Hyperfine interaction studies of local environments of probe atoms in intermetallic compounds

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Interactions of nuclear moments with internal fields in solids lead to nuclear spin precessions. Precession frequencies of nuclei of a small number of radioactive isotopes that have favorable nuclear properties can be detected using the method of perturbed angular correlation of gamma rays (PAC). In particular, the interaction of the quadrupole moment of a probe with electric field gradients (EFG) leads to quadrupole interaction frequencies that are characteristic of each lattice location of the probe in the solid. The lattice location comprises the occupied lattice site as well as presence or absence of nearby point defects. Partial information can be obtained about the point symmetries of the lattice sites; for example, the frequency is zero at sites of cubic symmetry, and one can determine whether or not there is at least a three-fold axis of charge symmetry at a site.

In my talk, I will provide an overview of some PAC studies carried out in Pullman over the past decade, all using the ^{111}In probe:

- NiAl and FeAl are materials of interest in high-temperature structural applications. Formation and migration energies of vacancies were measured, as well as binding energies of the vacancies with the indium impurity probe. Clusters of up to four vacancies were observed to form at low temperatures in FeAl by “condensation” on In-probes.

- Studies of the model compound Al_2Gd, in which Al, Gd and the In-probe are all trivalent, showed that indium impurities switch from the Gd-site to the Al-site with increasing temperature and/or as the composition becomes more Gd-rich. The transfer energy between the sites was measured to be 0.343(7) eV. We believe this was the first accurate measurement of such an energy.

- A few years ago we showed that, for diffusion on sublattices in which the orientation of the EFG changes in each jump, one can determine jump frequencies of the probe from measurements of nuclear relaxation arising from decoherence of the spin precessions. Jump frequencies can be measured with good precision and were found to be thermally activated with linear Arrhenius dependences. Results will be shown for several crystal structures.