Highlights

Microwave induced transformation of defect in SiC and GaAs

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- 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 (Kozlovskii et al. (2000); Schrimpf and Fleetwood (2004))

(Kitchen et al. (2014); Zohm et al. (2000); Bhunia and Bose (1998); Bacherikov et al. (2003); Pashkov et al. (1994); Boltovets et al. (2002); Milenin et al. (1994); Belyaev et al. (2002); Ashkinadze et al. (1996); Ermolovich et al. (1998); Belyayev et al. (1998); Bacherikov et al. (2008); Zayats et al. (2015); Belyayev et al. (2012).)

Kitchen et al. (2014); Zohm et al. (2000)

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Boltovets et al. (2002); Pashkov et al. (1994); Milenin et al. (1994); Belyaev et al. (2002); Ermolovich et al. (1998); Zayats et al. (2015); Belyayev et al. (2012)

Bacherikov et al. (2003)

Bacherikov et al. (2003); Belyayev et al. (1998); Zayats et al. (2015)

Milenin et al. (1994)

Belyayev et al. (1998)

Bacherikov et al. (2008)

Belyaev et al. (2002); Ermolovich et al. (1998); Belyayev et al. (1998)

2. Experimental details

Boltovets et al. (2002); Milenin et al. (1994); Belyaev et al. (2002); Ashkinadze et al. (1996); Ermolovich et al. (1998)

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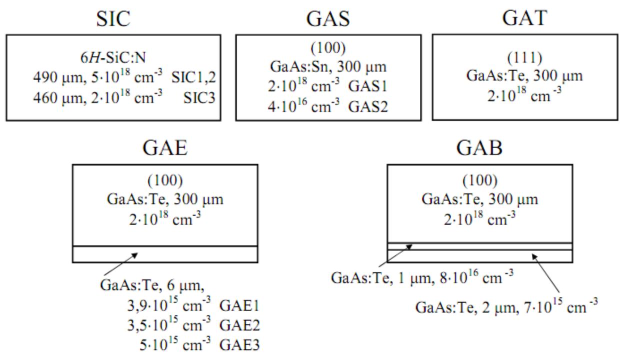

Figure 1: Structure of samples

Ostrovskii et al. (1998); Ostrovskii and Olikh (1998); Gromashevskii et al. (2013); Abbate et al. (1995)

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

Ostrovskii et al. (1998); Abbate et al. (1995)

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

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

Godwod et al. (1976)

Belyayev et al. (1998)

3. Results and discussion

Pavlović et al. (2000)

Bulyarskii et al. (2000); Makram-Ebeid and Lannoo (1982)

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$^{2\ \mathrm{a)}}$	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*

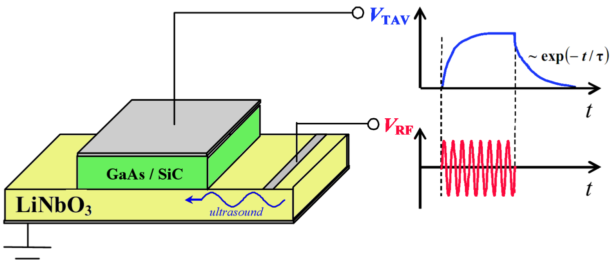

Figure 2: The scheme of TAV measurement. The time dependencies of the radio impulse V_{RF} for the excitation of ultrasound in a piezoelectric plate and the resulting TAV signal V_{TAV} are schematically shown as well.

Stellmacher et al. (2001)

Bourgoin and De Angelis (2001)

Bourgoin and De Angelis (2001)

Bourgoin et al. (1988)

Pavlović et al. (2000)

Lebedev (1999); Anikin et al. (1991a,b)

Kuznetsov and Edmond (1997)

Lebedev (1999)

Lebedev (1999)

Anikin et al. (1991a,b)

Lebedev et al. (2000)

Lebedev et al. (2001)

Hemmingsson et al. (1999)

Lebedev et al. (2001)

