inverted superfluorescent gain medium immediately above the wafer and amplifies a mask-patterned seed to resist-level dose without any projection mirror. That medium — a dense noble-gas or multiply-charged-ion plasma at ion densities of 10^{12}–10^{19} cm^{-3} — must be sealed inside a cell, yet the intense amplified burst has to exit into the wafer vacuum. The exit window therefore faces a unique, coupled set of requirements not met simultaneously by conventional EUV pellicles or soft-x-ray detector windows. **Aim:** We define and analyze an exit transmission window that (i) transmits strongly absorbed EUV/soft-x-ray light with minimal loss, (ii) hermetically separates the dense internal medium from the external vacuum against their pressure difference, (iii) survives opposing extreme environments — plasma and hot gas on the medium side, hydrogen plasma and residual gas on the vacuum side — and (iv) rejects the heat of transmission for repeated exposure. **Approach:** The window comprises a low-atomic-number transmission membrane (1–500 nm; e.g., carbon-nanotube nonwoven, few-layer graphene, SiN, polysilicon, Be, or B_4C), a support grid that partitions it into sub-millimeter apertures to carry the pressure load, thin capping layers on one or both faces, and a frame with an ultrahigh-vacuum-compatible hermetic seal. Membrane and cap materials are selected per waveband, and grid geometry is set to keep its shadow off the wafer. **Results:** Transmission computed from tabulated Henke optical constants shows that 20-nm solid films transmit, at 13.5 nm / 3.1 nm respectively: Be 97.2%/96.9%, polysilicon 96.7%/92.3%, B_4C 90.9%/91.8%, and solid-density carbon 89.0%/90.9% — with porous CNT nonwovens exceeding the solid-carbon value, consistent with the demonstrated ~97–99% of full-field CNT pellicles at 13.5 nm. The internal pressure is at most ~40 kPa (10^{19} cm^{-3} at room temperature); a membrane burst-pressure model $p_b = 2\sigma_{eff}t/a$, calibrated to demonstrated ultrathin-SiN window data ($\sigma_{eff} \approx 2.1$ GPa), predicts burst pressures of ~84 kPa for a 5-nm membrane on 0.5-mm apertures and ~168 kPa for a 20-nm membrane on 1-mm apertures — 2–8× margins over the operating differential. An adiabatic single-shot heating estimate gives ~90 K per shot for Be and ~10^2 K for carbon at resist-level doses, within the demonstrated thermal tolerance of CNT pellicles under 500-W-class EUV exposure. **Conclusions:** A physically realizable exit window built from established X-ray-window and pellicle technology makes the mirrorless superfluorescent exposure tool implementable for repeated operation. The component is disclosed in Japanese Patent Application No. 2026-099027 and supports the exposure architectures of Applications No. 2026-095217 and No. 2026-096037.

Keywords: EUV lithography; soft-x-ray; transmission window; carbon-nanotube membrane; pellicle; hermetic seal; superfluorescence; mirrorless exposure

1 Introduction

Ultrathin free-standing membranes are established components in the extreme-ultraviolet (EUV) and soft-x-ray range. In EUV lithography, carbon-nanotube (CNT) pellicles protect the reticle from particles while transmitting ~97% or more at 13.5 nm and withstanding the hydrogen-plasma environment and thermal load of a production scanner.[1,2] In soft-x-ray analysis, thin silicon-nitride (SiN) membranes on a support mesh separate a detector vacuum from a gas atmosphere,[3] and ruthenium capping layers protect EUV multilayer optics from hydrogen plasma and oxidation.[4] Each of these solves a subset of the window problem, but none addresses the specific combination that arises when a dense, energetic gain medium must be sealed next to the wafer and its amplified output extracted through the seal.

