Reassessment of the Recombination Parameters of Interstitial Cr and CrB pairs in Silicon

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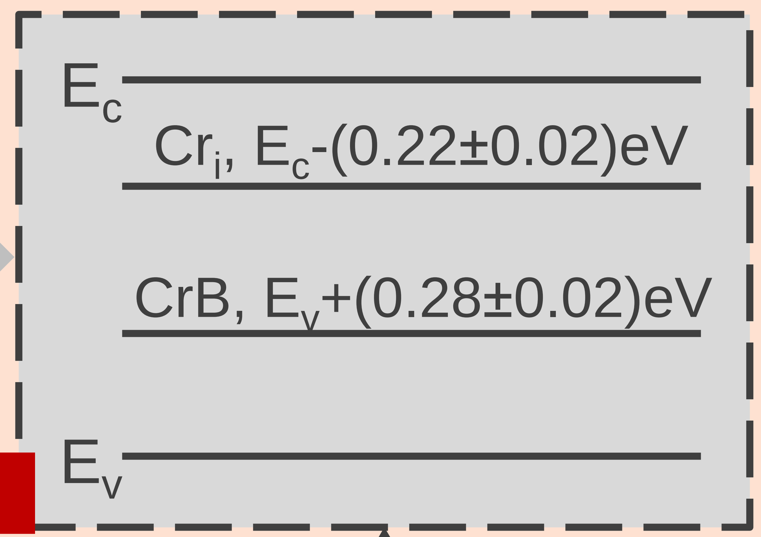
Cr in photovoltaic silicon materials

- **Transition-metal impurities such as Cr** are **detrimental** to silicon devices.
- But such impurities are **common** in photovoltaic grade silicon materials.
- Cr in photovoltaic grade multicrystalline silicon wafers: **10^{12} ~10^{13}cm^{-3} range**.

Recombination activity of Cr

In n-Si: isolated interstitial chromium Cr_i

In p-Si: Cr_i^++B^- ⇄ CrB pairs (~25ºC → ; ← >200~300ºC)



Deep recombination centers

Enhance recombination & Reduce carrier lifetime

Defect parameters: Capture cross sections & Energy level

Capture cross sections → Vary across orders of magnitudes in literature

Energy level → Well-established

✓ Reassessing the recombination parameters is significant as such knowledge is helpful in detecting and removing Cr.

Reassessment of recombination parameters

Samples: 5 n-type Cr-doped samples and 5 p-type ones. They are cut from different positions (different solidified fraction g, different doping) of two Czochralski ingots.

Doping level- and injection-dependent lifetime data of both types of samples —Fit→ Shockley-Read-Hall (SRH) model → Recombination parameters & uncertainty range

Combined analysis of the two defects → Reduced uncertainty and tightened range

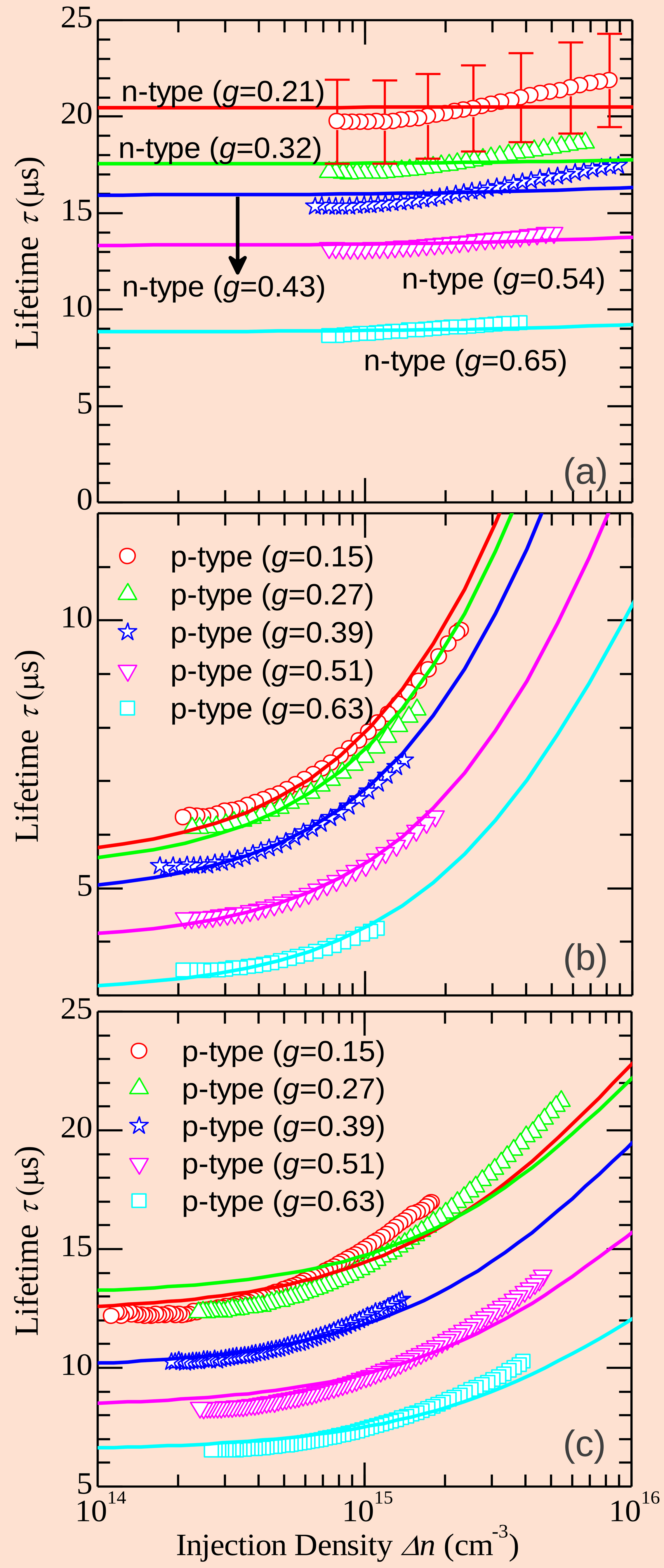


Figure 1

FIG. 1. Lifetime measurements (symbols) and SRH fits (solid lines) for (a) n-type samples, (b)p-type samples in fully associated state, and (c) p-type samples directly after quenching.

