



## Probing Charge-Dynamics of Ionic-Liquid Electrolytes within Energy Storage Devices by Operando X-Ray Photoelectron Spectroscopy

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Energy Supply and Storage Systems occupy the center-point of current and future scientific and technological activities and batteries are still on top of the list. However, batteries are slow, since they involve sluggish chemical reactions. Electrical-Double Layer Capacitors, or Super-Capacitors have recently been proposed as an alternative, since they involve transport of ions at liquid/solid interfaces.<sup>1</sup> Dynamics of the ion transport is the key for controlling performance of these devices and need to be investigated during their operation (In-Operando). XPS is one of the most informative surface analyses techniques, which can deliver chemical as well as electrical properties of systems, when used in-Operando (o-XPS). Unfortunately, the technique requires Ultra-High-Vacuum environment, not very suitable for volatile liquids like water, but there are also several non-volatile liquids, like ionic liquids, which are also excellent electrolytes for battery and super-capacitor applications. Emergence of Ionic Liquids with several promising properties, including their low volatility, has rekindled the use of XPS.<sup>2</sup> Our recent efforts had also concentrated on ionic-liquids and their interfaces under **dc** and **ac** bias, and extended to monitoring electrochemical reactions, as well.<sup>3-5</sup> The common theme in our studies is the use of the bias dependent shifts in the positions of the core-levels as reflection of the electrical potentials, recorded in a non-invasive and chemically resolved fashion. We use the magnitude and the frequency dependence of such potentials to extract pertinent information related to static, as well as dynamic chemical and/or electrochemical properties of the materials and their interfaces, configured as devices,<sup>6,7</sup> with particular emphases on the ionic liquids' certain chemical/physical parameters, like steric effects, ion size, diffusivity, etc.<sup>8</sup> Examples using ionic liquids, liquid poly-ethylene-glycol (PEG) and salts, as well as their mixtures, as electrolytes, with special emphases on energy storage systems, will be presented and discussed.

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