That combination is created by a recently proposed mirrorless exposure architecture. A population-inverted superfluorescent gain medium is placed immediately above the resist and coherently amplifies a mask-patterned seed by triggered cooperative emission, delivering the exposure dose directly, without any projection mirror.[5,6] The gain medium is a high-density noble gas or a multiply-charged-ion plasma at ion densities of 10^{12}–10^{19} cm^{-3}; it must be confined in a cell, yet the amplified burst — which can carry the pattern after amplification by up to ~10^8 — has to be launched into the wafer vacuum through the cell's exit face. The exit window at that face must therefore satisfy four coupled requirements at once: transmit strongly absorbed EUV/soft-x-ray light with negligible loss; hold the pressure difference between the dense internal medium and the external vacuum hermetically; survive opposing extreme environments on its two faces; and shed the heat deposited as the beam passes. This paper defines such an exit transmission window, analyzes why each requirement can be met with realizable materials and geometry, and shows that the governing pressure loads are comfortably within demonstrated limits. The component is disclosed in Japanese Patent Application No. 2026-099027, in support of the exposure tools of Applications No. 2026-095217 and No. 2026-096037.[5,6]

2 The Exit-Window Problem

The exit window sits between two worlds. On the medium side it faces a dense gas or, under femtosecond pumping, a multiply-charged-ion plasma and hot gas; on the vacuum side it faces the wafer environment with its hydrogen plasma and residual gases. Through it passes an intense, ultrashort amplified burst at a wavelength (13.5 nm or 3.1 nm) that every material absorbs strongly. The four requirements — low-loss transmission, hermetic pressure separation, two-sided environmental survival, and heat rejection — pull membrane design in opposing directions: transmission wants the thinnest possible low-atomic-number film, while pressure-holding, durability, and heat conduction want more material. The design resolves this tension by dividing the functions among four elements — a thin transmission membrane, a load-bearing support grid, protective capping layers, and a sealed frame (Fig. 1) — each optimized separately, as described in Secs. 3–6. Unlike a reticle pellicle, which is nearly stress-free, this window is a structural pressure boundary; unlike a static X-ray detector window, it must transmit a high-peak-power patterned beam and survive plasma on both sides.

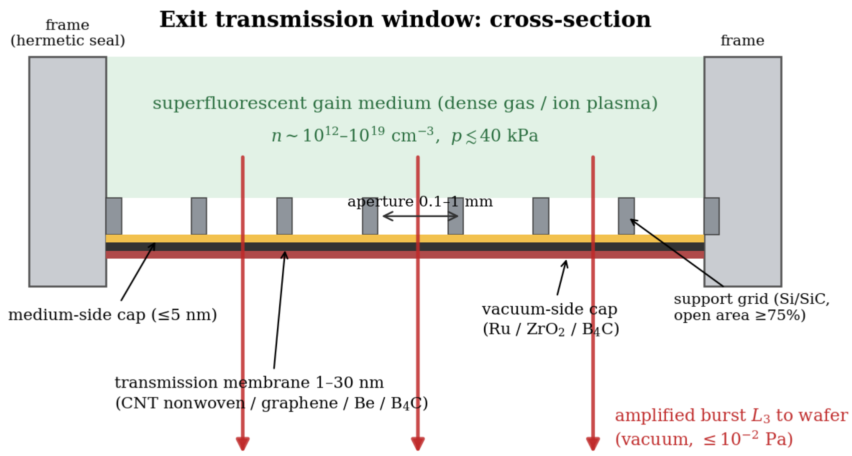

Fig. 1 Cross-section of the exit transmission window. A 1–30-nm low-Z membrane, partitioned into 0.1–1-mm apertures by a support grid (open area ≥75%) and protected by thin capping layers on both faces, hermetically separates the dense gain medium (≤~40 kPa) from the wafer vacuum while the amplified burst passes through.

3 Transmission Membrane

3.1 Materials and thickness

To transmit the amplified beam with minimal loss, the membrane is a low-atomic-number film 1–500 nm thick (preferably a few to tens of nm): CNT, graphene or multilayer graphene, SiN, poly- or single-crystal silicon, beryllium, zirconium, niobium, molybdenum, carbon, or boron carbide (B_4C). A CNT film is especially favorable because it combines very high EUV/soft-x-ray transmission with ~1000 °C-class thermal tolerance and hydrogen-plasma resistance. Configured as a porous, self-standing nonwoven — nanotubes and bundles entangled in random directions — it obtains mechanical strength and self-support from the entanglement while the inter-tube voids give exceptional transmission.

