The recent advancement of aberration-corrected transmission electron microscopy (TEM) and in situ techniques unlocks a door to a new era of discovery in materials science. It allows us to study the local structure, chemical composition, and electronic properties of materials with atomic resolution, and to probe the dynamic evolution of local structure and properties in response to applied fields and to the change of environments in real-time. In this talk, I will present our studies of ferroelectric heterostructures and nanocatalysts by aberration-corrected imaging, novel 4D STEM diffraction imaging and vibrational microscopy. Using a novel MEMS-based gas cell, we directly observed the formation of a Pt shell on Pt₃Co nanoparticle at elevated temperature under oxygen at atmospheric pressure, and the evolution of the structure and morphology of Pt nanoparticles induced by adsorbed gas molecules. I will then present our recent development of a 4D STEM diffraction imaging method for studies of local electric field and charge density with the sub-Å spatial resolution. We can directly measure the electron charge density, dipole moment, and bonding characteristics between atoms and at heterointerfaces, providing deep insight into the origin of ferroelectric polarization and the electronic charge transfer at oxide interfaces. Finally, I will show that the high energy resolution (~4.2 meV at 30 kV) electron energy-loss spectroscopy is capable for measuring the vibration of molecules and crystal lattice at sub-nanometer scale. An abnormal, thermally induced phonon energy shift in SiC was observed in TEM with in-situ heating. This shift can be used as a powerful tool for temperature measurements of nanostructures, providing a new avenue to measure local temperature in nanodevices.