First Fabrication of High Q-Factor Rho-SiTaN for Optical Spectroscopy: Enabling Low-Cost Breathalyzer Detection of Lung Cancer

Kompella, Kireeti (School: Interlake High School)

Recent efforts in photonic material development have aimed to create high-performance, low-cost components that can be integrated into portable diagnostic systems, especially for use in under-resourced medical environments. Lung cancer, responsible for over 1.8 million deaths and 2.4 million new cases annually, remains one of the deadliest forms of cancer worldwide. However, significant detection disparities in low-resource regions may contribute to an underestimation of more than 1.1 million cases. This project introduces a novel silicon–tantalum–nitride-based material, ?-SiTaN, synthesized using a strain engineering approach through thin-film deposition. Strain modulation techniques were employed to induce a potentially new allotrope of SiTaN with enhanced optical and structural properties. ?-SiTaN was integrated to create an on-chip frequency comb resonator for the detection of volatile organic compounds (VOCs), with a focus on ethane—a biomarker of oxidative stress and a critical early indicator of lung cancer. The resulting optical resonator demonstrated an ultrahigh Q-factor of 8.3 million with a resonant wavelength at 3.3 μm, aligning with the spectral signature of ethane. Profilometry, reflectometry, atomic force microscopy (AFM), and scanning electron microscopy (SEM) confirmed the film's strain, refractive index and extinction coefficient and electron bandgap. This novel material enables a compact, highly sensitive, and scalable sensing platform capable of VOC detection in breath analysis. The results support the development of next-generation noninvasive screening tools for lung cancer diagnosis in underserved populations, potentially lowering barriers to early intervention.

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