Spin-dependent processes in amorphous silicon-rich silicon-nitride solar cells

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1. Introduction

Pulsed electrically detected magnetic resonance (pEDMR) allows us to explore the nature of spin-coupling of localized paramagnetic defect states in materials with weak spin-orbit coupling (e.g. silicon materials). The method allows detection of coherent spin-motion by transient observation of spin-dependent charge transport and recombination.

2. Motivation

• Photovoltaic semiconductor electrode for photoelectrochemical (PEC) hydrogen production cell*
• Band-gap tunable LED†

*V. Rajevac, et al., Philosophical Magazine B 89, 2723 (2009)

Goal of this study:
Determine whether spin-dependent transitions in a-SiN0.3:H are similar to intrinsic amorphous silicon (a-Si:H) or whether small amounts of nitrogen lead to observable differences in transport and recombination?

4. What pEDMR can do?

Under constant optical excitation and magnetic field (B₀)

Weakly coupled Spin pair

Strongly coupled Spin pair

Electrical detection of coherent spin motion allows us to distinguish different couplings in electron spin pairs


5A. Electrically detected spin Rabi nutation

Coherent spin Rabi nutations induce oscillating photovoltaic currents
Oscillation frequency reflects coupling in spin pairs

5B. Rabi frequency vs. spin-coupling

2νRabi = γB₁
Weakly coupled spin pairs*

2νRabi = γB₁
Dipolar coupled spin pairs†


2νRabi = 2γB₁
Weak B₁ field dependence (not shown)
⇒ exchange coupled spin pairs**


6. Conclusions

• Only weakly coupled spins
• Dipolar and exchange coupled spins

I. In contrast to a-Si:H where all detectable strongly exchange and dipolar coupled pairs are geminate, there are non-geminate pairs in a-SiN0.3:H which are strongly coupled.
II. The presence of strongly coupled non-geminate pairs in a-SiN0.3:H could increase the quantum efficiency of light harvesting.