

RESEARCH HIGHLIGHT

## Tantalum pentoxide for 3D photonic integration

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*Monolithic integration of tantalum pentoxide (tantala) devices directly onto a patterned TFLN substrate enables multilayer nonlinear photonic circuits on a single chip.*

To address the diverse application requirements of integrated photonic systems, strategies for combining high-performance nonlinear materials with integrated-photonics platforms have garnered increasing attention. Monolithic integration presents a compelling solution through the sequential fabrication of multiple device layers on a common substrate. However, material and process compatibility remain a major challenge.

Now, Grant M. Brodnik from National Institute of Standards and Technology (NIST), USA and colleagues have proposed to use tantalum pentoxide (tantala) for 3D photonic integration [1]. They achieved monolithic integration of tantala photonic circuits directly onto a patterned thin-film lithium niobate (TFLN) substrate. This success stems from tantala's processing advantages, including room-temperature ion-beam sputtering, moderate-temperature annealing, and intrinsically low residual stress, which together allow for full-wafer stacking without compromising the underlying TFLN devices.

The platform features tantala microresonators with intrinsic quality factors exceeding 5 million, periodically poled LN waveguides, and adiabatic interlayer tapers with < 0.5 dB loss per transition. By combining the  $\chi^{(3)}$  nonlinearity of tantala with the  $\chi^{(2)}$  nonlinearity of LN, the authors showcase diversified nonlinear processes in a single

chip: optical parametric oscillation (OPO) and dark-pulse microcombs in tantala microresonators, second-harmonic generation (SHG) in poled LN, and cascaded operations such as OPO followed by SHG, as well as supercontinuum generation combined with SHG for  $f-2f$  self-referencing.

This monolithic 3D integration approach presents a scalable and versatile platform that unifies different nonlinear functionalities, thereby opening new avenues for compact photonic systems with diverse and enhanced capabilities.

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### Reference

1. Brodnik, G.M., Spektor, G., Williams, L.M., Zang, J., Carollo, A.R., Dan, A., Black, J.A., Carlson, D.R., Papp, S.B.: Monolithic 3D integration of tantalum pentoxide nonlinear photonics. *Nature* **652**(8111), 899–905 (2026)