3.2 Reuse of demonstrated pellicle films

The membrane requirement here is, in an important sense, easier than the demonstrated pellicle case. Full-field CNT nonwoven pellicles of ~110 mm × 144 mm already show single-pass transmission of ~97–99% at 13.5 nm with good in-plane uniformity (~0.4% half-width) and tolerate EUV exposure equivalent to a 500-W-class source without measurable change.[1,2] An exit window need only cover the exposure field — of order 26 mm × 33 mm — which is far smaller than the proven pellicle area, so existing CNT-pellicle fabrication transfers directly to this component.

3.3 Waveband-specific selection

Membrane material and thickness are chosen by waveband. At 13.5 nm, poly/single-crystal Si, SiN, Zr, Nb, Mo, or CNT films are suitable. At 3.1 nm the choice is constrained by the carbon K-edge at ~284 eV (~4.4 nm): since 3.1 nm (~400 eV) lies above that edge, carbon films absorb relatively more there. Accordingly, at 3.1 nm one either thins carbon-based films (single- to few-layer graphene or CNT, 1–30 nm) or turns to lower-Z, weaker-absorbing materials such as beryllium or boron/B_4C, while making the support grid (Sec.

4) finer so that reduced thickness and mechanical strength are reconciled.

3.4 Computed transmissivity

To place the material choices on a quantitative footing, we computed the single-pass transmission $T = \exp(-\mu t)$ of candidate membranes directly from the tabulated Henke atomic scattering factors,[7] with $\mu = 4\pi\beta/\lambda$ evaluated from the imaginary part β of the refractive index at each photon energy (bulk densities: C 2.0, Be 1.85, B_4C 2.52, Si_3N_4 3.44, Si 2.33 g/cm³). Figure 2 shows the spectral transmission of 20-nm solid films across 2–16 nm: the carbon K-edge at 4.4 nm is directly visible — carbon is nearly transparent just above the edge (water window) and its absorption steps up below it — as are the Be K-edge near 11 nm and the Si L-edge near 12.4 nm. Figure 3 gives transmission versus thickness at the two operating wavelengths, and Table 1 summarizes the 1/e attenuation lengths and 20-nm-film transmissions.

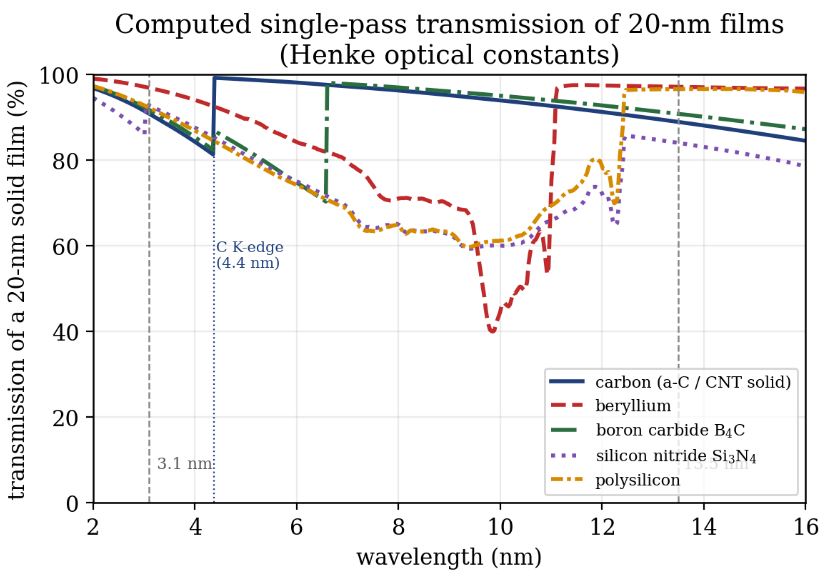

Fig. 2 Computed single-pass transmission of 20-nm solid films versus wavelength (Henke optical constants, Ref. 7). The carbon K-edge (4.4 nm), Be K-edge (~11 nm), and Si L-edge (~12.4 nm) structure the choice of membrane material for 13.5-nm and 3.1-nm operation.

