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Operando Raman spectroscopy for hydrogen energy storage

Hydrogen is now considered a major energy carrier capable of reducing greenhouse gas emission of both industrial and mobility sectors owing to the diversity of production and use of low-carbon and renewable hydrogen. The storage and transport of hydrogen energy is however still a serious technological challenge. Multiple cost- and energy-efficient alternates are actively researched beyond the current compressed gas solution, including liquid H_2 storage, chemical storage or solid-state hydrogen storage materials. We will show through diverse applications that Raman spectroscopy is a key technique for the development of these alternate solutions. For *materials-based* hydrogen storage, borohydrides and ammine metal borohydrides in particular (Fig. 1) are interesting compounds for the release of large H_2 quantity with high purity under mild temperature conditions. In-situ Raman spectroscopy is used to analyze the thermolysis dehydrogenation process and gain insight into the hydrogen storage mechanism [1]. For *chemical* hydrogen storage, ammonia shows decisive advantages in terms of energy density and existing industrial infrastructures. New multifunctional catalytic materials are being evaluated to improve the energy efficiency of NH_3 production and make it compatible with green H_2 sources [2]. Operando Raman spectroscopy at high temperature and pressure is developed in our group to elucidate the chemical reaction mechanisms at play in novel Li_xNH_y catalytic systems for both NH_3 synthesis and decomposition. For hydrogen storage *as a liquid*, cryogenic temperatures are required and the ortho spin isomer of H_2 needs to be converted to para-H_2 to improve long term storage capabilities [3]. Operando rotational Raman spectroscopy performed in cryogenic heat exchanger is developed to monitor the kinetics and catalytic activity of ortho/para-hydrogen conversion catalysts.

References

[1] H. D. Nguyen *et al*, submitted (2023)
[2] J. W. Makepeace *et al*, Phys. Chem. Chem. Phys. 23 (2021) 15091
[3] R. K. Ahluwalia et al, Int. J. Hydrog. Energy, 33 (2008) 4622

Figures

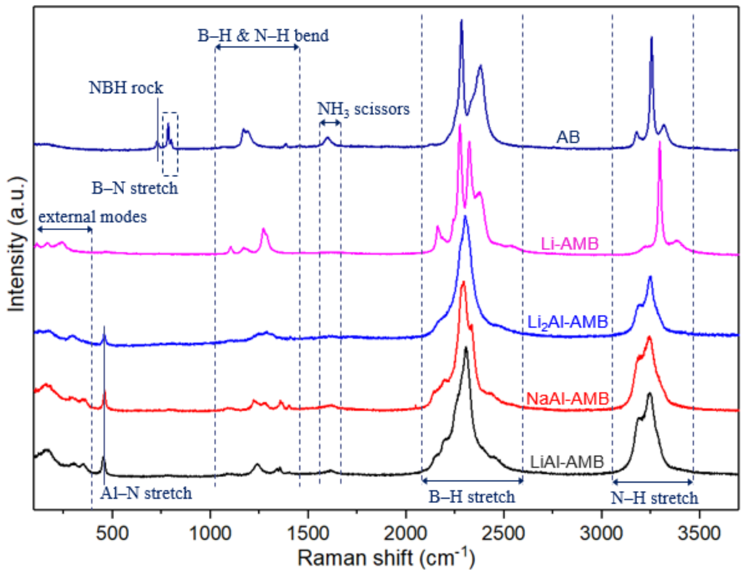

Figure 1: Raman spectra of various synthesized ammine metal borohydrides compounds (AMB) compared to pure ammonia borane (AB)