**Variability in FeB Pair Association Rates in Silicon under Ultrasound Loading: Effects of Acoustic Wave Types**

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Ultrasound (US) is recognized as an effective tool for defect engineering in materials science, as detailed in sources [1-2]. Its broad utility stems from the ability to modify both the frequency and type of acoustic waves, allowing for a targeted approach to specific defect types. Recent studies [1] have demonstrated that US loading can force an increase in the association rate of FeB pairs in silicon solar cells, likely due to a lowered energy barrier for iron ion migration. The magnitude of acoustically-induced (AI) energy reduction Δ*E*US is foreseeably dependent on the power of the excited acoustic waves (see Figure~1) and can reach up to 15 meV.

Further examination using Cz-silicon n⁺-p-p⁺ structures has unveiled a striking paradox. While the AI energy change ( \Delta E\_{US} ) increases with the frequency of transverse acoustic waves, it decreases under longitudinal waves. This distinct response of the FeB center suggests the presence of an anisotropic deformation field within the silicon's crystal lattice, revealing intriguing aspects of its physical behavior under different ultrasonic conditions.

Further investigations using Cz-silicon *n*⁺-*p*-*p*⁺ structures revealed a paradoxical divergence in the frequency dependency of Δ*E*US when using longitudinal and transverse waves. Specifically, under transverse acoustic wave loading, the AI energy change increased with rising of US frequency. In contrast, the frequency rising of longitudinal waves resulted in a decrease in Δ*E*US value. The observed qualitatively different response of FeB center is a reliable and intriguing evidence of anisotropic deformation field tied to this center in the crystal lattice of silicon.

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| *Figure 1: Dependencies of acoustically induced changes in iron ion migration energy on ultrasound intensity using longitudinal (L, left panel) and transverse (T, right panel) acoustic waves of different frequencies*. | |

[1] A.U. Thor, Appl. Surf. Sci. 111, 222 (1999).

[2] Author1, Author2, and Author3, J. Nucl. Mater 11, 222 (2000).

It is well known that ultrasound (US) can be effective tool for defects engineering [1-2]. The wide-ranging US capabilities are closely associated with the ability to adjust the frequency and the type of acoustic waves. Such versatility enables the selection of an ultrasound loading regime tailored to the specific type of targeted defects. Recent research [1] has indicated that US loading conditions can accelerate the association of FeB pairs in silicon solar cells. This effect is believed to result from a reduced energy barrier for iron ion migration:  (where Δ*E*US is the acoustically induced (АІ) change).

Further investigations using Cz-silicon *n*⁺-*p*-*p*⁺ structures revealed a paradoxical divergence in the frequency dependency of Δ*E*US when using longitudinal and transverse waves. Specifically, under transverse acoustic wave loading, the AI energy change increased with rising of US frequency. In contrast, the frequency rising of longitudinal waves resulted in a decrease in Δ*E*US value. The observed qualitatively different response of FeB center is a reliable and intriguing evidence of anisotropic deformation field tied to this center in the crystal lattice of silicon.

Ultrasound (US) is recognized as an effective tool for defect engineering in materials science, as detailed in sources [1-2]. Its broad utility stems from the ability to modify both the frequency and type of acoustic waves, allowing for a targeted approach to specific defect types. Recent studies [1] have demonstrated that specific US loading conditions can enhance the association of FeB pairs in silicon solar cells, likely due to a lowered energy barrier for iron ion migration, represented by the acoustically induced (AI) change ( \Delta E\_{US} ).

Further examination using Cz-silicon n⁺-p-p⁺ structures has unveiled a striking paradox. While the AI energy change ( \Delta E\_{US} ) increases with the frequency of transverse acoustic waves, it decreases under longitudinal waves. This distinct response of the FeB center suggests the presence of an anisotropic deformation field within the silicon's crystal lattice, revealing intriguing aspects of its physical behavior under different ultrasonic conditions.