Our research focuses on the rational design and nanoscale integration of highly complex inorganic nanostructures through chemical synthesis or physical assembly. A strong emphasis is placed on the hetero-integration of multi-composition, multi-structure and multi-function at nanoscale, with an aim to create a new generation of integrated nanosystems with unique functions or unprecedented performances that can break the boundaries of traditional technologies. In this presentation, I will describe two such examples. In a first example, I will discuss our ongoing effort in using chemical synthesis to hetero-integrate a nanoscale photovoltaic device with two redox catalysts in a single nanostructure to form a standalone photoelectrochemical nanodevice as highly efficient photocatalysts for artificial photosynthesis and solar fuel production. In a second example, I will briefly describe how we use physical assembly approach to integrate graphene with a self-aligned nanowire gate to achieve a graphene transistor with record breaking speed.