Silicon Carbide, Some electrical Properties and Applications

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Abstract

The structure and some electrical propertie of SiC are reviewed, making enphasis in the application in high temperature and high power electronics .Some semiconductors devices are discused.

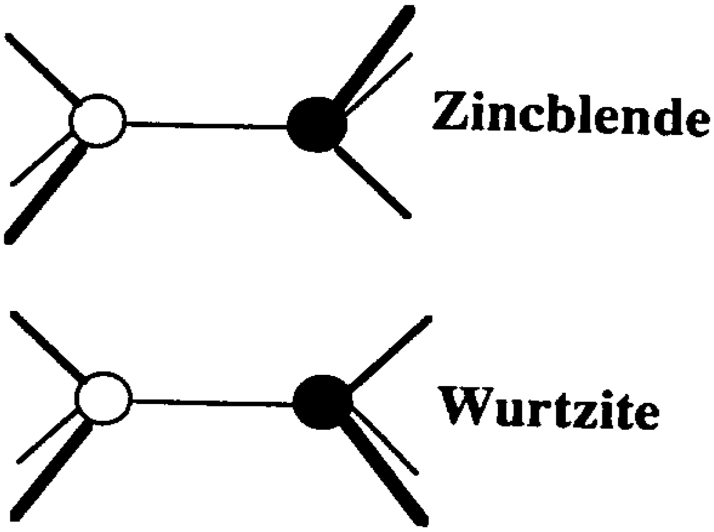

Figure 1: Zinc-blende and wurtizite bonding in SiC, Zinc blende bonds are rotated 60 degrees with respect to nearest neighbors while hexagonal bonds are mirror images

1 Introduction

Silicon Carbides are materials with a wide range of application. Its physical properties make it ideal for high temperature and high power electronic aplications, its optical applications are of great importance. In this article some electrical properties of SiC are reviewed and some applicaction are discused as well as some of the SiC electronic devices.

2 Structure

Silicon Carbide polytypes belongs to a family of closed packed materials. They are composed of coordinating tetrahedra that could be either SiC_4 or CSi_4. They share corners so that the 4 fold coordination requirements of the carbon and silicon are satisfied. The tetrahedra are at positions similar to those of spheres in close-packed structures. The stacking sequence of the tetrahedra gives the different SiC polytypes, and the stacking periodicity determines the overall crystal symmetry while bond length and local atomic environments are almost the same/cite1. One of the corners of the tetrahedra lies out of the layer plane, therefore there will be tetrahedrally bonded Si-C bilayers. The stacking sequence of the bilayers is described by an ABC notation. The ABCABC stacking will be cubic zinc-blende structure denoted as 3C SiC and also called beta SiC (Fig. 1), in the notation the 3 refers to the bilayer periodicity of the stacking and the C refers the overall cubic symmetry. The ABAB stacking will have hexagonal symmetry and two bilayer stacking periodicity, it is denoted as 2H SiC. Therefore depending on the stacking the bonding will be zinc-blende or wurtzite nature. There are many other polytypes, but basically they are mixtures of the 3C SiC and 2H SiC. Possible structures will be 4H and 6H SiC where the 4H is composed equally of cubic and hexagonal bonds while the 6H is two thirds cubic. The hexagonal

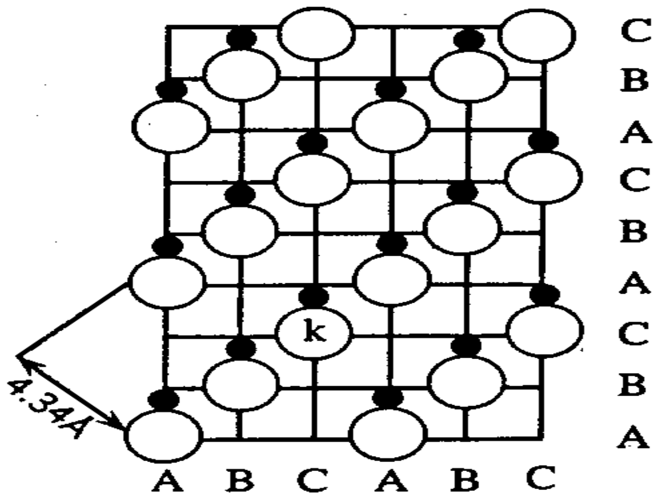

Figure 2: Cubic 3C SiC polytype, k represents cubic symmetry

polytypes is also called alpha SiC. [2]

