EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Proposal to the ISOLDE and Neutron Time-of-Flight Committee

Direct Measurement of Self-Diffusion Jump Rates in an Intermetallic Compound

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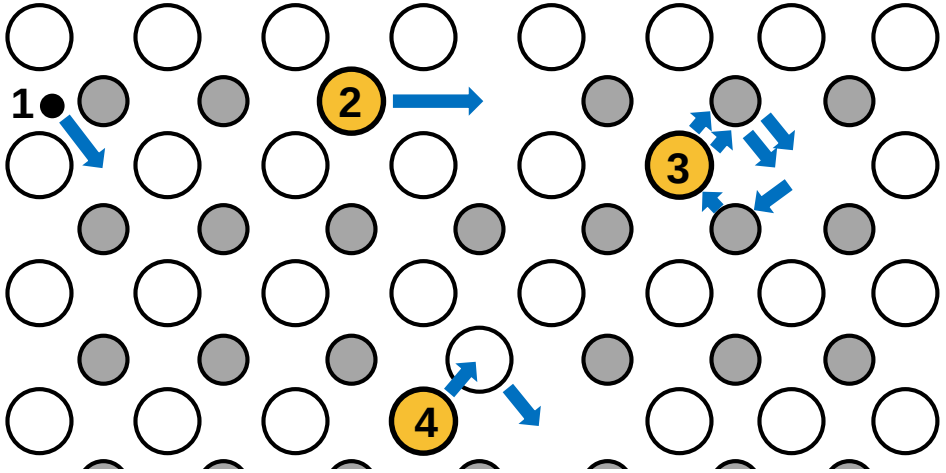
Outline

- Background
- Project description
- Why ISOLDE?
- Project feasibility
- Requested beam shifts
- Future prospects

Background/Motivation

- Diffusion is of fundamental importance in solid state reactions → affects processing and selection of materials
- Need to understand in detail how atoms move through solids to engineer new materials

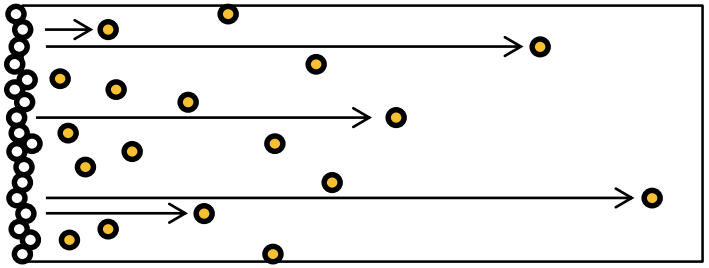


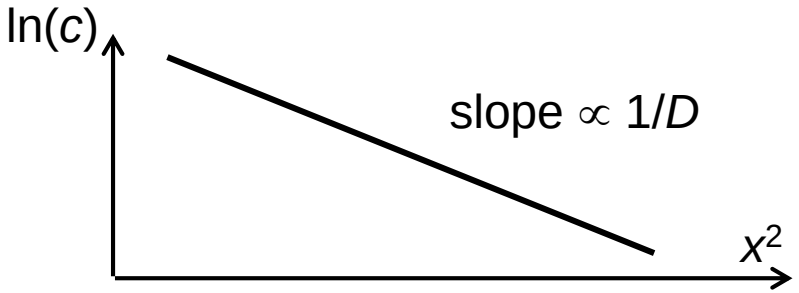
Tracers undergo correlated random walks in vacancy-mediated diffusion mechanisms (2-4)

- Intermetallic compounds interesting because atoms can move through the “wrong” sublattice

