In this talk, I want to briefly present some work on materials development for battery and hydrogen applications, with an emphasis on materials characterization techniques. In the field of battery, recent breakthroughs are in great part related to an understanding starting from the atomic level. For instance, using in-situ TEM it is possible to show the conditions for the synthesis of carbon coated $LiFePO_4$, one of the safest cathode materials in Li-ions battery.

On the other hand, metallic Li is considered one of the most attractive anode candidates for solid-state battery technology as well as for the next generation Li-ions batteries due to its ultrahigh theoretical specific capacity (3860 $mAhg^{-1}$). However, the widespread commercial usage of Li metallic necessitates a much better understanding of its microstructure and chemical nature. Metallic lithium is highly sensitive to hydrogen, oxygen, nitrogen, and carbon dioxide, which are the major components of wet air, and are likely to form rapidly LiOH, $Li_2O$, $Li_2O_2$, $Li_3N$, and $Li_2CO_3$ species. I will present the direct HRTEM study of the surface chemical nature of metallic Li sheets through Spatially-Resolved EELS (SR-EELS).

On the hydrogen side, $H_2$ can play a significant role to reduce greenhouse emissions. For this reason, large amount of funding is presently being spent to develop green hydrogen production. In fact, the International Energy Agency estimates that global cumulative investments in hydrogen technology must increase to USD 1.2 trillion by 2030 and USD 10 trillion by 2050 in order to reach global net zero emission by 2050. However, a number of materials breakthroughs are needed in order for a hydrogen economy to be viable.

As of today, hydrogen is produced mainly through natural gas reforming (with large $CO_2$ emissions), with a small fraction through water electrolysis. For sunny coastal regions, if seawater could be used directly, photocatalytic water splitting could be very attractive. At the beginning of this year, a solar-to-hydrogen conversion of around 9.2% was achieved. This hydrogen production method could be quite interesting if the photocatalysts can resist long-term degradation. I will present High-Resolution Electron Microscopy and EELS analyses done to understand the stability properties of some p-Ga(In)N nanowire-arrays in pure water.

Finally, I will show the direct degradation observation of Pt catalysts on carbon support used in fuel cells, in an air environment at elevated temperature. This last example will illustrate the importance not only of in-situ experiments but also the importance of multi-modes observations, in this case 2D vs 3D.