NMR Studies of Spin Decoherence in Phosphorus-doped Silicon

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Si:P NMR

$^{10^{21}}$Si-29 nuclei at Room T

![FT of FID](15.3 \text{ Tesla}
128 scans (6s/scan)]

$^{10^{19}}$P-31 nuclei at Room T

![P-31 Hahn Echo](7.03 \text{ Tesla}
$10^6$ scans (2ms/scan) 33 minutes)

![FT of Echo](7.03 \text{ Tesla}
33 minutes)
• Why do this?

  - Proposals for Scalable Solid-state Qubits based on spin require "long" nuclear spin decoherence times
  
  - In real samples we don't know how long "long" is

• Time scales to be measured

  - $T_1$, $T_2^*$, $T_2$, ... etc.

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Si:P NMR

Measuring Spin Dynamics of Si-29

Si-29 $T_1 = 5$ sec

$10^{21}$ Si-29 nuclei at Room T
Si:P NMR

$10^{21}$ Si-29 nuclei at Room T
Hahn Echo Formation in the Rotating Coordinate System

- Spins initially polarized along Z-axis
- "$\pi/2$-Pulse" applied along X-axis
  - Spins begin to precess
- Free Precession begins (no H1)
  - Fully polarized along Y-axis
- "Pancake" forms in free precession (no H1)
- "$\pi$-Pulse" applied along X-axis
  - "$\pi$-Pulse" continues
- "Inverted Pancake" forms within free precession
  - Refocussing
- Free Precession continues
CPMG Echo Sequences on $^{29}$Si at 4K

Short Delay Between Echoes
1.14 msec

Long Delay Between Echoes
2.68 msec

Longer Delay Between Echoes
10.36 msec
Other Pulse Sequences for $^{29}$Si at Room Temperature

MLEV-4
$\Pi_Y\Pi_Y\Pi_Y\Pi_Y$
3.14ms Delay

XY-8
$\Pi_X\Pi_Y\Pi_X\Pi_Y\Pi_Y\Pi_Y\Pi_X$
7.21ms Delay

CPMG with Composite Pulses
$\Pi_Y = X_{90^\circ} Y_{180^\circ} X_{90^\circ}$
4.18ms Delay
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Summary-

• Measurements in samples relevant to scalable, solid-state qubits
  - $T_2^*$ is a lower limit

• Interesting Dynamics to Understand
  - Spin-Spin Coupling for a small number of neighbors
  - Spin Locking Effects in Pulse NMR

• Next Steps
  - Lower Dopant Concentrations
  - Optically Pumped NMR
  - Higher B/T

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