3 Some Physical Properties

SiC is one of the first known semiconductors, it has many application in the industry for its different properties, not only its electrical but it is used in many high temperature application as heat engines/cite2. Some of the electronic properties are its high electron saturation velocity, its wide band gap that can range from 2.3 eV for 3C SiC to 2.9 eV in 6H SiC to 3.3 eV for 2H SiC, its high thermal conductivity among others/cite1. It also can be oxidized giving a entire range of oxide-based devices to be made. Table 1 gives us a good idea of the possibilities of SiC as a high temperature and high power electronic material. We have in table 1 others materials that can be used with the same purposes. The most notables features are the large thermal conductivity and breakdown voltages. Also we can see the maximum device operating temperature parameter, this is the temperature at which the carrier concentration equals 5x10 exp 15 cm-3 and it tells about the band gap limitation on device operation. In (Fig. 4) we see the behavior of the saturation velocity with the electric field, it shows that SiC works well at much higher electric fields than conventional semiconductors.

4 Some Applications in Electronics.

SiC have been used in field-effect transistors (FET). The band gap allows low leakeage current and large breakdown voltages, so that the devices can be used at high temperatures. There are several types of SiC FETs that have been fabricated: MOSFETs,junction FETs (JFET) and metal semiconductor FETs. MOSFETs have use in high power applications.

Property	Si	GaAs	GaP	3C SiC (6H SiC)	Diamond	GaN
Band gap (eV) at 300 K	1.1	1.4	2.3	2.2 (2.9)	5.5	3.39
Maximum operating temperature (K)	600?	760?	1250?	1200 (1580)	1400(?)	
Melting point (K)	1690	1510	1740	Sublimes >2100	Phase change	
Physical stability	Good	Fair	Fair	Excellent	Very good	Good
Electron mobility RT, $cm^2/V\,s$	1400	8500	350	1000 (600)	2200	900
Hole mobility RT, $cm^2/V\,s$	600	400	100	40	1600	150?
Breakdown voltage E_b, 10^6/V/cm	0.3	0.4	-	4	10	5?
Thermal conductivity c_T, W/cm	1.5	0.5	0.8	5	20	1.3
Sat. C . elec. drift vel. v(sat), 10^7 cm/s	1	2	-	2	2.7	2.7
Dielectric const. K	11.8	12.8	11.1	9.7	5.5	9

Figure 3: Table 1. Important properties of some semiconductors

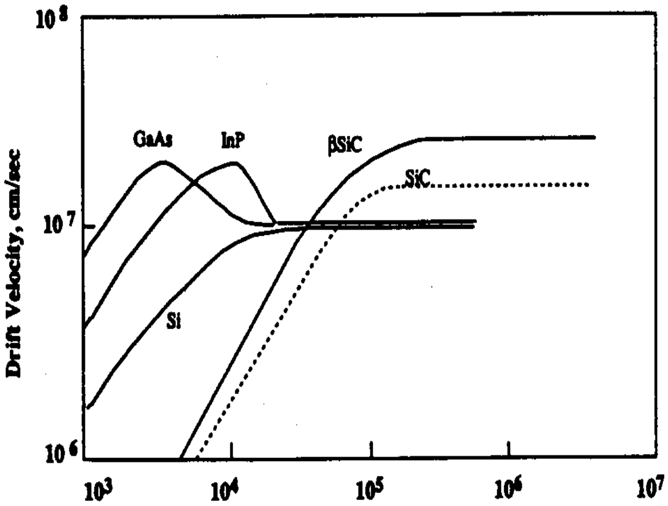

Figure 4: Cubic 3C SiC polytype, k represents cubic symmetry

The current handling capabilities of Si MOSFETs are limited. The higher-field operation of SiC devices reduce the specific resistivity improvbing the currents capabilities of SiC, 6H SiC could perform 13 times the power of Si devices/cite1. We also can mention The siC bipolar transistor, that could work at higher temperarures than Si transistor. The SiC rectifiers has some remarkables power handling capabilities at high temperatures. SiC electronic devices also can have application for optical detection.

References

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