Plasmonic High Entropy Carbides at Elevated Temperatures

D.E. Wolfe, M.J. Ammendola, R.C. Koennecker

Abstract: Multifunctional materials with tunable and thermally stable plasmonic properties are essential for optical and telecommunication applications. Traditional plasmonic metals (e.g. Cu, Au, Ag) are ductile and unsuitable for high temperature conditions (< 1000 °C), necessitating novel plasmonic systems that can survive in harsh environments. Plasmonic high entropy carbides (PHECs) exhibit superior thermal, chemical, and mechanical properties while demonstrating a strong plasmonic resonance in the near-infrared to visible wavelength range. Current research efforts have demonstrated that the magnitude and wavelength of this response is highly tunable by explicitly tailoring the composition of the high-entropy system.

Multiple characterization techniques have been explored for measuring plasmonic resonance, including reflection electron energy loss spectroscopy (REELS) and spectroscopic ellipsometry (SE). REELS measures the inelastic scattering of reflected electrons caused by plasmon excitations. By contrast, SE is an optical technique that measures the change in polarization of light as it reflects off the sample. Data analysis can extract the real and imaginary parts of the dielectric function, which are crucial in characterizing the behavior of the plasmonic response.

Through these techniques, it has been observed that at least 12 different PHECs exhibit plasmonic resonance at temperatures up to 1000 °C. These PHECs show discernible plasmonic behavior at various energies and intensities based on the composition, demonstrating considerable versatility for a variety of applications. Furthermore, these properties remain largely unchanged with increasing temperature, indicating superior high temperature stability over traditional plasmonic systems. These discoveries pave the way for producing multifunctional and tunable optical materials for extreme environment applications.