Tamm–Boggild Disposable Photonic Sensor Chip

A Collaboration Whitepaper on Low-Δn Tamm Plasmon Sensing via Block Copolymer Self-Assembly

Collaboration Whitepaper | Not a Funding Request

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Note: This document uses a whitepaper format because its purpose is to solicit collaboration on an unverified concept, not to report results. The author is an independent researcher with a systems engineering background, not a photonics specialist. This context should be weighed accordingly when evaluating the technical claims herein.

1. Introduction

Surface plasmon resonance (SPR) is widely used for label-free biomolecular detection, achieving refractive index sensitivities in the range of 10^{-6} to 10^{-7} RIU. The instruments that deliver this performance, such as the Cytiva Biacore T200 and Reichert 4SPR, cost approximately £100,000 to £400,000, with individual sensor chips priced between £40 and £250. This cost structure confines SPR to centralised laboratories and places it beyond the reach of point-of-care, field-deployed, or disposable diagnostic applications.

Label-free biomolecular detection underpins drug discovery, clinical diagnostics, food safety, and environmental monitoring. Fibre Bragg grating sensors offer multiplexing capability but achieve lower refractive index sensitivity, around 10^{-4} RIU. The point-of-care diagnostics market is growing at over 10% annually, driven by demand for decentralised testing. No existing technology that the author is aware of combines SPR-class sensitivity with a manufacturing cost compatible with single-use disposable deployment, though this gap may reflect fundamental physical constraints rather than a missed opportunity.

This whitepaper identifies a combination of known photonic elements that, to the best of the author's knowledge after a limited prior-art search, has not been previously reported: Optical Tamm States at the interface of a thin plasmonic metal film and a low-refractive-index-contrast photonic crystal multilayer fabricated by block copolymer (BCP) self-assembly, inspired by the lamellar architecture observed in Boggild-gap labradorite feldspar.

Whether this combination produces a Tamm plasmon resonance that is spectrally resolvable and surface-sensitive under low-Δn conditions is unknown. The resonance linewidth, quality factor, and evanescent field penetration depth have not been calculated or measured. These are prerequisites that must be established by transfer matrix modelling before experimental work is justified. The purpose of this whitepaper is to invite collaboration from researchers with the domain expertise to answer these questions.

2. Background

2.1 Proposed Architecture

The proposed sensor structure has two principal components. The first is a photonic crystal multilayer produced by BCP self-assembly, containing 50 to 100 or more bilayer pairs, with a refractive index contrast (Δn) of approximately 0.008 to 0.1. The second is a thin (approximately 30 nm) plasmonic metal film—silver or gold—deposited on top of the BCP multilayer. At the metal–dielectric interface, the intent is that an Optical Tamm State forms: a localised electromagnetic mode at the boundary between the metal film and the photonic stopband of the multilayer.

A critical caveat applies here. The reflectivity of a distributed Bragg reflector (DBR) scales with both Δn and bilayer count. At the low end of the proposed Δn range (approximately 0.008), it is not established whether even 100 bilayers produce sufficient stopband reflectivity for a well-defined Tamm resonance. **This is the central physics question of the proposal and represents a potential showstopper.** A 1D transfer matrix calculation for a 100-bilayer stack at $\Delta n = 0.01$ with a 30 nm Ag cap is a straightforward computation that would resolve this question to first order. The author has not performed this calculation and acknowledges this as a significant gap. [HYPOTHESIS]

2.2 Geological Analogy: Scope and Limits

The Boggild miscibility gap in plagioclase feldspar produces nanoscale lamellar exsolution structures responsible for labradorescence—structural colour from low-Δn multilayers with high bilayer counts. This geological system suggested the parameter space (low Δn, high layer count) explored in this proposal.

The analogy has clear limits. The geological system forms by thermodynamic equilibrium over geological timescales; BCP self-assembly operates on fundamentally different kinetics (minutes to hours via solvent or thermal annealing) governed by microphase separation thermodynamics, not feldspar exsolution. The Boggild system is the inspirational source for the parameter space, not a predictive model for the synthetic system. It provides no quantitative guidance for BCP formulation, layer thickness control, or optical performance.