Results in comparison with the literature

		σ_n(cm^2)	σ_p(cm^2)	σ_n/σ_p
Cr_i	Literature	(0.73, 25)×10^{-14}	(0.91,12.5)×10^{-14}	2~5
	This work	2.4 (-1.0, +0.3)×10^{-14}	0.8 (-0.3, +0.2)×10^{-14}	3.2(-0.6, +0)
CrB	Literature	(0.5,15)×10^{-14}	(0.15,8.4)×10^{-14}	0.5~60
	This work	3.8 (-1.6, +0.5)×10^{-14}	0.7(-0.3,+0.6)×10^{-14}	5.8(-3.4, +0.6)

Comparison of Cr in n- and p-type silicon

A **direct experimental comparison** (Fig. 2) shows Cr_i in p-Si >(more active than) Cr_i in n-Si

We also found that CrB in p-Si > Cr_i in p-Si

✓ Since dissolved chromium will exist as CrB pairs in p-Si under standard solar cell operation conditions, we can conclude that **Cr has a greater negative impact on carrier lifetimes in p-type silicon than n-type silicon** with similar doping levels.

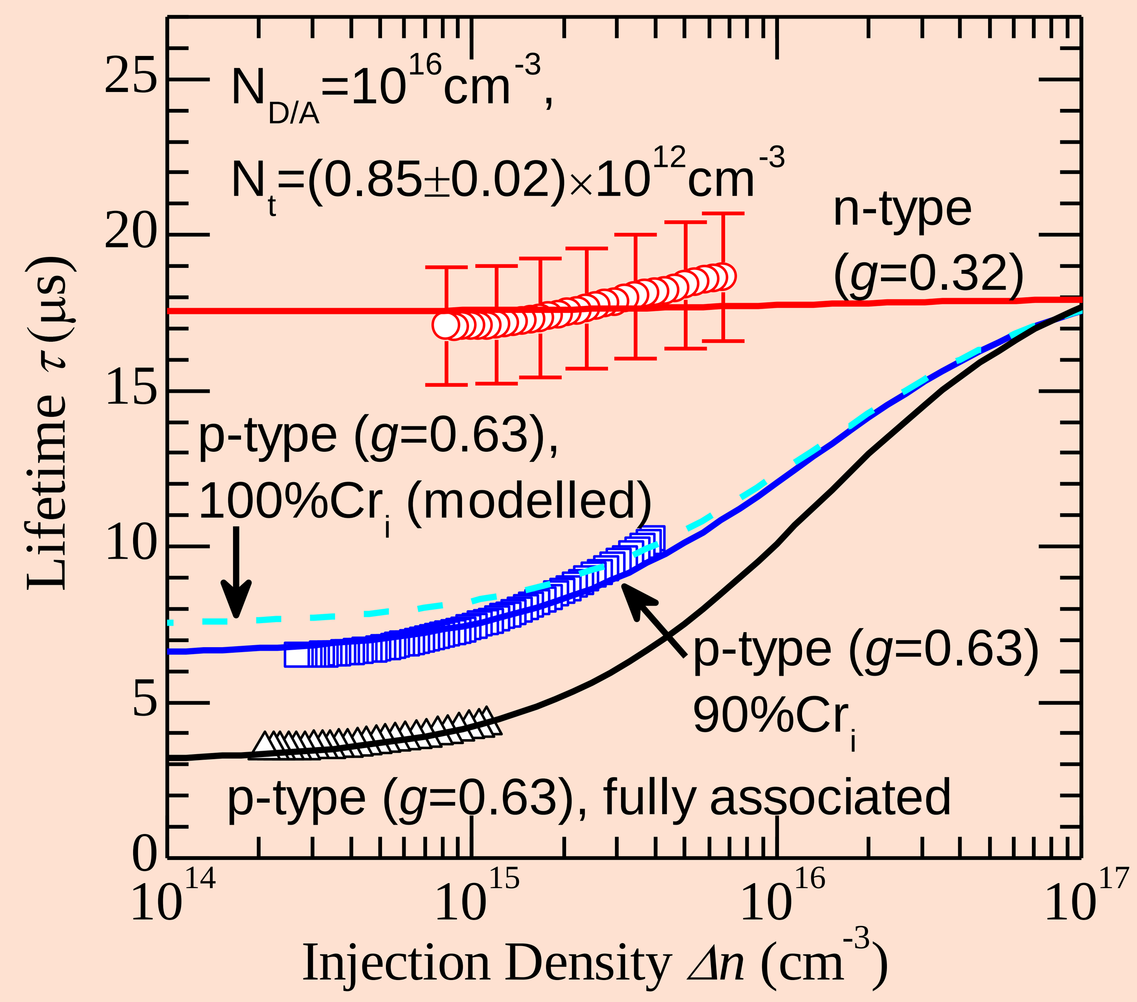


Figure 2

FIG. 2. Lifetime measurements (symbols) for samples n-type (g=0.32) and p-type (g=0.63). The two samples have similar doping levels and Cr concentration.

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