CVD Growth and Characterization of β-SiC for IR Windows

Jitendra S. Goela

Morton Advanced Materials, 185 New Boston St., Woburn, MA 01801

ABSTRACT

The status of transparent SiC for short wave (3–5 μm) windows and domes is reviewed. Transparent β-SiC was fabricated by the pyrolysis of methyltrichlorosilane in the presence of excess H_2 and argon in a hot wall, chemical vapor deposition reactor. Characterization of the material indicates that the transparent SiC is a theoretically dense, void free, highly pure (99.9996%) cubic material possessing high optical transmission in the wavelength region 0.5-6 μm, excellent thermal shock resistance and good optical, mechanical, thermal, and electrical properties of interest for windows and domes. Important properties of transparent SiC are compared with those of the other candidate window materials in the 3-5 μm region. Silicon carbide samples of different transparency were characterized to correlate the material transmission with other important material properties. Finally, use of transparent SiC as windows and domes for severe environments is discussed.

Keywords: Silicon Carbide, SiC optics, SiC window, Beta-SiC, CVD-SiC, Transparent SiC, SiC domes

1. INTRODUCTION

High speed missiles flying at Mach number > 3 place stringent requirements on the properties of transmissive dome materials that are used to provide environmental protection to infrared detectors. The dome material must withstand not only the excessive thermal heat loads but also be more durable and resistant to rain and dust erosion at high Mach numbers. The ideal dome material should have high transmission in short wave (3-5 μm) or long wave (8-12 μm) infrared bands, low absorption and scattering of radiation, low thermal expansion coefficient and density, high flexural strength and thermal conductivity, and high thermal shock and oxidation resistance. Bulk diamond is considered one good candidate dome material for the long wave infrared region but issues such as cost, fabricability, i.e. grinding and polishing, low deposition rates, scalability, non-uniform bulk properties, and low flexural strength and oxidation threshold (< 600°C) need to be resolved to make its use attractive for this application. In the 3-5 μm region, sapphire is considered better than several competing dome materials such as spinel, ALON, MgF_2, and Y_2O_3 but sapphire is anisotropic, possesses low compressive strength at elevated temperatures and is produced in a single crystal form, which presents issues of scalability and near-net shape fabrication.

Beta-SiC is considered an attractive candidate material in the visible and short wave infrared regions due to its isotropic properties (i.e. cubic structure), low density and thermal expansion coefficient, high thermal conductivity and flexural strength, and high thermal shock, oxidation and rain

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15. SUBJECT TERMS
Silicon Carbide; SiC optics; SiC window; Beta-SiC; CVD-SiC; Transparent SiC; SiC domes

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erosion resistance potential. In the past β-SiC has been fabricated extensively by using different methods such as single crystal growth, chemical vapor deposition (CVD), sintering and hot pressing and reaction bonding techniques. However, none of these past attempts succeeded in producing large size, bulk β-SiC of good optical transmission. Although single crystal[1-2] or thin film epitaxial growth techniques[3-5] yielded good quality β-SiC, the size or thickness of the material produced was quite small. Efforts that used post-deposition annealing of CVD SiC β-SiC[6] had the potential of yielding large area transparent SiC, but the best value of attenuation coefficient obtained at 3 μm was about 11 cm^{-1}, which is large for high-speed missile applications. Other efforts that used CVD techniques[7-9], and were focused specifically on improving optical transmission of β-SiC, also had limited success. Weiss and Diefendorf[8-9] obtained small pieces of translucent SiC (attenuation coefficient = 6 cm^{-1} at 0.6328 μm) by flowing reagents in a small slot at high speed, but when the same reagents were made to flow in a larger area box, opaque SiC was produced. Chu and Han[10] correlated the SiC deposit morphology to infrared transmission, but from their manuscript, it is not clear what value of attenuation coefficient they obtained. Finally, translucent, yellow colored SiC dummy wafers (thickness < 0.5-mm) have been made by some SiC manufacturers for semiconductor applications[11]. Although the exact value of the absorption coefficient for this material is not known, the transmission through these wafers is not sufficiently large for them to be useful for window applications.

