Imaginenano-Graphene 2013

Enabling the Era of Carbon Electronics: Turning Diamond into Graphene

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Abstract

The potential uses of carbon in electronics has grown rapidly in the last 10 years as the breadth of its potential applications has begun to be appreciated fully. We are now able to design electronic devices based on the allotropes of carbon materials, including diamond, diamond-like carbon and graphene. While graphene is an electrically conductive 2-dimensional sheet of sp2 bonded carbon atoms, in diamond the carbon atoms bond in an sp3tetrahedral structure and the wide band gap (5.5 eV) semiconductor diamond is formed. The combination of extreme electronic and thermal properties found in synthetic diamond produced by chemical vapor deposition (CVD) make it an ideal semiconductor material. Experimental studies have demonstrated charge-carrier mobilities of >3000 cm2V–1s–1, thermal conductivities >2000 Wm–1K–1, and has a breakdown field strength in excess of 10 MVcm–1. Diamond is the perfect semiconductor material wherever high frequencies, high powers, high temperatures or high voltages are required.

We will present a novel technology that allows the fabrication of graphene directly on diamond substrates thus enabling the creation of novel graphene on diamond electronics devices enabling the new era of carbon electronics

Table 2 Intrinsic material properties and figures of merit (normalized to Si = 1) at room temperature for Si, 4H-SiC, GaN, natural and synthetic CVD diamond[1]. 4H is the polytype of SiC that is considered best suited for power electronic devices as it has the highest mobility.

	Si	4H-SiC	GaN	Natural Diamond	CVD Diamond	Potential device application benefit
Bandgap (eV)	1.1	3.2	3.44	5.47	5.47	High temperature
Breakdown field ($MVcm^{-1}$)	0.3	3	5	10	10	High voltage
Electron saturation velocity ($\times 10^7$ $cm\ s^{-1}$)	0.86	3	2.5	2	2	High frequency
Hole saturation velocity ($\times 10^7$ $cm\ s^{-1}$)	n/a	n/a	n/a	0.8	0.8	
Electron mobility ($cm^2\ V^{-1}\ s^{-1}$)	1450	900	440	200–2800	4500	
Hole mobility ($cm^2\ V^{-1}\ s^{-1}$)	480	120	200	1800–2100	3800	
Thermal conductivity ($Wcm^{-1}\ K^{-1}$)	1.5	5	1.3	22	24	High power
Johnson's figure of merit	1	410	280	8200	8200	Power-frequency product
Keyes' figure of merit	1	5.1	1.8	32	32	Transistor behavior thermal limit
Baliga's figure of merit	1	290	910	882	17200	Unipolar HF device performance

References

[1] A. Galbiati, "Contacts on Diamond", *US Patent* US8119253, (2012).

Figures: [2] Balmer et al., "Diamond as an Electronic Material", Materials Today, Issue 1-2, (2008), p.25