3. The Conceptual Framework

A prior-art search was conducted across USPTO, EPO, and WIPO patent databases and academic literature (Google Scholar, Web of Science) during January to February 2026. Search terms included “Tamm plasmon sensor BCP,” “block copolymer photonic crystal biosensor,” “low refractive index contrast Tamm state,” and “disposable plasmon sensor roll-to-roll.” The search was conducted by the author alone and may not be exhaustive. Six elements of potential novelty were identified; independent corroboration by domain experts is required.

3.1 Low-Δn BCP Multilayer with Tamm Plasmon Metal Cap for Sensing

The closest published work identified (Augué/Fainstein group, Centro Atómico Bariloche, Argentina; Nuguri et al. 2021, ACS Appl. Mater. Interfaces) uses inorganic mesoporous materials with substantially higher Δn. The low-Δn BCP variant does not appear in the literature searched. It is possible that this combination has been considered and rejected by researchers who determined it to be non-viable; the absence of literature is not evidence of feasibility. [HYPOTHESIS]

3.2 Disposable Roll-to-Roll Tamm Sensor Chip Format

All Tamm plasmon sensing identified in the search uses laboratory-fabricated PVD structures. A roll-to-roll format does not appear to exist. This may reflect manufacturing barriers rather than a gap in the literature. [HYPOTHESIS]

3.3 Dark-Ground Readout Architecture

The concept exploits the narrow Boggild stopband as a spectral background against which the Tamm dip is measured, potentially reducing or eliminating the reference-channel subtraction required by conventional SPR. Three unresolved issues qualify this claim. First, the stopband width and depth at Δn of approximately 0.008 have not been established. Second, sidelobe structure from a stepped (non-sinusoidal) refractive index profile could contaminate the measurement window. Third, whether this architecture provides any signal-to-noise benefit relative to conventional approaches has not been quantified. This remains a hypothesis requiring modelling, not a demonstrated advantage. [HYPOTHESIS]

3.4 Rugate-Like Filter Approximation

BCP self-assembly produces a discrete stepped (lamellar) refractive index profile, not a true sinusoidal Rugate profile. At high bilayer counts (50 to 100+), the stepped profile may approximate Rugate behaviour and suppress higher-harmonic stopband ripples, but this approximation has not been validated for the Δn range proposed here. Optical simulation is required to determine whether the approximation holds. [HYPOTHESIS]

3.5 Angle-Multiplexed Sensing

Multiple sensing channels at different incidence angles on the same physical substrate is a standard technique in thin-film optics. Its application to this specific architecture would need evaluation once the base Tamm state is confirmed. [HYPOTHESIS]

3.6 Boggild Geological Model as Parameter-Space Inspiration

This is a conceptual framing contribution. It is not a testable technical claim and provides no predictive power for the synthetic system. Its value, if any, lies in having directed attention to a region of parameter space—low Δn, high layer count—that appears under-explored in the Tamm plasmon literature.

4. Discussion and Limitations

4.1 Open Questions Requiring Collaboration

The questions below are listed in order of criticality. The first is a prerequisite gate: if the answer is negative, the remaining questions are moot and the concept should be abandoned.

4.1.1 Does a Spectrally Resolvable Tamm State Exist at the Proposed Low-Δn Range?

This is the fundamental physics question. For a 100-bilayer BCP stack with Δn in the range 0.008 to 0.1, capped with a 30 nm Ag or Au film, what is the stopband reflectivity, Tamm resonance linewidth, and quality factor? The author has not performed this calculation. Until this is answered—ideally by transfer matrix modelling—no other question in this proposal matters. If the stopband reflectivity is insufficient, there is no Tamm state, and the concept fails at the physics level.

4.1.2 Does the Evanescent Field Extend into the Analyte Region?

Tamm states are localised at the metal–DBR interface. The evanescent field may be largely confined between the metal film and the first few bilayers of the DBR, not at the outer sensing surface. Without modelling of the field profile, there is no basis to assume the architecture is sensitive to surface binding events. Even if the Tamm state exists, it may not be useful for sensing.