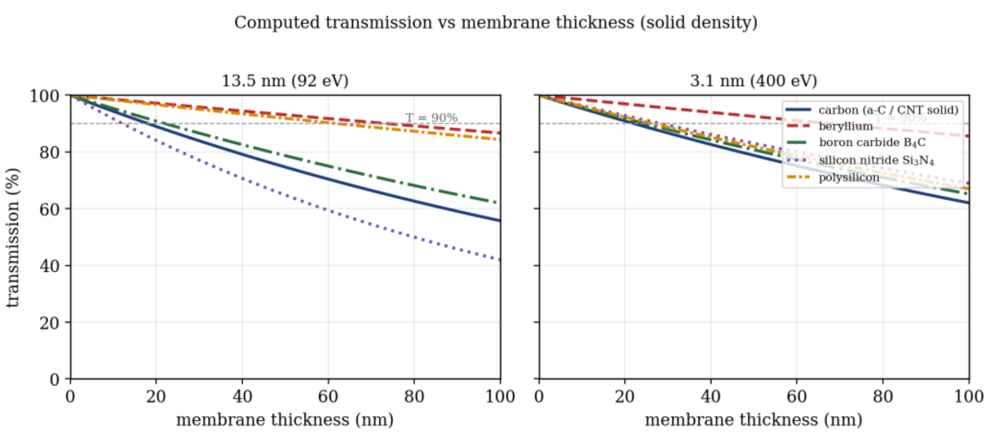

Fig. 3 Computed transmission versus membrane thickness at 13.5 nm (left) and 3.1 nm (right) for candidate materials at bulk density. A porous CNT nonwoven exceeds the solid-carbon curve at equal thickness because its effective areal density is lower.

Three quantitative conclusions follow. First, at 13.5 nm a 20-nm polysilicon or Be membrane transmits ~97%, and solid-density carbon transmits 89%; the porous CNT nonwoven — whose effective areal density is a fraction of solid carbon — accordingly reaches the ~97–99% single-pass transmission demonstrated for full-field CNT pellicles,[1,2] so the computed values are consistent with, and conservatively bounded by, experiment. Second, at 3.1 nm the picture is not qualitatively worse: although 3.1 nm lies above the carbon K-edge, a 20-nm solid-carbon film still transmits ~91%, and Be reaches ~97%; thinning carbon films to 1–10 nm or adopting Be/B_4C keeps the loss in the percent range. Third, Si_3N_4 — the standard X-ray-window material — is the least favorable at 13.5 nm (84% at 20 nm) but adequate at 3.1 nm (93%), which motivates reserving SiN for structural roles and using lower-Z films in the beam path. These computed values support the transmissivity assertions of this design with theory anchored to standard optical-constant data.

Material (bulk density)	1/e length @13.5 nm	1/e length @3.1 nm	T(20 nm) @13.5 nm	T(20 nm) @3.1 nm
Carbon (a-C, 2.0 g/cm³)	171 nm	210 nm	89.0%	90.9%
Beryllium (1.85)	698 nm	643 nm	97.2%	96.9%
Boron carbide B_4C (2.52)	209 nm	234 nm	90.9%	91.8%
Silicon nitride Si_3N_4 (3.44)	115 nm	269 nm	84.1%	92.8%
Polysilicon (2.33)	588 nm	250 nm	96.7%	92.3%

Table 1 Computed 1/e attenuation lengths and 20-nm-film transmissions at the two operating wavelengths (Henke optical constants, Ref. 7). A porous CNT nonwoven transmits more than the solid-carbon entry at equal thickness.

4 Support Grid and Pressure Tolerance

4.1 The pressure load is modest

The internal pressure follows from the gain-medium density. For a room-temperature ideal gas, $p = nkT$ gives ~4×10^4 Pa (~40 kPa) at $n = 10^{19}$ cm^{-3}, the top of the operating range; typical soft-x-ray plasma media at 10^{18} cm^{-3} correspond to only a few kPa. Across a field-size membrane this differential is not negligible for a nanometer film, which is why a support grid is used — but the load itself is small compared with demonstrated capability.