Background/Motivation

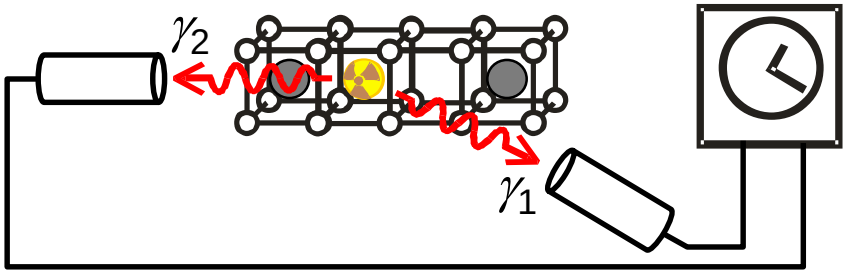
Microscopic techniques (concentration profiling)

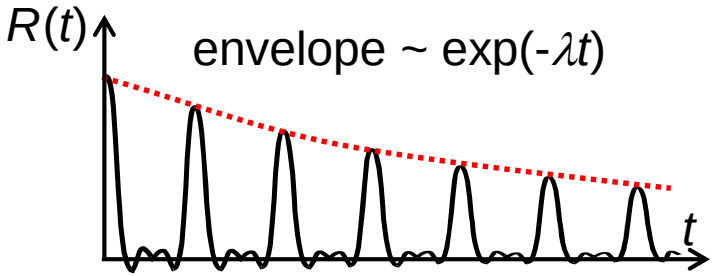




$D = g \cdot a^2 \cdot f \cdot w$

Nuclear techniques (PAC)





$\lambda = g' \cdot P_{\Delta efg} \cdot w$

to find *f* = correlation factor, which gives diffusion mechanism

Project description

- Goal: first-time measurement of absolute jump rate of a tracer diffusing via a vacancy mechanism
- Objective: measure Cd jump rate at different temperatures and compositions in $NbCd_3$

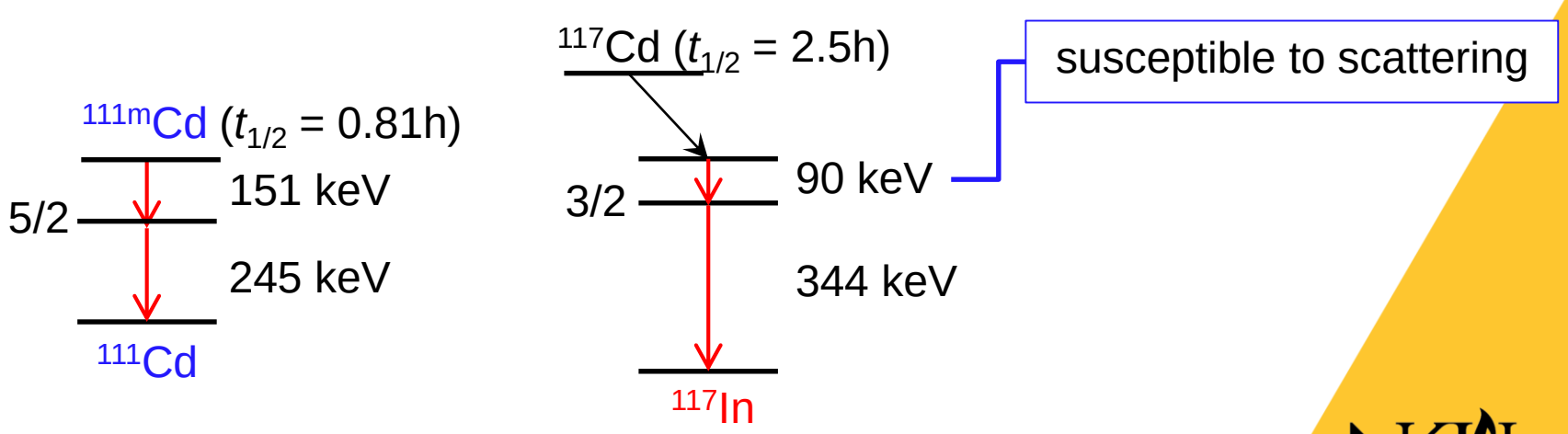
- Sample preparation & characterization
  - Alloy formation at NKU
  - Compound formation verified using x-ray diffraction at NKU

- Implantation, anneals, and measurement using ^{111m}Cd PAC at ISOLDE

NKU

Why ^{111m}Cd PAC at ISOLDE?