4.1.3 Can BCP Formulations Achieve the Required Optical Uniformity?

Roll-to-roll manufacturing of 50 to 100+ bilayer BCP films at the optical uniformity required for quantitative spectral measurement has not been demonstrated at any scale. “Sensor-grade” in this context would require layer thickness uniformity sufficient to keep the stopband centre wavelength within the spectrometer resolution element across the sensing area of a single chip. If ±2% layer thickness variation—which may be optimistic—shifts the Tamm dip outside the measurement window, individual chip calibration becomes mandatory. This is the hardest manufacturing challenge in this proposal.

4.1.4 What Is the Long-Term Stability of the Plasmonic Metal Film?

Silver oxidises to Ag_2S in ambient atmosphere within days to weeks without encapsulation. This is a near-certainty, not a risk. Polymer–metal adhesion under flexion is poor. Gold is more stable but significantly more expensive. Encapsulation layers add cost and complexity. Any viable device requires a quantified shelf-life specification and a corresponding packaging solution.

4.1.5 What Spectrometer Resolution Is Required?

The minimum resolution depends on the Tamm resonance linewidth, which is unknown until Question 4.1.1 is answered. Chip-scale spectrometers (e.g. NanoLambda NSP32, approximately £8 OEM) have fixed resolution that may or may not be sufficient.

4.2 Known Risks and Failure Modes

All three primary failure modes identified through structured review are catastrophic—there is no graceful degradation pathway for any of them.

4.2.1 Fundamental Physics Risk [Critical—Potential Showstopper]

The Tamm state may not be spectrally resolvable at the low-Δn values proposed. If the DBR reflectivity is insufficient, no Tamm resonance forms, and the entire concept fails. Even if a Tamm state exists, the evanescent field may be confined to the metal–DBR interface rather than extending to the sensing surface. Both of these are physics-level constraints that cannot be engineered around. Transfer matrix modelling can partially assess this risk before any experimental investment.

4.2.2 Metal Film Failure [High Risk—Near-Certain Without Mitigation]

The 30 nm plasmonic metal film is the most fragile element. Silver oxidation is not a risk—it is a certainty in unpackaged devices. Loss of film continuity destroys the Tamm resonance condition entirely. The failure mode is catastrophic: signal-to-noise does not degrade gradually but collapses completely once the plasmonic interface is compromised.

Mitigation options exist—gold substitution, hermetic encapsulation, protective dielectric overlayers—but each adds cost and complexity. A systems-level tension emerges: the cheapest version of this device (unencapsulated silver) is the version that fails fastest, and the version that survives (encapsulated gold) may not be cheap enough to justify the disposable cost model. This tension is unresolved.

4.2.3 BCP Batch Variation [Medium-High Risk]

If layer thickness varies by ±2% across a roll-to-roll web—which may be optimistic for current BCP deposition technology—each chip will have a different centre wavelength. At Δn of approximately 0.008, the stopband is narrow; a 2% thickness shift may move the Tamm dip partially or fully outside the measurement window. Individual calibration would then become mandatory, potentially eliminating the disposable chip cost advantage.

4.2.4 Rugate Approximation [Low-Medium Risk]

If the stepped BCP lamellar profile does not suppress higher harmonics, sidelobe interference may degrade measurement precision. Optical simulation is required to evaluate this.

4.2.5 Cost Estimate Uncertainty

The target production cost of £0.05 to £0.40 per chip is an order-of-magnitude aspiration based on general roll-to-roll polymer processing economics, not a calculated bill-of-materials. Substrate cost, metal deposition cost (a vacuum process), quality control overhead, yield losses, and packaging (which may be mandatory given the metal film stability issue) are not included. This figure should be treated as a directional target, not a specification.

