Historically, the association of nuclear magnetic resonance (NMR) spectroscopy with nanomaterials goes back as early as 1960 in an early quest to understand quantum behavior of conduction electrons in a confined space of nanometer size (i.e., the quantum size effect–QSE) [1], long before nanoscienc and nanotechnology become contemporary buzz words nowadays. Over the next two decades, NMR had indeed been one of the major spectroscopic techniques employed to study the QSE because of the direct relationships between the two major NMR observables, the Knight shift $K$ and the nuclear spin-lattice relaxation time $T_1$, and the electronic properties of metal nanoparticles (NPs) that would be affected by the QSE as predicted by the classic Kubo theory and its later variants [1].

In 1980s, Slichter and co-workers pioneered a new line of research by demonstrating the unique aptness of $^{195}$Pt and $^{13}$C NMR in unraveling some of the fundamental aspects of heterogeneous catalysis of transition metal-based (including Pt) real-world nanoscale catalysts [2]. The ensuring refinement of NMR techniques and their theoretical interpretations has been advanced to a point where connections with other experimental techniques and with some theories of chemisorption can be made explicitly [3-5].

Since early 1990s, a new development in combining interfacial electrochemistry and NMR, which was largely inspired by Slichter’s and others’ NMR work in gas-phase nanoscale systems, has been put in motion due to the pioneering work of Wieckowski and co-workers [6]. The unique feature of this new approach is that it combines the elegance of electrochemistry in controlling chemical environments with the exquisite chemical specificity and electronic structural sensitivity of NMR, although overcoming the intrinsic incompatibility between electrical conduction of electrochemistry and NMR detection has been and still is a challenging perspective.

In this talk, I will discuss cases that demonstrate the unique investigative power of NMR, in particular electrochemical NMR, in probing fundamental properties of metal-based nanomaterials, particularly the spatially-resolved $^{195}$Pt NMR of Pt-based electrocatalysts and $^{13}$C NMR in determining the level alignment at metal-molecular junctions.

References