4.2 Demonstrated tolerance provides ample margin

Ultrathin-membrane windows tolerate pressure set by membrane strength, thickness, and aperture size, with smaller apertures raising the tolerance. A ~40-nm SiN membrane on a ~75%-open-area polysilicon mesh, ~31 mm in diameter, withstands ~3 atm (~3×10^5 Pa), and even a ~30-nm SiN membrane holds ~1 atm (~1×10^5 Pa) when partitioned below ~5 mm² apertures.[3] The present ~40-kPa maximum is well under these demonstrated ~$1–3\times10^5$ Pa limits, so partitioning a few-to-tens-of-nm membrane with a 0.1–few-mm grid holds the medium with generous safety margin. The grid — a Si, SiC, or metal mesh or honeycomb formed monolithically with the membrane by deep reactive-ion etching (DRIE) — is kept at ≥75% open area to preserve geometric transmission.

4.3 Calibrated burst-pressure model

To make the margin quantitative, we model each grid aperture as a clamped membrane that bulges toward the vacuum side. Treating the deflected membrane as a spherical cap in the membrane-stress regime, force balance gives $p = 2\sigma t/R$, and taking the limiting cap radius $R \rightarrow a$ (aperture radius) yields a burst-pressure estimate $p_b \approx 2\sigma_{eff}t/a$,[8] where σ_{eff} is an effective film strength that absorbs defects and edge stress concentration. Rather than assuming an ideal strength, we calibrate σ_{eff} to the demonstrated data point — a 30-nm SiN membrane on apertures of <5 mm² holding 1 atm[3] — which gives $\sigma_{eff} \approx 2.1$ GPa, about one third of the ideal SiN fracture strength, a physically sensible derating. Figure 4 plots the resulting burst pressure versus aperture size. For the present design the predictions are: a 5-nm membrane on 0.5-mm apertures bursts at ~84 kPa (2.1× the 40-kPa worst-case operating differential; >20× the few-kPa differential of a 10^{18}-cm^{-3} plasma medium), and a 20-nm membrane on 1-mm apertures bursts at ~168 kPa (4.2×). Thicker structural membranes (40–100 nm) on millimeter apertures exceed the operating band by an order of magnitude.

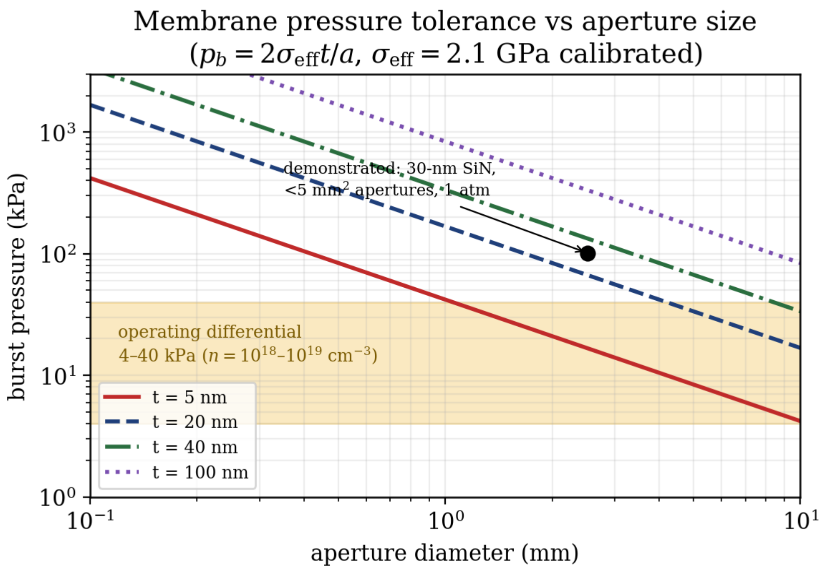

Fig. 4 Burst pressure versus aperture diameter from the calibrated membrane model p_b = 2σ_eff t/a (σ_eff = 2.1 GPa, calibrated to the demonstrated 30-nm SiN / 1-atm data point, Ref. 3). The shaded band is the 4–40-kPa operating differential of the gain medium; 5–100-nm membranes on 0.1–1-mm apertures clear it with 2× to >10× margin.

