Highlights

Microwave induced transformation of defect in SiC and GaAs

Oleg Olikh, Petro Lytvyn

- The microwave irradiation increase interstitial defect concentration at near surface region

- Stress intensity the microwave induced defect transformation

- Microwave treatment decreases σ_n of vacancy related defects in SiC and GaAs monocrystal

- The transient acoustoelectric spectroscopy used for determining properties of defects in SiC and GaAs.

- A microwave annealing of defects in SiC and GaAs was observed.

Microwave induced transformation of defect in SiC and GaAs

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Abstract

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Keywords: Microwave, SiC, GaAs, Defect transformation

1. Introduction

It is well known (**??**) (**??????????????**.)
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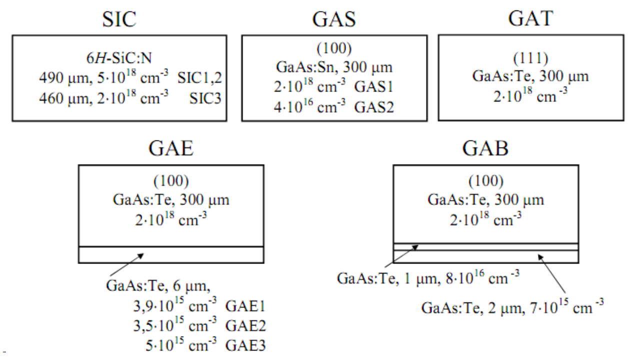

Figure 1: Structure of samples

2. Experimental details

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$$V_{\mathrm{TAV}}(t) = V_{\mathrm{TAV},0}\exp(-t/\tau). \tag{1}$$

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$$\tau = \frac{1}{\sigma_n\, \upsilon_{\mathrm{th},n}\, N_c}\exp\left(\frac{E_c - E_t}{kT}\right). \tag{2}$$

where $\upsilon_{\mathrm{th},n}$ is the electron thermal velocity N_C is the densities of states in the conduction band.
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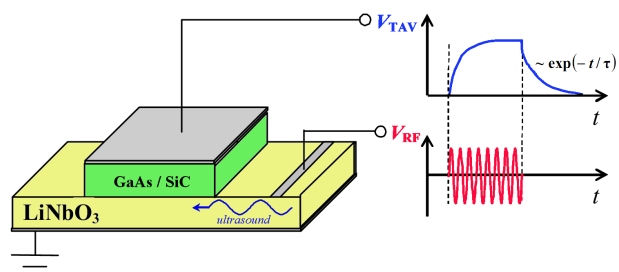

Figure 2: The scheme of TAV measurement. The time dependencies of the radio impulse V_{RF} for the excitation of ultrasound in a piezoelectric plate and the resulting TAV signal V_{TAV} are schematically shown as well.

Table 1: The determined parameters of defects in the samples n–GaAs and n–$6H$–SiC samples

Sample	t_{MWT}, s	Level	$(E_c - E_t)$, eV	σ_n, cm^2 [a)]	R_{cur}, m	ξ_{cur}
SIC1	0	ESC1	0.33 ± 0.01	$(7 \pm 4) \cdot 10^{-18}$	∞	0
	20	ESC1	0.33 ± 0.01	$(5 \pm 3) \cdot 10^{-19}$	170.2	$8.7 \cdot 10^{-7}$
	40	ESC2	0.26 ± 0.01	$(2 \pm 1) \cdot 10^{-19}$		-
	80		weak signal			
SIC2	0	ESC1	0.33 ± 0.01	$(7 \pm 4) \cdot 10^{-18}$	> 2000	$< 1.2 \cdot 10^{-7}$
	20	ESC1	0.33 ± 0.01	$(5 \pm 3) \cdot 10^{-19}$	171.9	$1.4 \cdot 10^{-6}$
SIC3	0	ESC1	0.34 ± 0.02	$(3 \pm 2) \cdot 10^{-18}$	3.8	$6.1 \cdot 10^{-5}$
	20	ESC2	0.29 ± 0.01	$(5 \pm 3) \cdot 10^{-19}$	5.5	$4.2 \cdot 10^{-5}$
	40	ESC2	0.26 ± 0.01	$(10 \pm 7) \cdot 10^{-20}$		-
	80	ESC2	0.23 ± 0.01	$(6 \pm 4) \cdot 10^{-20}$		
GAS1	0	EGA1	0.32 ± 0.02	$(3 \pm 2) \cdot 10^{-17}$	-53.8	$-2.8 \cdot 10^{-6}$
	20	EGA1	0.31 ± 0.01	$(2 \pm 1) \cdot 10^{-17}$	22.9	$6.5 \cdot 10^{-6}$
	40		weak signal			-
GAS2	0	EGA1	0.32 ± 0.01	$(4 \pm 2) \cdot 10^{-17}$	17.2	$8.7 \cdot 10^{-6}$
	20	EGA2	0.28 ± 0.01	$(5 \pm 2) \cdot 10^{-18}$	14.7	$1.0 \cdot 10^{-5}$
	40		weak signal			
GAT	0	EGA3	0.49 ± 0.02	$(5 \pm 3) \cdot 10^{-14}$		
	20	EGA4	0.40 ± 0.02	$(2 \pm 1) \cdot 10^{-15}$		
GAE1	0	EGA5	0.24 ± 0.01	$(2 \pm 1) \cdot 10^{-18}$		
	60	EGA2	0.29 ± 0.01	$(10 \pm 6) \cdot 10^{-18}$		
GAE2	0	EGA5	0.25 ± 0.01	$(2 \pm 1) \cdot 10^{-18}$		
	60	EGA2	0.30 ± 0.01	$(2 \pm 1) \cdot 10^{-17}$		
GAE3	0	EGA6	0.43 ± 0.01	$(8 \pm 5) \cdot 10^{-17}$		-
	60	EGA6	0.46 ± 0.02	$(7 \pm 4) \cdot 10^{-16}$		
GAB1	0	EGA4	0.39 ± 0.01	$(10 \pm 7) \cdot 10^{-18}$		
	20	EGA4	0.39 ± 0.01	$(4 \pm 2) \cdot 10^{-17}$		
	40	EGA6	0.43 ± 0.02	$(10 \pm 6) \cdot 10^{-17}$		
GAB2	0	EGA4	0.40 ± 0.01	$(10 \pm 6) \cdot 10^{-17}$		
	20	EGA4	0.41 ± 0.01	$(10 \pm 6) \cdot 10^{-17}$		
	40	EGA6	0.45 ± 0.02	$(4 \pm 2) \cdot 10^{-16}$		

