Recent research in nanoscience has advanced toward controlling nanoparticles with atomic precision. In this talk I will present some breakthroughs in gold nanoparticle research, including the atomically precise synthesis, structure determination by X-ray crystallography, new properties under the atomic-level control, and applications in catalysis. Such perfect gold nanoparticles possess well-defined formulas of \( \text{Au}_n(\text{SR})_m \), where SR = thiolate ligand, n and m refer to the precise numbers of gold atoms and surface ligands, respectively. With the success in atomically precise synthesis, significant progress has been achieved in determining the total structures of \( \text{Au}_n(\text{SR})_m \) nanoclusters ranging from subnanometer \( \text{Au}_{18}(\text{SR})_{14} \) to 2.2 nm \( \text{Au}_{246}(\text{SR})_{80} \). These ultrasmall nanoparticles exhibit intriguing electronic and optical properties with manifestations of strong quantum size effects, and also allow for quantum-state manipulation at the single-electron level. The attainment of atomically precise nanoparticles has offered exciting opportunities to pursue many fundamental issues that were previously difficult to tackle. Such nanoclusters also hold potential in catalysis, optics, energy conversion, and sensing applications.