- Compound(s) with the $L1_2$ crystal structure are ideal
- Need isotope that substitutes for the non-cubic sublattice and is a host element to study self-diffusion
- Candidate experiments:
  ^{111m}Cd/Cd in NbCd_3 or ^{117}Cd/In in RIn$_3$ (R=rare earth)



- Isotopes, sample handling, and measurement facilities only available at ISOLDE

Project feasibility

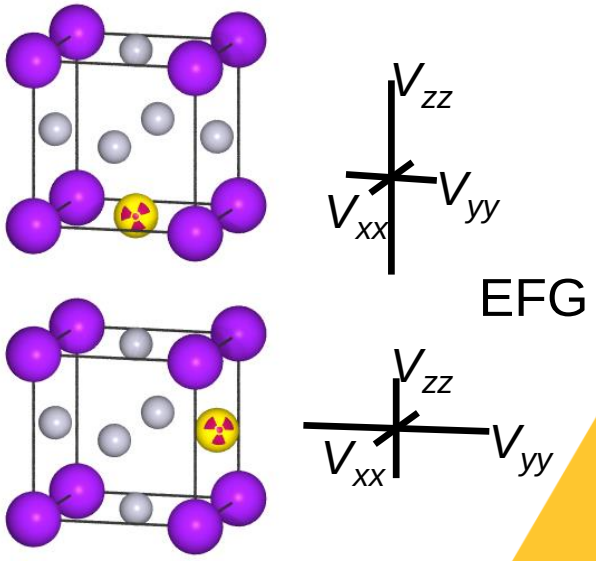
^{111}In/Cd PAC used previously to measure Cd-motion-induced damping in 22 compounds with $L1_2$ structure

Indides: $LaIn_3$, $CeIn_3$, $PrIn_3$, $GdIn_3$, $TbIn_3$, $DyIn_3$, $HoIn_3$, $ErIn_3$, $TmIn_3$, $LuIn_3$

Stannides: $LaSn_3$, $CeSn_3$, $SmSn_3$, $GdSn_3$

Gallides: $DyGa_3$, $ErGa_3$, $LuGa_3$

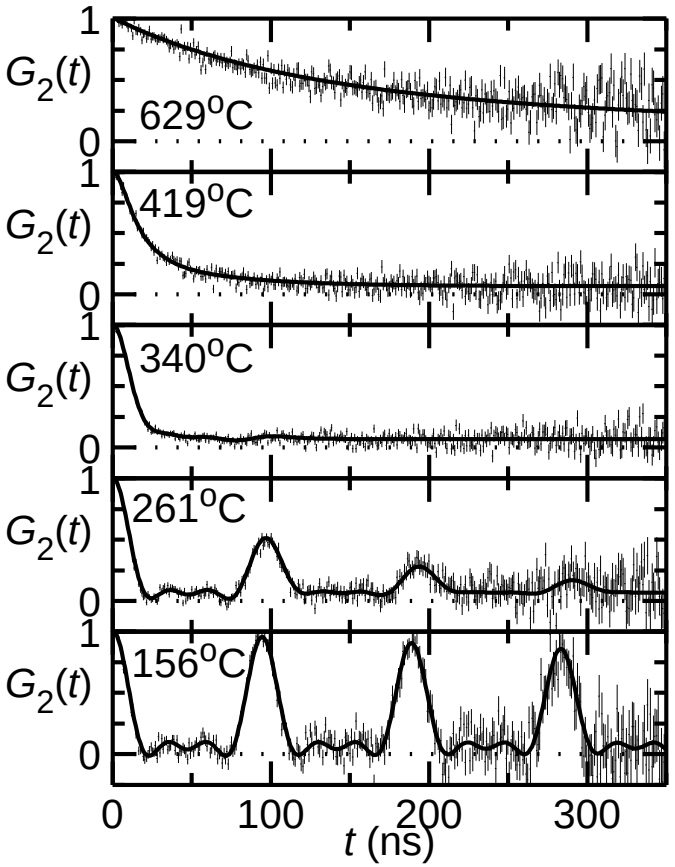
Other: ErAl3, $PrPd_3$, $NdPd_3$, $EuPd_3$, $SmPd_3$