Kol'chenko and Lomako (1994)
Samoylov et al. (1994)
Vaytkus et al. (1988)
Kol'chenko et al. (1989)
Ermolovich et al. (2007)
Boltovets et al. (2002); Belyayev et al. (2012)
Bacherikov et al. (2003); Pashkov et al. (1994); Boltovets et al. (2002); Milenin et al. (1994); Belyaev et al. (2002)

$$\mathrm{V_{Si}\,V_C + V_{Si}\,V_C + C_{\mathit{i}} + C_{\mathit{i}} \rightarrow V_{Si} + V_{Si} \rightarrow V_{Si}\,V_{Si}}\,.$$

$$\mathrm{V_{As} + As_{\mathit{i}} \rightarrow V_{Si}\,As_{\mathit{i}}}\,.$$

Zohm et al. (2000)
Fang et al. (1990)

$$\mathrm{V_{Ga}\,Ga_{\mathit{i}}\,V_{As} \rightarrow Ga_{Ga}\,V_{As} \rightarrow Ga_{As}\,V_{Ga}}$$

$$\begin{aligned} \mathrm{SiC} &: \quad \mathrm{V_{Si}\,V_{Si} + Si_{\mathit{i}} + Si_{\mathit{i}} \rightarrow 0}\,; \\ \mathrm{GaAs} &: \quad \mathrm{V_{Si}\,As_{\mathit{i}} \rightarrow 0}\,; \quad \mathrm{V_{As} + Ga_{\mathit{i}} \rightarrow Ga_{As}}\,. \end{aligned}$$

Abbate et al. (1995); Ostrovskii and Olikh (1998); Ostrovskii et al. (1998)
Boltovets et al. (2002); Belyayev et al. (2012)
Yousefi et al. (1995); Mircea and Mitonneau (1975); Bourgoin et al. (1988); Ashby et al. (1976); Fang et al. (1987); Lefèvre and Schulz (1977); Kol'chenko et al. (1989)

$$\mathrm{V_{Ga}\,V_{As} + Ga_{\mathit{i}} + As_{\mathit{i}} \rightarrow V_{As}\,As_{\mathit{i}}}$$

$$\mathrm{V_{Ga}\,Ga_{As} + As_{\mathit{i}} \rightarrow Ga_{Ga}\,V_{As} + As_{\mathit{i}} \rightarrow V_{As}\,As_{\mathit{i}}}$$

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.

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	Richter et al. (2000)
0.33	-	-	DLTS	no	Neild et al. (1991)
$0.31 \div 0.33$	-	V_{As}	LDA	no	Schultz (2015)
0.33	$1 \cdot 10^{-17}$	-	TSC	no	Pavlović et al. (2000)
0.323	$1 \cdot 10^{-14}$	-	DLTS	yes	Yousefi et al. (1995)
0.334	$2 \cdot 10^{-15}$		DLTS	yes	Yousefi et al. (1995)
0.35	-	complex with V_{As}	PA	no	Kuisma et al. (1997)
$0.315 \div 0.325$	$3 \cdot 10^{-17}$	-	TSC	no	Pavlović and Desnica (1998)
0.33	-	-	TSC	no	Tomozane and Nannichi (1986)
$0.30 \div 0.33$	-	-	DLTS	no	Lang et al. (1976)
		EGA2, $(E_c - E_t) = (0.28 \div 0.30)$ eV			
0.28	$5 \cdot 10^{-18}$	$V_{As}As_i$	TSC	no	Pavlović et al. (2000)
0.26	$3.5 \cdot 10^{-15}$	-	DLTS	yes	Yousefi et al. (1995)
0.277	$5 \cdot 10^{-17}$	-	TSC	no	Pavlović and Desnica (1998)
0.284	$1 \cdot 10^{-17}$	-	TSC	no	Pavlović and Desnica (1998)
0.28	-	intrinsic	TP	no	Abele et al. (1987)
0.28	$8 \cdot 10^{-15}$	-	DLTS	yes	Mircea and Mitonneau (1975)
0.30	-	complex with Te	DLTS	no	Kol'chenko and Lomako (1994)
0.30	$6 \cdot 10^{-15}$	$V_{As}As_i$	DLTS	no	Pons and Bourgoin (1985)
		EGA3, $(E_c - E_t) = 0.49$ eV			
0.50	-	Sb_{Ga}	DLTS	no	Samoylov et al. (1994)
0.48	$4 \cdot 10^{-16}$	As_{Ga}^{++}	TSC	no	Pavlović et al. (2000)
0.485	$2 \cdot 10^{-16}$	-	TSC	no	Pavlović and Desnica (1998)
0.48	-	impurity	TP	no	Abele et al. (1987)
0.51	$1 \cdot 10^{-12}$	-	DLTS	no	Martin et al. (1977)
0.48	$3 \cdot 10^{-13}$	-	DLTS	no	Lang et al. (1976)
0.50	$1 \cdot 10^{-15}$	V_{As}, $V_{Ga}Ga_iV_{As}$	DLTS	no	Pons and Bourgoin (1985)
		EGA4, $(E_c - E_t) = (0.39 \div 0.41)$ eV			
0.42	-	-	DLTS	no	Neild et al. (1991)
0.41	-	$V_{Ga}V_{As}$	DLTS	no	Samoylov et al. (1994)
0.39	-	$V_{Ga}Ga_{As}$	TSC	no	Fang et al. (1990)
0.41	$2 \cdot 10^{-13}$	-	DLTS	yes	Bourgoin et al. (1988)
0.40	-	-	SCRC	yes	Ashby et al. (1976)
0.37	$2 \cdot 10^{-14}$	-	DLTS	yes	Fang et al. (1987)
0.40	-	$V_{Ga}Ga_{As}$	DLTS	no	Vaytkus et al. (1988)
0.387	$2 \cdot 10^{-14}$	-	DLTS	yes	Yousefi et al. (1995)
		EGA5, $(E_c - E_t) = (0.24 \div 0.25)$ eV			
0.23	-	-	DLTS	no	Neild et al. (1991)
0.23	$2 \cdot 10^{-17}$	-	TSC	no	Pavlović et al. (2000)
$0.22 \div 0.25$	$8 \cdot 10^{-19}$	-	TSC	no	Lin et al. (1976)
0.26	-	complex with V_{Ga}	TSC	no	Fang et al. (1990)
0.24	-	-	TSC	no	Tomozane and Nannichi (1986)
0.23	-	intrinsic	TP	no	Abele et al. (1987)
0.23	-	$V_{Ga}V_{As}$	DLTS	no	Morrow (1991)
0.23	$1 \cdot 10^{-14}$	$V_{Ga}V_{As}$	DLTS	no	Bourgoin et al. (1988)
0.23	$7 \cdot 10^{-15}$	-	DLTS	yes	Mircea and Mitonneau (1975)
0.22	$2 \cdot 10^{-15}$	-	DLTS	no	Fang et al. (1987)
0.258	$4 \cdot 10^{-16}$	-	DLTS	yes	Yousefi et al. (1995)
		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	Pavlović et al. (2000)
0.44	$9 \cdot 10^{-15}$	-	TSC	no	Pavlović and Desnica (1998)
0.43	$7 \cdot 10^{-16}$	intrinsic	DLTS	yes	Lefèvre and Schulz (1977) Bourgoin et al. (1988)
0.44	$2 \cdot 10^{-15}$	complex with V_{As}	DLTS	yes	Kol'chenko et al. (1989)

