

## From solids to liquids: A coordinated approach for studying dynamic processes in the deep Earth using large-volume apparatus and synchrotron radiation

YANBIN WANG

Center for Advanced Radiation Sources, The University of Chicago, 5640 S. Ellis Ave., Chicago, IL 60637, USA (wang@cars.uchicago.edu)

For the past fifteen years, we have been developing synchrotron-based large-volume high pressure (LVP) techniques at the GeoSoilEnviroCARS (GSECARS) sector of the Advanced Photon Source (APS) for a better understanding of the thermodynamic state, the dynamic processes, and the evolution of the Earth and other planets. The technical and scientific developments have enabled us to conduct coordinated studies on materials in both the solid and liquid states under simultaneously high pressure and high temperature conditions. In this presentation I will discuss the following dynamic aspects of recent scientific studies: (1) rheological properties of earth materials at high pressure and temperature, using the deformation DIA (D-DIA) – recent results on olivine deformation will be used as an example, (2) textural evolution in multi-phased materials under large shear deformation using the high-pressure x-ray tomographic microscope (HPXTM) – applications of such studies on mantle dynamics will be discussed, (3) in-situ high-pressure tomographic studies on Fe-S melt segregation from silicate using HPXTM and new constraints on the timing of formation of the Earth's core, and (4) new development for melt studies, including fusion curve, structure, density, and elasticity, aiming at a “complete suite” of physical properties for a better understanding of melt physics. A brief discussion on future prospect will also be presented.

## Quantitative $^2\text{H}$ NMR as site-specific $^2\text{H}/^1\text{H}$ probe to study organic matter

Y. WANG<sup>1</sup>, G.D. CODY<sup>1</sup>, C.M.O'D. ALEXANDER<sup>2</sup> AND M.L. FOGEL<sup>1</sup>

<sup>1</sup>Geophysical Laboratory, Carnegie Institution of Washington (ywang1@ciw.edu, gcody@ciw.edu, mfofel@ciw.edu)

<sup>2</sup>Department of Terrestrial Magnetism, Carnegie Institution of Washington (alexander@dtm.ciw.edu)

Recent studies show that the biosynthetic fractionation between fatty acids and water can vary by up to 500‰, depending on biological and environmental factors that include: species, metabolic pathways, aridity, and salinity. These variations are poorly understood, which has restricted the specificity of biomarker  $\delta^2\text{H}$  records and thus their use as paleoenvironmental and geobiological proxies. Direct detection of the site-specific  $^2\text{H}$  distribution via  $^2\text{H}$  NMR provides a powerful means for investigating these variations and the underlying mechanisms. Unlike approaches that employ chemical/thermal fragmentation and IRMS measurements,  $^2\text{H}$  NMR is non-destructive, applicable to almost all types of organic molecules, and free of isotopic fractionation. Similar to the advent of compound-specific isotope analyses, it has the potential to open a new door to the study of organic materials that will benefit a broad range of biogeochemical and low-temperature geochemical studies.

Historically,  $^2\text{H}$  NMR experiments on natural samples have been difficult due to the scarcity of the  $^2\text{H}$  nucleus and its low receptivity to radio frequency radiation which together lower the sensitivity by  $\sim 7 \times 10^5$  times compared to  $^1\text{H}$  NMR. Furthermore, the  $^2\text{H}$  NMR spectra is complicated by the quadrupolar interaction of the  $^2\text{H}$  nuclei. We have successfully developed a solid state  $^2\text{H}$  NMR experimental protocol to significantly amplify the signal-to-noise ratio and yield simplified, purely isotropic spectra.

With this method, we studied the site-specific  $^2\text{H}$  distribution in residual organic matter from two carbonaceous chondrite meteorites and a bituminous coal. Combined with  $^1\text{H}$  NMR spectra and bulk  $^2\text{H}/^1\text{H}$  analyses, we derived the  $\delta^2\text{H}$  values for aliphatic and aromatic sites and the  $^2\text{H}/^1\text{H}$  fractionation factor between these groups, which provide a unique basis for coupling the  $^2\text{H}/^1\text{H}$  distribution to the chemical history of chondrites. In an on-going study, we investigated H isotope exchange rates by incubating pristane, cumene, and anthracene, separately, with clay minerals soaked in  $^2\text{H}$ -enriched water. Liquid state  $^2\text{H}$  NMR was used to study the efficiency of  $^2\text{H}$  substitution at methyl, methylene, methine, and aromatic sites. The results will improve our understanding of the influences on H isotopic composition of sedimentary organic matter and petroleum.