4.2.6 Fragility Assessment

Three independent failure modes—insufficient Tamm state, metal film degradation, and batch non-uniformity—can each independently produce total loss of function. Two of these (metal oxidation, batch variation) are near-certain without significant engineering investment not scoped in this proposal. The third (insufficient sensitivity) is the core physics unknown. The underlying physics components—Tamm states, BCP self-assembly, SPR—are individually well-established; the risk is entirely in their combination under the proposed constraints.

4.3 Target Applications

The following applications are entirely conditional on positive outcomes from transfer matrix modelling confirming a resolvable and surface-sensitive Tamm state, and on fabrication feasibility demonstration. No estimate of achievable sensitivity has been made for this architecture, and no comparison to existing sensor performance should be inferred.

Potential application domains include trace gas detection (NO_2, SO_2, NH_3) for environmental monitoring and industrial hygiene; food spoilage gas sensing (biogenic amines, H_2S, volatile organic compounds) for smart packaging and cold-chain verification; medical breath diagnostics (acetone, nitric oxide) as disposable point-of-care devices; and temperature sensing for cold-chain and structural health monitoring. Each domain would require its own validation programme once the fundamental physics and manufacturing questions are resolved.

4.4 Acknowledged Gaps

For transparency, the following gaps are explicitly acknowledged. This whitepaper contains no transfer matrix calculations or optical simulations of any kind, no estimate—even order-of-magnitude—of the expected sensitivity, no experimental data, no quantified comparison to existing sensor technologies beyond the cost figures cited, no bill-of-materials or manufacturing process specification, and no timeline or milestones.

The absence of even a first-order transfer matrix calculation—a standard and accessible computation in thin-film optics—is a significant gap. A collaborator may reasonably ask why this was not performed before circulating the whitepaper. The honest answer is that the author lacks the photonics modelling expertise to perform the calculation with confidence, which is itself an argument for seeking collaboration.

5. Conclusion and Invitation to Collaborate

This whitepaper is issued as an open invitation to research collaboration. The author is not seeking funding at this stage.

Collaboration is sought from researchers, institutions, and industry partners who can contribute expertise in thin-film optics and plasmonics (particularly transfer matrix modelling of Tamm states), block copolymer chemistry and self-assembly, roll-to-roll manufacturing engineering, biosensor design and clinical validation, environmental gas sensing, and chip-scale spectrometer development.

The first and most valuable contribution a collaborator could make is to run the transfer matrix calculation described in Section 4.1.1. If the result is negative, the concept is dead and no further effort is warranted. If positive, the subsequent questions become worth investigating.

If any aspect of this proposition aligns with your own research programme, or if you can identify flaws not documented here, the author would welcome the conversation. The goal is to determine whether this concept survives first contact with quantitative analysis.

All intellectual property generated through collaboration would be jointly held under terms agreed prior to commencement of work.

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6. References

Internal Project Documents

[PL1] Project Labradorite: Commercial Applications of Synthetic Labradorescence (Deep Research Report, Feb 2026).

[PL3] Strategic Evaluation and Commercial Roadmap for Project Labradorite (Technical Analysis, 2026).

[Res1] Critical Evaluation and Strategic Enhancement of Project Labradorite (External Review, 2026).

[PL2] Improvements to Project Labradorite (Enhancement Brief, 2026).

Note: Internal document codes are project management references, not academic citations. These documents are available to collaborators on request.

External References

Kaliteevski, M. et al. (2007) Tamm plasmon-polaritons: Possible electromagnetic states at the interface of a metal and a dielectric Bragg mirror. Physical Review B, 76(16), 165415.

Symonds, C. et al. (2013) Confined Tamm Plasmon Lasers. Nano Letters, 13(7), 3179–3184.

Nuguri, S.S. et al. (2021) Sensing Using Optical Tamm States on Mesoporous Platforms. ACS Applied Materials & Interfaces.

Augué, B. & Fainstein, A. group, Centro Atómico Bariloche / CNAB, Argentina—Tamm plasmon polariton sensing research.

External citations marked with DOIs have been verified; those without DOIs should be independently confirmed.