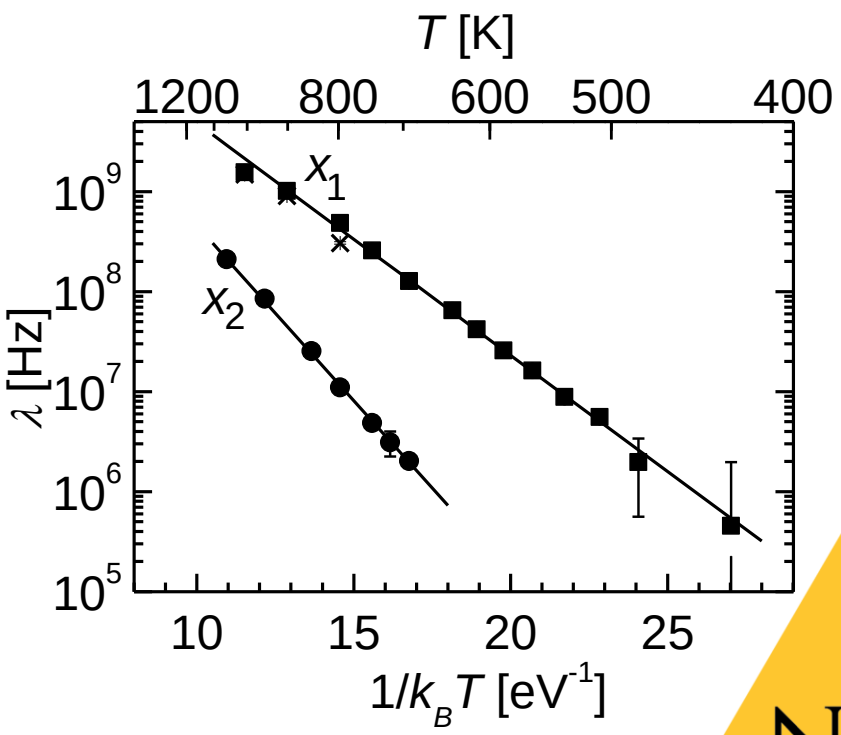


- Collins, Jiang, Bevington, Selim, Zacate. *PRL* **102**, 155901 (2009)
- Jiang, Zacate, Collins. *Def & Diff Forum* **289-292**, 725 (2009)
- Wang, Collins. *Hyperfine Interact* **221**, 85 (2013)
- Lockwood, Norman, Newhouse, Collins. *Def & Diff Forum* **311**, 159 (2011)

