Nuclear resonant spectroscopy

W. STURHAHN

Argonne National Laboratory, 9700 South Cass Avenue, Argonne, IL 60532, USA; sturhahn@anl.gov

Nuclear resonant scattering techniques at third generation synchrotron radiation facilities opened new opportunities for the study of vibrational and magnetic properties of condensed matter in research areas like geophysics, biophysics, and nanoscience. In particular, the determination of the vibrational density of states with nuclear resonant inelastic x-ray scattering (NRIXS) and the study of valences and magnetic properties with synchrotron Mössbauer spectroscopy (SMS) provided remarkable results [1].

In this contribution, we discuss the combination of nuclear resonant spectroscopy with diamond anvil cell technology and its impact on the geo-scientific area. We will specifically address NRIXS, a method that uses probe nuclei with suitable resonances to measure the vibrational density of states, and SMS for the determination of valences, spin states, and magnetic ordering analogous to conventional Mössbauer spectroscopy. The sensitivity of these methods in combination with the isotope selectivity allowed NRIXS and SMS investigations on materials under pressures in the megabar regime using diamond anvil cells and Laser heating.

Nuclear resonant spectroscopy under extreme conditions is a key method to provide sound velocities and elasticity on iron, iron alloys, and iron oxides [2,3], to study valence and high-spin to low-spin transitions in lower mantle minerals [4,5], and to investigate melting of iron-bearing materials [6]. Examples will illustrate the present and potential future use of nuclear resonant spectroscopy in the Earth and planetary sciences.

Even though ^{57}Fe has spawned the largest interest so far, we will review the selection of other suitable nuclear resonances that could become important for future applications. Nuclear resonant spectroscopy methods, which include NRIXS and SMS, continue to evolve with the development of new instrumentation, the improvement of synchrotron radiation sources, the increased diversity in nuclear resonant methods, and the synergy with other experimental techniques like x-ray diffraction, inelastic x-ray scattering, and x-ray fluorescence analysis. We will speculate about their potential impact on the experimental realizations and the applications of nuclear resonant spectroscopy.

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References

[1] Sturhahn W. (2004) J. Phys.: Condens. Matter **16,** S497.
[2] Mao H.-K. et al. (2001) Science **292**, 914.
[3] Lin J.-F. et al. (2005) Science **308**, 1892.
[4] Jackson J.M. et al. (2005) American Mineral. **90**, 199.
[5] Lin J.-F. et al. (2006) Phys. Rev. B **73**, 113107.
[6] Jackson J.M., Sturhahn W. et al. (in preparation).