# Abstract

This study reports the optical and plasmonic properties of unconventional transition metal nanoparticles (UTM-NPs), which include Ti, Mo, Rh, Zn, Ta, Sc, Au, Ag and Re by analyzing their quality factor (Q-factor), dielectric constants and plasma frequency across a nanoparticle size range of 10 nm to 400 nm. Theoretical modeling and numerical simulation of secondary data using the Drude model and Mie theory were used to determine the quality factor, plasma frequency and dielectric constants of the UTM-NPs. These methods enabled systematic characterization and comparative study of their plasmonic properties with those of conventional noble metals Au, Ag & Cu. Compared to the noble metals, the UTM-NPs exhibited unique plasmonic behaviors with size-dependent plasmon resonance characteristics in the visible to near-infrared range. The UTM-NPs in the size range 10 nm to 150 nm presented lower Q-factors due to increased damping and atomic disorder while those in the size range 200 nm to 400 nm exhibited higher Q-factors due to higher energy losses resulting from surface scattering. The results indicated that an optimal NP size range for each transition metal is between 275 nm to 325 nm, where the Q-factor is optimal. Titanium demonstrated the highest Q-factors in this optimal range, whereas Scandium and Zinc show limited visible-range plasmonic response due to strong UV-range interband absorption. Ag and Au NPs outperformed UTM-NPs in plasmonic quality factors across visible energies due to low intrinsic damping and favorable dielectric properties. UTM-NPs exhibited richer spectral dependence, with some materials showing discrete windows of improved Q-factor, reflecting complex interband electronic structure effects. These trends emphasized that plasma frequency, interband transitions and radiative damping jointly dictate plasmon coherence, and must be considered when selecting materials for wavelength-specific plasmonic applications. These findings positioned some unconventional transition metals like Ti, Mo and Re as thermally stable alternatives to noble metals in next-generation optoelectronic and plasmonic applications.