[a)] *at $T = 300$ K for SIC, GA, GAE and at $T = 340$ K for GAB*

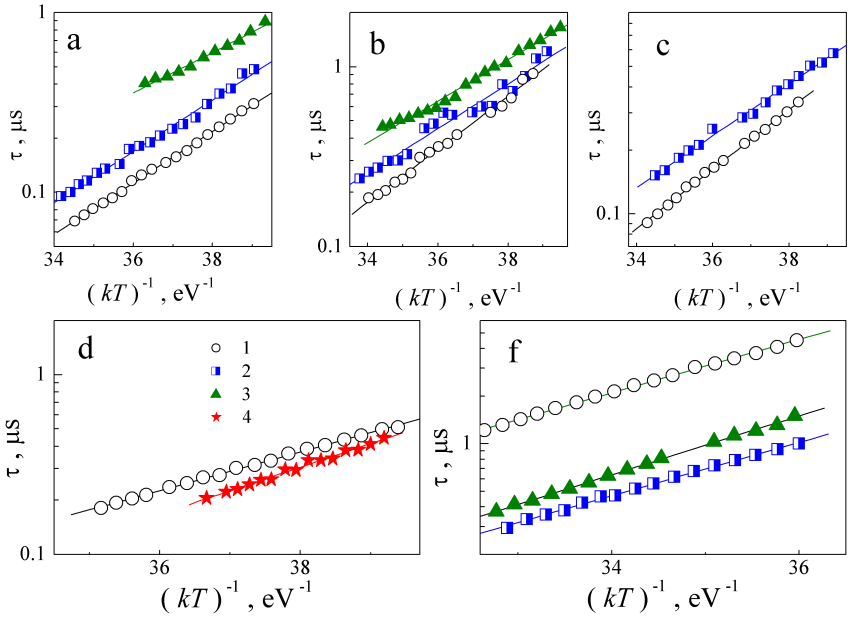

Figure 3: Dependences of TAV relaxation time on inverse temperature for samples SIC2 (a), SIC3 (b), GAS2 (c), GAE2 (d) and GAB1 (e) before and after MWT. $t_{\mathtt{MWT}}$, c: 0 (curves 1), 20 (2), 40 (3), 60 (4)

3. Results and discussion

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$$V_{Si}\,V_C + V_{Si}\,V_C + C_i + C_i \rightarrow V_{Si} + V_{Si} \rightarrow V_{Si}\,V_{Si}\,.$$

$$V_{As} + As_i \rightarrow V_{Si}\,As_i\,.$$

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$$V_{Ga}\,Ga_i\,V_{As} \rightarrow Ga_{Ga}\,V_{As} \rightarrow Ga_{As}\,V_{Ga}$$

$$\begin{aligned} \mathrm{SiC} \quad &: \quad V_{Si}\,V_{Si} + Si_i + Si_i \rightarrow 0\,; \\ \mathrm{GaAs} \quad &: \quad V_{Si}\,As_i \rightarrow 0\,; \quad V_{As} + Ga_i \rightarrow Ga_{As}\,. \end{aligned}$$