[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*

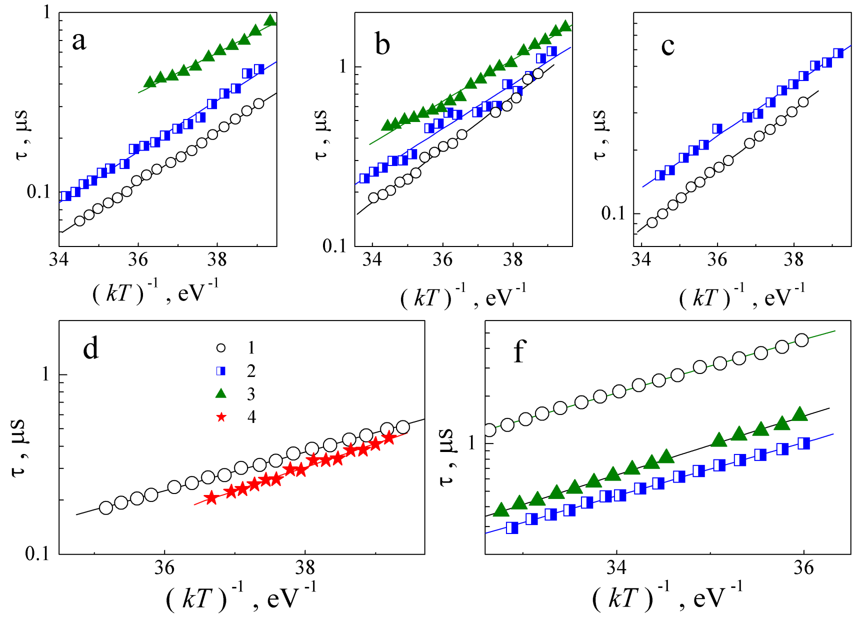

Figure 3: Dependences of TAV relaxation time on inverse temperature for samples SIC2 (a), SIC3 (b), GAS2 (c), GAE2 (d) and GAB1 (e) before and after MWT. $t_{\mathtt{MWT}}$, c: 0 (curves 1), 20 (2), 40 (3), 60 (4)

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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