

Microwave induced transformation of defect in SiC and GaAs

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)

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

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

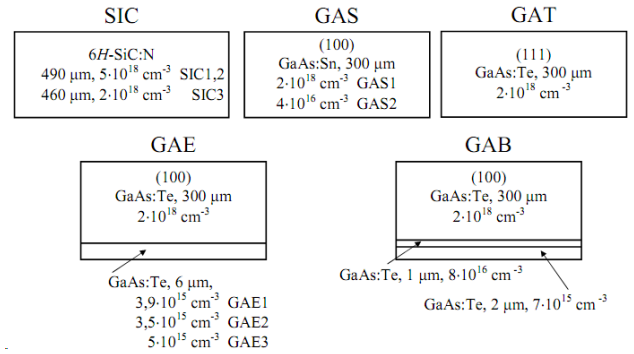


Figure 1: Structure of samples

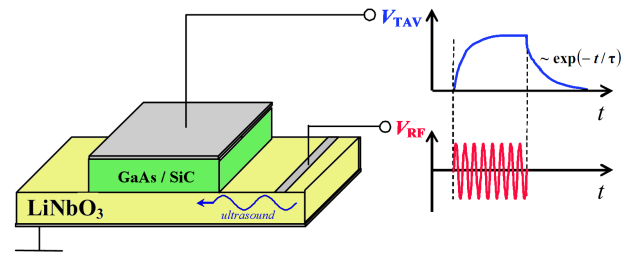


Figure 2: The scheme of TAV measurement. The time dependencies of the radio impulse V_{RF} for the excitation of ultrasound in a piezoelectric plate and the resulting TAV signal V_{TAV} are schematically shown as well.

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

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

where $v_{th,n}$ 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)

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)

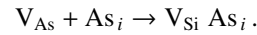
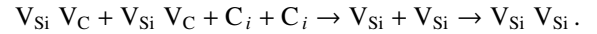
Vaytkus et al. (1988)

Kol'chenko et al. (1989)

Ermolovich et al. (2007)

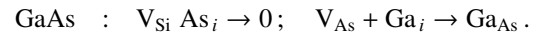
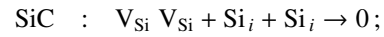
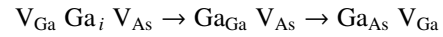
Boltovets et al. (2002); Belyayev et al. (2012)

Bacherikov et al. (2003); Pashkov et al. (1994); Boltovets et al. (2002); Milenin et al. (1994); Belyaev et al. (2002)



Zohm et al. (2000)

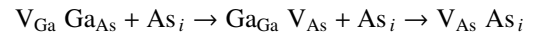
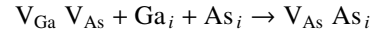
Fang et al. (1990)



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)



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.

Acknowledgment

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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						