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$$V_{Ga}\,V_{As} + Ga_i + As_i \rightarrow V_{As}\,As_i$$

$$V_{Ga}\,Ga_{As} + As_i \rightarrow Ga_{Ga}\,V_{As} + As_i \rightarrow V_{As}\,As_i$$

Table 2: Literature data for levels closed to the location of detected levels

$(E_c - E_t)$, eV	σ_n, cm^2	configuration	method [a]	epi–structure	Reference
EGA1, $(E_c - E_t) = (0.31 \div 0.32)$ eV					
0.33	-	complex with V_{As}	DLTS	no	?
0.33	-	-	DLTS	no	?
$0.31 \div 0.33$	-	V_{As}	LDA	no	?
0.33	$1 \cdot 10^{-17}$	-	TSC	no	?
0.323	$1 \cdot 10^{-14}$	-	DLTS	yes	?
0.334	$2 \cdot 10^{-15}$		DLTS	yes	?
0.35	-	complex with V_{As}	PA	no	?
$0.315 \div 0.325$	$3 \cdot 10^{-17}$	-	TSC	no	?
0.33	-	-	TSC	no	?
$0.30 \div 0.33$	-	-	DLTS	no	?
EGA2, $(E_c - E_t) = (0.28 \div 0.30)$ eV					
0.28	$5 \cdot 10^{-18}$	$V_{As}As_i$	TSC	no	?
0.26	$3.5 \cdot 10^{-15}$	-	DLTS	yes	?
0.277	$5 \cdot 10^{-17}$	-	TSC	no	?
0.284	$1 \cdot 10^{-17}$	-	TSC	no	?
0.28	-	intrinsic	TP	no	?
0.28	$8 \cdot 10^{-15}$	-	DLTS	yes	?
0.30	-	complex with Te	DLTS	no	?
0.30	$6 \cdot 10^{-15}$	$V_{As}As_i$	DLTS	no	?
EGA3, $(E_c - E_t) = 0.49$ eV					
0.50	-	Sb_{Ga}	DLTS	no	?
0.48	$4 \cdot 10^{-16}$	As_{Ga}^{++}	TSC	no	?
0.485	$2 \cdot 10^{-16}$	-	TSC	no	?
0.48	-	impurity	TP	no	?
0.51	$1 \cdot 10^{-12}$	-	DLTS	no	?
0.48	$3 \cdot 10^{-13}$	-	DLTS	no	?
0.50	$1 \cdot 10^{-15}$	V_{As}, $V_{Ga}Ga_iV_{As}$	DLTS	no	?
EGA4, $(E_c - E_t) = (0.39 \div 0.41)$ eV					
0.42	-	-	DLTS	no	?
0.41	-	$V_{Ga}V_{As}$	DLTS	no	?
0.39	-	$V_{Ga}Ga_{As}$	TSC	no	?
0.41	$2 \cdot 10^{-13}$	-	DLTS	yes	?
0.40	-	-	SCRC	yes	?
0.37	$2 \cdot 10^{-14}$	-	DLTS	yes	?
0.40	-	$V_{Ga}Ga_{As}$	DLTS	no	?
0.387	$2 \cdot 10^{-14}$	-	DLTS	yes	?
EGA5, $(E_c - E_t) = (0.24 \div 0.25)$ eV					
0.23	-	-	DLTS	no	?
0.23	$2 \cdot 10^{-17}$	-	TSC	no	?
$0.22 \div 0.25$	$8 \cdot 10^{-19}$	-	TSC	no	?
0.26	-	complex with V_{Ga}	TSC	no	?
0.24	-	-	TSC	no	?
0.23	-	intrinsic	TP	no	?
0.23	-	$V_{Ga}V_{As}$	DLTS	no	?
0.23	$1 \cdot 10^{-14}$	$V_{Ga}V_{As}$	DLTS	no	?
0.23	$7 \cdot 10^{-15}$	-	DLTS	yes	?
0.22	$2 \cdot 10^{-15}$	-	DLTS	no	?
0.258	$4 \cdot 10^{-16}$	-	DLTS	yes	?
EGA6, $(E_c - E_t) = (0.43 \div 0.46)$ eV					
0.44	$1 \cdot 10^{-14}$	$V_{As}As_i$, V_{As}	TSC	no	?
0.44	$9 \cdot 10^{-15}$	-	TSC	no	?
0.43	$7 \cdot 10^{-16}$	intrinsic	DLTS	yes	? ?
0.44	$2 \cdot 10^{-15}$	complex with V_{As}	DLTS	yes	?

[a] *DLTS — deep level transient spectroscopy; TSC — thermally stimulated current; LDA — local density approximation; PA — positron annihilation techniques; TP — photoinduced transient spectroscopy; SCLC — space charge limited current*

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CRediT authorship contribution statement) **Oleg Olikh:** Conceptualization, Methodology, Validation, Formal analysis, Investigation, Writing - Review & Editing, Visualization. **Petro Lytvyn:** Conceptualization, Methodology, Validation, Resources, Writing - Original Draft.

Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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