At Morton Advanced Materials, bulk transparent β-SiC of superior properties was fabricated by a hot wall CVD process[12-17]. This material was produced by using the same CVD method as was used previously[18-24] for fabricating opaque bulk SiC but using a different set of process conditions. Transparent SiC is clear yellow in color as opposed to the dark gray or black color of the opaque material. Transparent SiC possesses high transmission in the wavelength range of 0.5–6 μm with attenuation coefficient of about 7 cm^{-1} and 2 cm^{-1} at 0.6328 μm and 3 μm respectively. Over the same wavelength range, the attenuation coefficient of the opaque SiC is greater than 60 cm^{-1}. If thin (<50 μm) samples of the opaque SiC are fabricated they appear yellow and transparent, but their attenuation coefficient was also measured to be > 60 cm^{-1}.

The purpose of this article is to review the current status of transparent β-SiC for use in infrared windows and domes. In the past few years, not much work was reported on the development of CVD or single crystal SiC for window applications. Most SiC research was concentrated on developing single crystal SiC for semiconductor device applications and polycrystalline SiC for semiconductor furnace furniture, wear parts and mirror applications.

In Section 2 that follows, experimental details about the CVD process used to fabricate transparent SiC are provided. For comparison purposes, the CVD process conditions that produce the opaque SiC are also discussed. Important properties of transparent SiC are presented in Section 3. A correlation between optical transparency of CVD SiC and other properties is provided in Section 4. The application of transparent SiC for windows and domes is discussed in Section 5. Also included in this section is a comparison of transparent SiC properties with other candidate window materials. Finally, summary and conclusions are provided in Section 6.

2. TRANSPARENT SiC CVD PROCESS

At Morton Advanced Materials, both, the opaque and transparent SiC have been produced by the pyrolysis of MTS in excess H_2 in a hot wall CVD reactor. The CVD process is attractive because it is scalable to large sizes, that it is reproducible and can provide near net shape and precision replicated parts. The key to obtaining material with good transmission is to slow down the reaction rate for the pyrolysis of MTS to minimize crystal disorder in the material. This is accomplished by adding a small amount of HCl in the reaction mixture and by operating the process at relatively low pressures and high temperatures.

The CVD process conditions used for producing the transparent SiC were: substrate temperature = 1380-1470°C, furnace pressure = 2-25 torr, and H_2/CH_3SiCl_3 molar ratio = 10-30. Addition of 5-20% HCI was determined to be beneficial in enhancing the transmittance of transparent SiC. The deposition rate was 0.2-1 μm/min. Further, elaborate arrangements were made to tailor the flow pattern in the deposition area to obtain good yield of transparent SiC. Transparent SiC samples up to a size of 30 cm^2 x 1.5 mm thick were fabricated. This material is currently under development at Morton.

To compare, the process conditions for producing the opaque SiC are as follows: substrate temperature = 1350°C, furnace pressure = 200 torr, and H_2/MTS molar ratio = 4-7. The deposition rate was 1-2 μm/min. The CVD-SiC process has been scaled to produce plates up to a size of 1.5 m diameter x 2.5 cm thick. The opaque SiC is currently being produced on a large scale and is available commercially under the trade name CVD SILICON CARBIDE®.

Figure 1 shows a schematic of the CVD process that was used to produce CVD-SiC. It consists of a resistivity heated furnace, with a maximum temperature capability of 1500°C. The outer chamber of this furnace is made of stainless steel, which is water-cooled. Inside this furnace the SiC deposition occurs on the inside walls of a graphite square box and on top of a horizontal circular baffle placed downstream. The flow of reagents is from top to bottom. Since MTS is a liquid at room temperature with a vapor pressure of about 140 torr, it is carried to the deposition area using argon as a carrier gas. After the reaction chamber, the reagents pass through a filter to trap solid particles, then to a scrubber to neutralize chlorine compounds and, finally, H_2 and argon are vented to the atmosphere.