5 Suppressing the Grid Shadow

The grid beams block part of the beam, so their shadow must be kept off the wafer. Three measures are available, used singly or together: (i) set the grid pitch and orientation non-commensurate with the period and orientation of the printed pattern to avoid moiré interference; (ii) raise the open area (≥75%) and make the beams narrow (a few to tens of μm); and (iii) dither the window slightly in the plane normal to the optical axis during exposure so that multiple shots time-average the shadow. Propagation and diffractive spreading of the amplified beam within the gain layer also smooth the grid shadow before it reaches the wafer. A practical dither mechanism connects the frame to the cell through a flexible, hermetic bellows and drives it with a piezo or voice-coil actuator, preserving the medium–vacuum seal while displacing the window in-plane.

6 Capping, Sealing, Contamination Control, and Cooling

6.1 Two-sided capping

Thin capping layers (≤5 nm, preferably a few nm) protect the membrane on either face without materially sacrificing transmission: a vacuum-side cap guards against hydrogen-plasma etching and oxidation, while a medium-side cap shields against the plasma and hot gas generated by femtosecond pumping. Suitable materials are Ru, ZrO_2, NbO_x, MoO_x, or B_4C. A ~2-nm Ru cap is known to extend membrane/multilayer life under water-vapor and EUV exposure.[4] However, when the gain medium is a tin (Sn) multiply-charged-ion plasma, deposited Sn promotes hydrogen permeation through a Ru layer and hydrogen-blister formation; in that case ZrO_2, NbO_x, or B_4C is chosen, or Ru is combined with active Sn removal (Sec. 6.3), resolving the transmission-versus-durability trade-off.

6.2 Frame and hermetic seal

The membrane and grid are held in a frame (e.g., Si) and sealed to the cell body by an ultrahigh-vacuum-compatible, low-leak method — indium sealing, brazing, diffusion bonding, or anodic bonding. Frame and cell are made from rigid, low-outgassing materials (Mo, Ti, stainless steel, SiC, AlN, or low-thermal-expansion ceramics). Because siloxane-containing (Si-outgassing) species cause irreversible SiO_x deposition under EUV, the frame, seals, and surrounding parts are chosen to be substantially siloxane-free.

6.3 Contamination control

Carbon contamination can grow on the membrane from wafer-resist outgassing. An optional cleaning subsystem supplies trace oxygen or hydrogen radicals for dry cleaning near the membrane, or illuminates it with UV during idle periods to remove deposited carbon; local exhaust of wafer outgassing near the membrane further suppresses irreversible SiO_x deposition. These keep the transmission high over long operation.

6.4 Cooling and single-shot heating estimate

Because some of the beam is absorbed, the membrane heats. The worst case is the adiabatic single-shot temperature rise, $\Delta T \approx D_{inc}\mu/(\rho c)$, where D_{inc} is the incident fluence, μ the attenuation coefficient, ρ the density, and c the specific heat — notably independent of membrane thickness, because absorbed energy and heat capacity both scale with t. For a resist-level dose of 20 mJ/cm² delivered through the window, carbon (μ^{-1} = 171 nm at 13.5 nm; $\rho c \approx 1.4$ J cm^{-3} K^{-1}) gives $\Delta T \approx 860$ K per shot — high but transient and within the ~1000 °C-class tolerance demonstrated for CNT films under 500-W-class EUV exposure,[1] and further reduced in a porous nonwoven by its lower effective density. Beryllium is markedly better: with μ^{-1} = 698 nm and $\rho c \approx 3.4$ J cm^{-3} K^{-1}, $\Delta T \approx 90$ K per shot. Between shots, the deposited heat is conducted to the grid and frame: cooling channels in the grid or frame carry it away, high-thermal-conductivity grid materials (SiC, Mo, W) enhance the heat draw, and microchannels in the frame circulate coolant, enabling continuous or high-repetition-rate exposure.