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 ÷ 0.33	-	V _{As}	LDA	no	Schultz (2015)
0.33	1 · 10 ⁻¹⁷	-	TSC	no	Pavlović et al. (2000)
0.323	1 · 10 ⁻¹⁴	-	DLTS	yes	Yousefi et al. (1995)
0.334	2 · 10 ⁻¹⁵	-	DLTS	yes	Yousefi et al. (1995)
0.35	-	complex with V _{As}	PA	no	Kuisma et al. (1997)
0.315 ÷ 0.325	3 · 10 ⁻¹⁷	-	TSC	no	Pavlović and Desnica (1998)
0.33	-	-	TSC	no	Tomožane and Nannichi (1986)
0.30 ÷ 0.33	-	-	DLTS	no	Lang et al. (1976)
EGA2, $(E_c - E_t) = (0.28 \div 0.30)$ eV					
0.28	5 · 10 ⁻¹⁸	V _{As} As _i	TSC	no	Pavlović et al. (2000)
0.26	3.5 · 10 ⁻¹⁵	-	DLTS	yes	Yousefi et al. (1995)
0.277	5 · 10 ⁻¹⁷	-	TSC	no	Pavlović and Desnica (1998)
0.284	1 · 10 ⁻¹⁷	-	TSC	no	Pavlović and Desnica (1998)
0.28	-	intrinsic	TP	no	Abele et al. (1987)
0.28	8 · 10 ⁻¹⁵	-	DLTS	yes	Mircea and Mitonneau (1975)
0.30	-	complex with Te	DLTS	no	Kol'chenko and Lomako (1994)
0.30	6 · 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 · 10 ⁻¹⁶	As _{Ga} ⁺⁺	TSC	no	Pavlović et al. (2000)
0.485	2 · 10 ⁻¹⁶	-	TSC	no	Pavlović and Desnica (1998)
0.48	-	impurity	TP	no	Abele et al. (1987)
0.51	1 · 10 ⁻¹²	-	DLTS	no	Martin et al. (1977)
0.48	3 · 10 ⁻¹³	-	DLTS	no	Lang et al. (1976)
0.50	1 · 10 ⁻¹⁵	V _{As} , V _{Ga} Ga _i V _{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 · 10 ⁻¹³	-	DLTS	yes	Bourgoin et al. (1988)
0.40	-	-	SCRC	yes	Ashby et al. (1976)
0.37	2 · 10 ⁻¹⁴	-	DLTS	yes	Fang et al. (1987)
0.40	-	V _{Ga} Ga _{As}	DLTS	no	Vaytkus et al. (1988)
0.387	2 · 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 · 10 ⁻¹⁷	-	TSC	no	Pavlović et al. (2000)
0.22 ÷ 0.25	8 · 10 ⁻¹⁹	-	TSC	no	Lin et al. (1976)
0.26	-	complex with V _{Ga}	TSC	no	Fang et al. (1990)
0.24	-	-	TSC	no	Tomožane 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 · 10 ⁻¹⁴	V _{Ga} V _{As}	DLTS	no	Bourgoin et al. (1988)
0.23	7 · 10 ⁻¹⁵	-	DLTS	yes	Mircea and Mitonneau (1975)
0.22	2 · 10 ⁻¹⁵	-	DLTS	no	Fang et al. (1987)
0.258	4 · 10 ⁻¹⁶	-	DLTS	yes	Yousefi et al. (1995)
EGA6, $(E_c - E_t) = (0.43 \div 0.46)$ eV					
0.44	1 · 10 ⁻¹⁴	V _{As} As _i , V _{As}	TSC	no	Pavlović et al. (2000)
0.44	9 · 10 ⁻¹⁵	-	TSC	no	Pavlović and Desnica (1998)
0.43	7 · 10 ⁻¹⁶	intrinsic	DLTS	yes	Lefèvre and Schulz (1977)
0.44	2 · 10 ⁻¹⁵	complex with V _{As}	DLTS	yes	Bourgoin et al. (1988)
					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

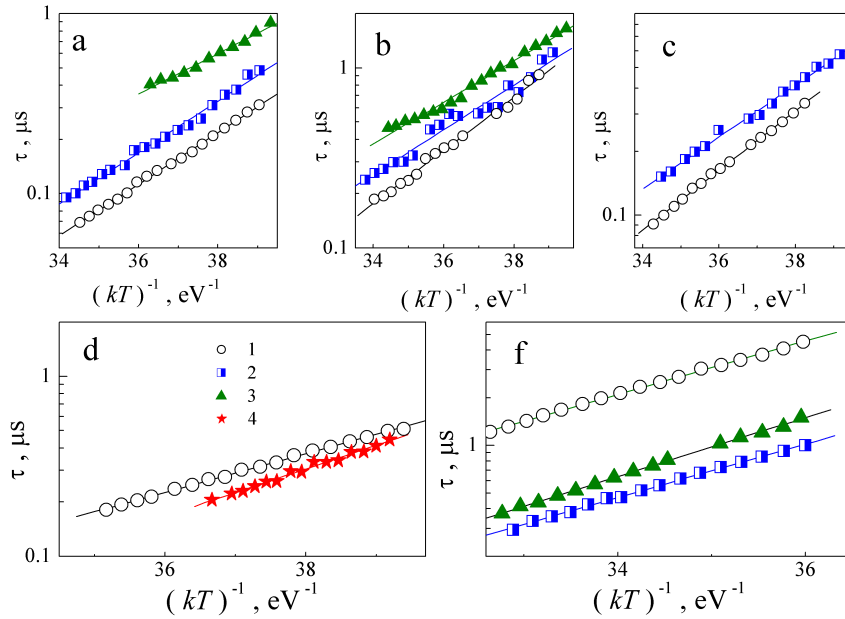


Figure 3: Dependences of TAV relaxation time on inverse temperature for samples SIC2 (a), SIC3 (b), GAS2 (c), GAE2 (d) and GAB1 (e) before and after MWT. t_{MWT} , s: 0 (curves 1), 20 (2), 40 (3), 60 (4)

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