SPRINGER NATURE Link Vol. 57, article number 129, (2025)

Machine learning-optimized titanium-based broadband absorber with high-efficiency performance across visible and infrared wavelengths

By

Jacob Wekalao

Jonas Muheki

Ngaira Mandela

Pelluce Kabarokole

Paschal Makoye

Abstract

This study introduces an advanced broadband absorber design featuring titanium-based square ring resonators on silicon dioxide substrates, optimized for superior absorption performance across visible and infrared wavelengths. The proposed absorber leverages a metal–insulator–metal configuration with a titanium resonator layer, SiO_2 substrate, and tungsten ground layer, achieving over 94% absorption across the 0.7–4 µm wavelength range, with peak efficiency surpassing 99% at 2.142 µm. Unlike conventional designs relying on noble metals, the proposed absorber utilizes titanium, offering a cost-effective, thermally stable, and scalable solution suitable for high-temperature applications. The key novelty of this work lies in integrating machine learning, specifically K-Nearest Neighbour (KNN) regression, to predict and optimize the absorption characteristics, achieving R^2 values of up to 0.99. This approach facilitates rapid design iterations, ensuring robust performance under varying structural and environmental conditions. Furthermore, the absorber demonstrates exceptional angular and polarization independence, maintaining high efficiency under both transverse electric (TE) and transverse magnetic (TM) polarizations. These attributes make the proposed design an innovative and versatile solution for applications in solar energy harvesting, thermal management, and broadband photonic sensing.

Keyword: Machine learning, titanium-based square, K-Nearest Neighbour, broadband absorber design