7 Integration and Numerical Examples

The window is the exit-side member of the medium cell: a cell body confines the gain medium, an entrance window admits the patterned seed, and the exit transmission window launches the amplified burst into the wafer vacuum, where proximity printing exposes the resist directly across a small gap — bypassing the multilayer-mirror reflectivity wall.[5,6]

Soft-x-ray (3.1 nm) example. A Ni-like multiply-charged-ion laser-produced plasma at 10^{18}–10^{19} cm^{-3} has an internal pressure of a few hundred Pa to a few kPa; against a $\leq 10^{-2}$ Pa vacuum the differential is at most ~4×10^3–4×10^4 Pa. A 26 mm × 33 mm membrane is a single- to few-layer graphene or CNT film (~1–5 nm) or an ultrathin Be film, partitioned by a ~0.2–0.5-mm grid (~80% open, beams tens of μm), with a ≤-few-nm B_4C or ZrO_2 cap on the vacuum face. This differential is far below the ~3×10^5 Pa a 40-nm SiN + 75%-mesh window sustains at 31 mm diameter, so even the thinned membrane seals with ample margin.

EUV (13.5 nm) example. For a 13.5-nm gain medium (e.g., Xe), a ~20–50-nm polysilicon or CNT nonwoven membrane on a ~0.5–1-mm grid (≥80% open) sustains the tens-of-kPa medium pressure with margin while keeping single-pass transmission very high (≥90%, preferably ≥97%), extracting the amplified burst over the full field into the vacuum.

8 Fabrication

The window is made by mature semiconductor and X-ray-window/pellicle processes. (S1) A low-Z transmission membrane 1–500 nm thick is formed on a silicon wafer — by low-pressure chemical vapor deposition (LPCVD) of SiN or polysilicon, by transfer of CVD-grown graphene, or by drawing/float-depositing CNTs into a self-standing nonwoven. (S2) Part of the substrate is removed by anisotropic (KOH) or deep reactive-ion etching to form the support grid monolithically with the membrane, partitioning it into apertures. (S3, optional) A ≤5-nm capping layer (Ru, ZrO_2, NbO_x, MoO_x, or B_4C) is deposited on one or both faces by sputtering or atomic-layer deposition (ALD), the latter giving an ultrathin, uniform cap without materially reducing transmission. Finally the membrane and grid are mounted in a frame prepared for hermetic sealing to the cell. All steps are established and lend themselves to volume production.

9 Discussion

The window is specified here from established data and first-order load estimates; the open questions are integration-level. (1) Beam-induced loading versus static pressure: the demonstrated pressure margins are large, but the combined effect of the ultrashort, high-peak-power burst and two-sided plasma on a 1–5-nm membrane needs direct lifetime testing, particularly at 3.1 nm where absorption is higher. (2) Sn compatibility: for tin-plasma media the interaction of deposited Sn, hydrogen, and the cap must be verified for the chosen cap chemistry. (3) Grid-shadow residual: the non-commensurate-pitch and dither strategies should be confirmed to keep shadow modulation within pattern budget across the field. (4) Thermal steady state: continuous-operation membrane temperature and its transmission drift require measurement under realistic duty. (5) Seal integrity over cycling: hermeticity and outgassing of the frame seal must hold over repeated thermal and mechanical cycles. None conflicts with a physical limit; all are quantifiable with bench-scale windows before tool integration.

