Diffusion in solids studied using nuclear quadrupole relaxation

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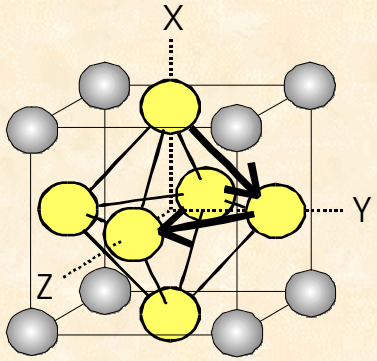
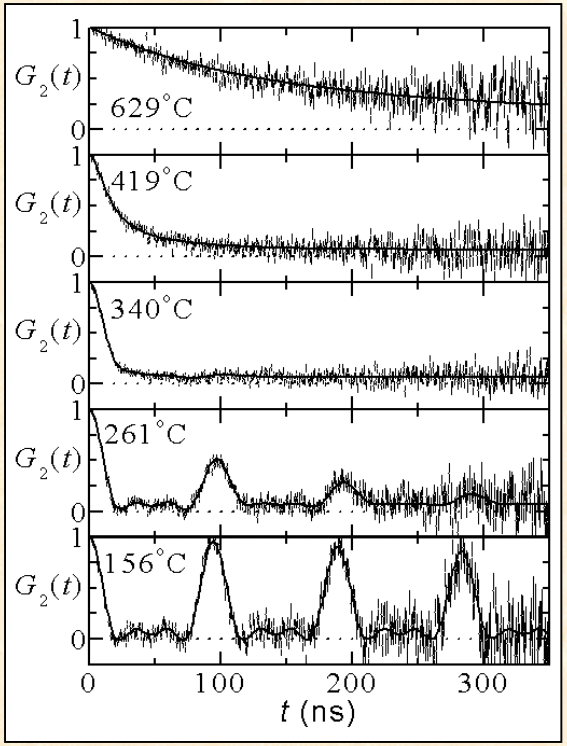
Summary

We discovered a new method for measuring jump frequencies of tracer atoms in solids. It is applicable for diffusion sublattices with non-cubic sites whose local axes reorient in each jump. First studies have involved radioactive Cd atoms jumping on the In-sublattice in In_3RE compounds that have the $L1_2$ structure (RE= rare earth). The diagram shows how the tetragonal axis of symmetry reorients by 90° in each jump.

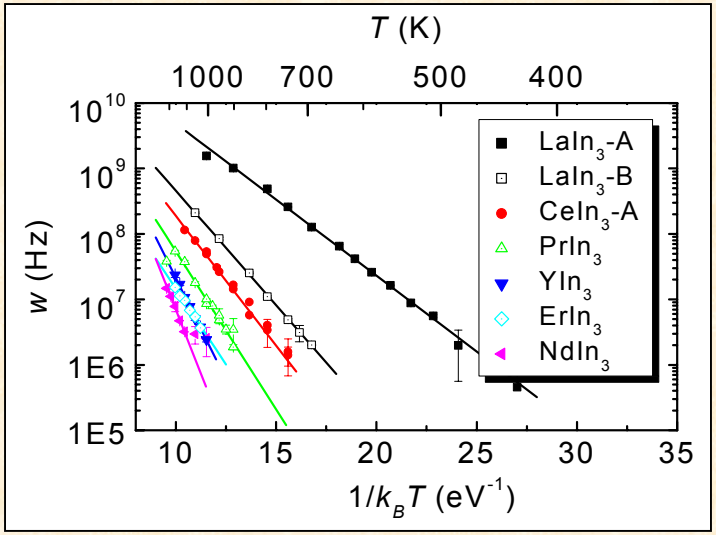


Experiments



The above figure essentially shows spin precessions of Cd nuclei, with increasing relaxation seen at higher temperatures that can be fitted to obtain jump frequencies of the Cd atoms.

Results



Above is shown an Arrhenius plot of fitted jump frequencies, which are directly proportional to diffusivities measured using conventional radiotracer profiling.

Our data show that In_3RE phases are unusual intermetallic compounds having very high jump frequencies. The two data sets for In_3La above were measured for compositions at opposing phase boundaries.

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Broad impact

Atom movement in solids is of fundamental importance in many areas of materials physics. Our method provides a new way to study it in compounds having noncubic diffusion lattices.

In_3RE appear as compounds having definite compositions in phase diagrams, but our measurements show jump frequencies at the two phase boundaries differing by factors of 10-100.

One application will be experimental determination of correlation coefficients for diffusion by combining tracer jump frequency with diffusivity measurements.

This work appeared in June 2004 in ***Physical Review Letters* 92, 225901 (2004)** and will appear in additional papers in ***Defect and Diffusion Forum*** (submitted) and ***Hyperfine Interactions*** (accepted).

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Education

Individuals contributing to these studies include three MS level graduate students at WSU, Li Kang, Denys Solodovnikov and Jipeng Wang, visiting graduate students from INSA, Rennes, France, Aurélie Favrot, and from the University of Groningen, The Netherlands, Egbert Nieuwenhuis. Contributing in a major way was Research Assistant Professor Matthew Zacate, who has just taken a permanent faculty position at Northern Kentucky University. Some group members and friends are shown at an informal get-together.