Project feasibility

Representative results: ^{111}In/Cd PAC in $La_{1-4x}In_{3+4x}$



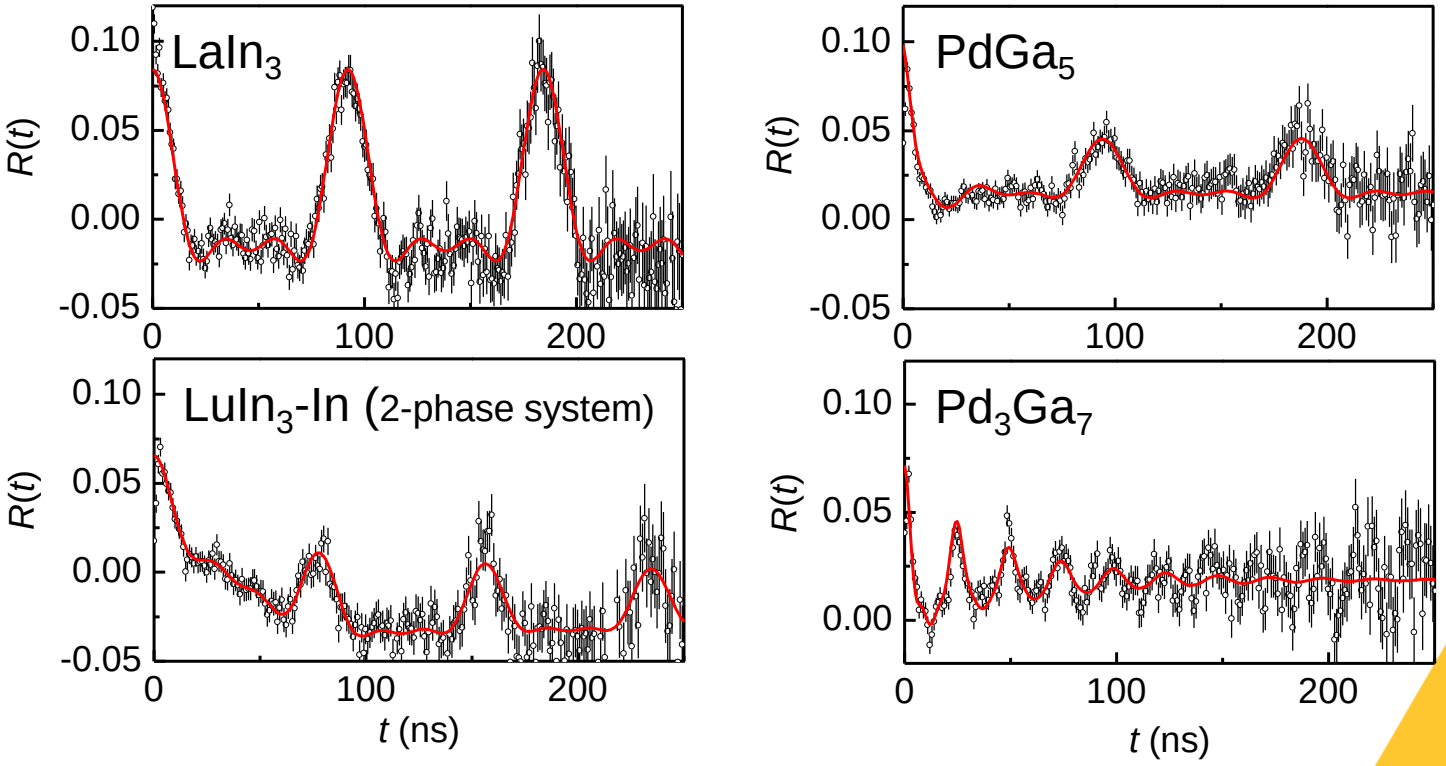


Zacate, Favrot, Collins,
PRL **92**, 225901 (2004)

Project feasibility

Previous ^{111m}Cd PAC measurements in intermetallic compounds show successful removal of implantation damage (experiment IS-514).

Room temperature measurements



Beam time request

Parent Isotope	$t_{1/2}$	Target	Ion source	Yield (ions/μC)	No. of shifts
^{111m}Cd	48 min	Sn (molten)	VADIS	10^8	12 (2017 & 2018)

Additional notes

- Activity to be implanted into samples in the solid state collection chamber on the GLM.
- Beam times can be shared with other experiments using the ^{111m}Cd isotope.
- Should not interfere with experiments utilizing higher mass isotopes on the central beam line.

Summary and Future Prospects

- This project will provide a measurement of tracer jump rates for a tracer diffusing via a vacancy mechanism for the first time.
  - A follow-up measurement of vacancy concentration will allow determination of vacancy jump rates.
- This project creates framework for a more comprehensive application of PAC using short-lived isotopes to identify diffusion mechanisms in other crystal structures.
  - Concentration profiling in conjunction with PAC
  - Use of PAC to observe transient defect configurations formed near PAC tracers during diffusion.

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