Appendix A. Document Metadata

Field	Value
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Appendix B. Glossary

Term	Definition
BCP	Block Copolymer. A polymer comprising two or more chemically distinct blocks covalently bonded together, capable of self-assembling into nanoscale periodic structures.
DBR	Distributed Bragg Reflector. A multilayer stack of alternating refractive index materials that reflects a narrow band of wavelengths through constructive interference.
FBG	Fibre Bragg Grating. An optical fibre with a periodic variation of refractive index inscribed in the core, used as a wavelength-selective reflector and sensor.
OEM	Original Equipment Manufacturer. A company that produces components or subsystems incorporated into another company's product.
OTS	Optical Tamm State. A localised electromagnetic mode that forms at the interface between a metallic layer and a photonic crystal (or DBR), analogous to electronic Tamm states at crystal surfaces.
PVD	Physical Vapour Deposition. A family of vacuum deposition methods used to produce thin films by condensation of a vaporised material onto a substrate.
RIU	Refractive Index Unit. The standard unit of measurement for refractive index sensitivity in optical sensors.
SPR	Surface Plasmon Resonance. The collective oscillation of conduction electrons at a metal–dielectric interface, exploited in optical sensors to detect changes in refractive index near the surface.
Δn	Delta-n. The refractive index contrast between alternating layers in a photonic crystal or multilayer structure.
Boggild gap	A miscibility gap in the plagioclase feldspar solid-solution series (approximately An_{47}–An_{58}) that produces nanoscale lamellar exsolution structures responsible for the optical phenomenon of labradorescence.
Labradorescence	The iridescent optical phenomenon displayed by labradorite feldspar, caused by interference and diffraction from nanoscale lamellar structures formed within the Boggild miscibility gap.
Rugate filter	An optical interference filter with a continuous sinusoidal refractive index profile, which suppresses harmonic sidelobes present in conventional quarter-wave stack designs.
Transfer matrix method	A computational technique for calculating the optical properties (reflectance, transmittance) of multilayer thin-film structures by multiplying characteristic matrices for each layer.

Appendix C. Methodology and Transparency Statement

Author Context and Expertise

The author is an independent researcher with 30 years of multi-sector experience in Systems Engineering but without specialist training in photonics, materials science, or thin-film optics. The analytical framework reflects a generalist perspective focusing on practical application and systems-level integration of technologies across disciplines. This background provides the systems thinking behind the proposal but not the domain expertise required to validate it. The domain validation is precisely what collaboration is sought to provide.

Digital Methodology and Accessibility

In the spirit of transparency, the author utilised a suite of Generative AI tools—specifically Claude, Google Gemini, and ChatGPT—to assist in the production of this paper. These tools were employed for data synthesis, literature search assistance, and editorial refinement. As a writer with dyslexia, the author uses these models as assistive technology to refine grammar and sentence structure. The intellectual direction, technical proposition, and all claims are the author's responsibility; the AI tools did not originate the core concept or validate any technical claims.

Verification and Integrity

While AI assisted in processing data, the intellectual oversight is entirely human. The author performed manual validation of all citations and accepts full responsibility for the accuracy and originality of the final output. External citations marked with DOIs have been verified; those without DOIs should be independently confirmed by collaborators.

Appendix D. Raw Author Notes

The core concept originated from Project Labradorite, which explored the commercial applications of synthetic labradorescence. During the investigation of geological lamellar structures in feldspar, the author recognised a structural parallel between the natural Boggild-gap multilayer system and the parameter space required for photonic crystal sensors. The low-Δn, high-layer-count regime characteristic of labradorite appeared under-explored in the Tamm plasmon literature, prompting the question: could a synthetic analogue of this geological structure, fabricated cheaply via block copolymer self-assembly, support a Tamm plasmon resonance suitable for disposable biosensing?

The author's background in systems engineering—not photonics—means this question cannot be answered without collaboration. The proposition is offered in that spirit: as a systems-level observation that may or may not survive quantitative scrutiny.

Appendix E. Change Log

Version	Date	Description
1.0	25 February 2026	Initial publication-ready version. Structured per Scientific/Conceptual template. All development artefacts removed from body text.