The peculiarities of the ultrasound influence on the FeB pair association in silicon structures

Oleg Olikh[1] and Nikolay Arutyunov[2,3]

[1] *Taras Shevchenko National University of Kyiv, 64/13, Volodymyrska Street, 01601, Kyiv, Ukraine*
[2] *Department of Physics, Martin Luther University Halle, 06120, Halle, Germany*
[3] *Leibniz-lnstitut für Kristallzüchtung (IKZ), Max-Born-St.-2, D-12489, Berlin, Germany*

olegolikh@knu.ua

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: $E_m \xrightarrow{\mathrm{US}} E_{m,0} - \Delta E_{US}$ (where ΔE_{US} is the acoustically induced (AI) change).

Further investigations using Cz-silicon n^+-p-p^+ structures revealed a paradoxical divergence in the frequency dependency of ΔE_{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 ΔE_{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.

The oversized core of Fe atom reveals itself in emitting the gamma-quanta of the element-specific electron-positron distribution, just as it has been observed for the point defects in diamond-like semiconductors [3,4]. This emission obeys both the dynamics and kinetics of the rate of positron localization and, as estimated, follows the qualitatively different response to US loading caused by longitudinal and transverse acoustic waves. The value of the positron trapping rate (Fig. 2) provides for reliable measurements of both the positron annihilation lifetime and coincidence Doppler broadening. We believe that FeB complex is effective positron trap and the experiments on verifying predictions for center microstructure based on the phenomenon of the electron-positron annihilation in the field of the ultrasound loading will be considered.

[1] O. Olikh *et al.*, *J. Mater Sci: Mater Electron* **2022**, *33*, 13133.
[2] M. Virot *et al.*, *J. Phys. Chem. C* **2012**, *116*, 15493.
[3] N. Arutyunov and R. Krauserehberg, *Sol. State. Phenom.* **2004**, *95-96*, 507.
[4] N. Arutyunov, V. Emtsev, A. Mikhailin and C. Humphreys, *Physica B* **2003**, *340–342*, 412.
[5] B. Paudyal, K. McIntosh and D. Macdonald, “Proceedings of the 34th IEEE Photovoltaic Specialists Conference (PVSC, 2009), p. 001588.
[6] A. Istratov, H. Hieslmair and E. Weber, *Appl. Phys. A: Mater. Sci. Process*. **1999**, *69*, 13.

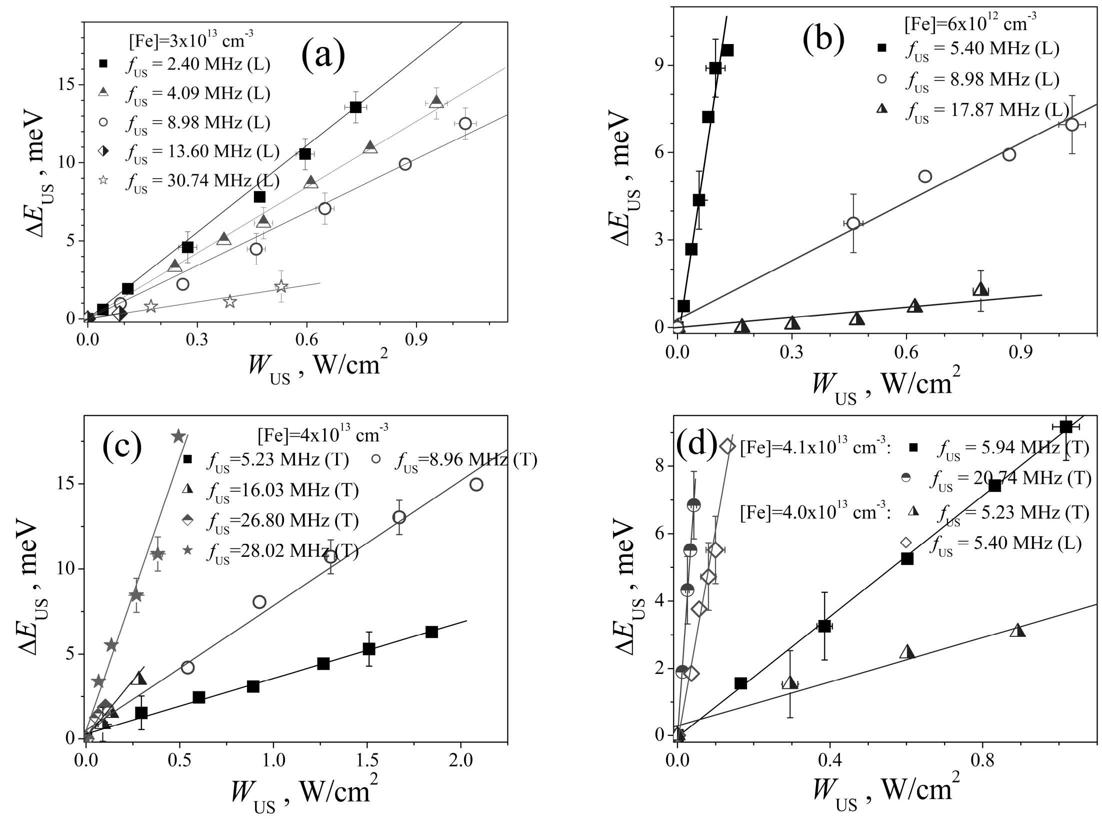

Fig. 1. Dependencies of acoustically induced changes in iron ion migration energy on ultrasound intensity using longitudinal (L) and transverse (T) waves of different frequencies. Points represent experimental data, and the lines are the linear fitted curves.

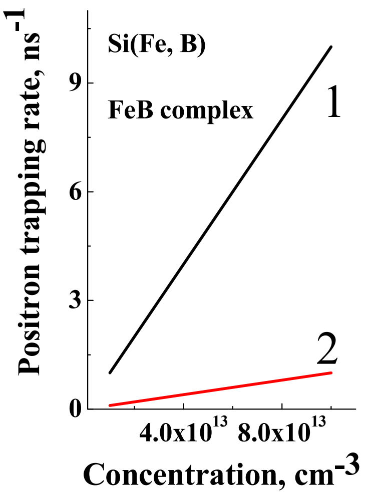

Fig. 2. The positron trapping rate (k) estimated for FeB complex with the positron trapping cross-section 10^{-11} cm^2 (curve 1) and 10^{-12} cm^2 at room temperature versus concentration (n_d) of Fe impurity atoms in Si. It is noteworthy that yet much larger values of cross-sections 3.32×10^{-11} cm^2 and 10^{-10} cm^2 related to excitonic Auger capture of holes and multiphonon emission capture, respectively, have been reported for the FeB complex [5,6]. The oversized ion core of the Fe impurity atom dominates in the emission of the elementally specific electron-positron annihilation radiation thus giving an identifying distinctive feature of the FeB complex in its energetically anisotropic reaction to US loading depending on wave type. As a result, the $k(n_d)$ dependency is a function of US loading.