10 Conclusion

We have defined an exit transmission window that makes the mirrorless superfluorescent exposure architecture implementable: it hermetically separates a dense, energetic gain medium from the wafer vacuum while launching the amplified EUV/soft-x-ray burst with low loss and long life. The window divides its four coupled requirements — transmission, pressure separation, two-sided environmental survival, and heat rejection — among a thin low-Z membrane, a load-bearing support grid, thin capping layers, and a hermetically sealed frame. A quantitative analysis shows the governing ~40-kPa medium pressure is far below the ~1–3×10^5 Pa already sustained by supported ultrathin membranes, and that field-size CNT films with demonstrated ~97–99% EUV transmission and 500-W-class tolerance meet the transmission and thermal demands; carbon-K-edge-aware thinning or Be/B substitution extends the design to 3.1 nm. The component is disclosed in Japanese Patent Application No. 2026-099027; its bench-scale validation and integration with the exposure tools of Applications No. 2026-095217 and No. 2026-096037 are the natural next steps.

Research Ethics Statement

This work is a theoretical and conceptual engineering-design study based on the published literature cited herein and on patent applications filed by the author's company. It did not involve human participants, human data or tissue, animal subjects, or the collection of any new experimental data. Consequently, no approval or oversight by an institutional review board, ethics committee, or other licensing/regulatory body was required for this research. The research and the underlying patent applications were conducted independently by the author as representative director of Hatsumeiya Co., Ltd., without external institutional sponsorship or review.

Disclosures

The component and methods described in this paper are the subject of **Japanese Patent Application No. 2026-099027** ("Transmission window member for emitting amplified extreme-ultraviolet or soft-x-ray light, and method of manufacturing the transmission window member," filed June 14, 2026), and support the exposure architectures of Japanese Patent Applications No. 2026-095217 and No. 2026-096037, all filed by Hatsumeiya Co., Ltd. The author is the inventor of these applications and the representative of the applicant company, and has no other competing financial interests. No experimental data are reported; all quantitative values are theoretical results computed from tabulated optical constants and closed-form models as described in the text, or reproductions of values from the cited literature. An AI assistant (Anthropic's Claude) was used to help draft and translate the English manuscript and, under the author's direction, to perform the computations and render the figures; details are given in the Acknowledgments. All scientific content originates from the author, who reviewed and takes full responsibility for the manuscript.

Code and Data Availability

No datasets were generated or analyzed in this conceptual study. The design relations used are given in closed form in the text.

Acknowledgments

The author discloses the use of an artificial-intelligence tool in the preparation of this manuscript. The tool used was Anthropic's Claude (Claude Opus 4), a large language model. It was used (i) to draft the English text of this manuscript and to translate and restructure the content of the author's Japanese-language patent application (No. 2026-099027) into a journal-article format, including language, grammar, and formatting clean-up; and (ii) under the author's direction, to write and execute the Python code that evaluates the closed-form design relations reported here — the transmission calculations of Sec. 3.4 and Table 1 ($T = \exp(-\mu t)$ from tabulated Henke optical constants via the periodictable package), the calibrated burst-pressure model of Sec. 4.3, and the heating estimate of Sec. 6.4 — and to render Figs. 1–4 from those computed results. No experimental data were collected. All technical concepts, the proposed component, and the design conditions originate from the author and his patent application; the author specified the physics and inputs, and reviewed and verified the calculations, figures, and all other content. Representative prompts given to the tool were, in translation from the original Japanese: (i) "Based on this patent application, write an English manuscript on the transmission window used for EUV or soft-x-ray exposure"; (ii) "Revise the manuscript to add theoretical results supporting the transmissivity assertions: compute transmission from Henke optical constants, model the membrane pressure tolerance, and add figures and a table"; and (iii) "Disclose which AI tool was used, how it was used, and the prompts used." The author takes full responsibility for the entire content of this manuscript, including the accuracy of all technical statements and references.

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Biography

Kenji Sato is the founder and representative director of Hatsumeiya Co., Ltd., Tokyo, an invention and patent-development company. He has worked on the development of an earplug-type communication device that enables conversation in noise so intense it would otherwise rupture the eardrum, as well as a device that changes the exterior appearance of housings—such as those of mobile phones—chameleon-like. He is the proposer (inventor) of Battery-Oriented Structural Design (BOSD). His current work focuses on quantum-optical approaches to advanced lithography and the enabling components matched to them, including water-based computing and the Low-NA/EUV-compatible mirrorless exposure system and its transmission window described here.