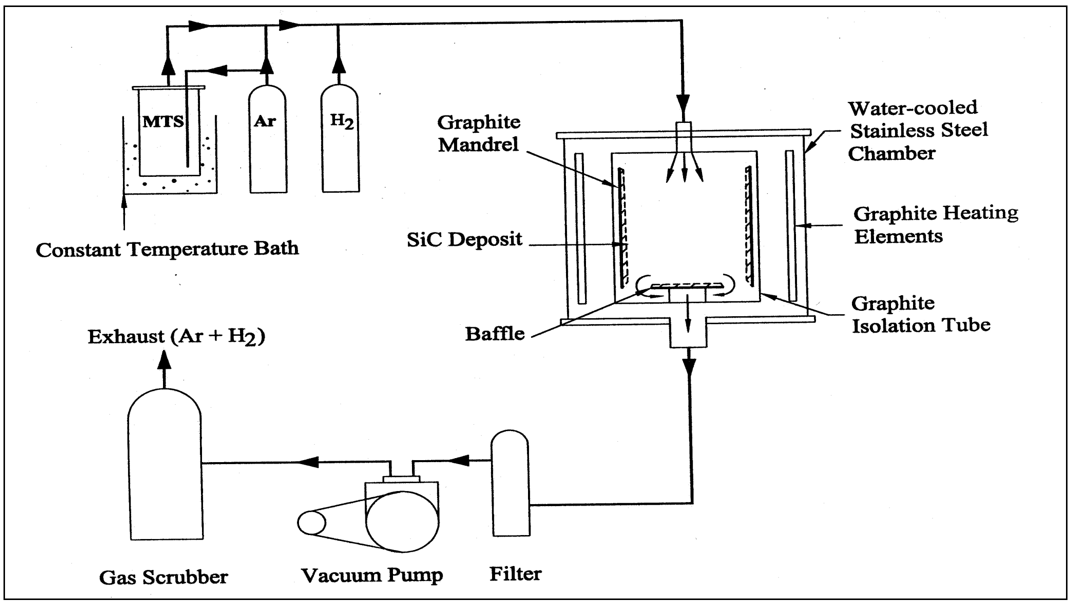


Figure 1: A schematic of CVD-SiC process used to produce transparent SiC.

Figure 2 shows a picture of a transparent SiC sample produced by the CVD process. The thickness of this sample is 0.54-mm. Due to the black and white picture the yellow color of the material cannot be seen in this picture. For the same thickness, the opaque material will appear black.

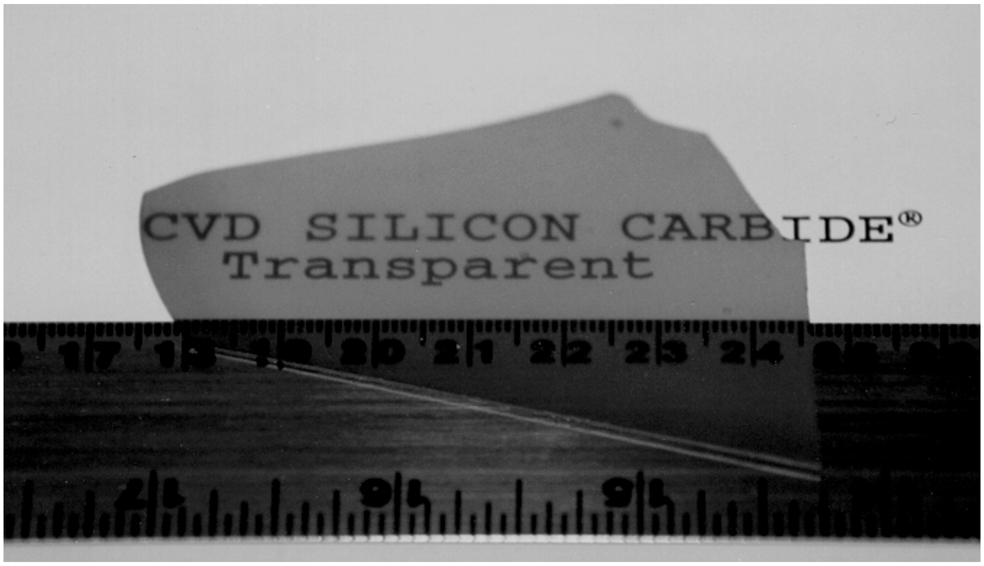


Figure 2: A picture of a transparent SiC sample of thickness = 0.54 mm. Due to black and white picture, the yellow color of the SiC sample is not visible.

3. PROPERTIES OF TRANSPARENT SiC

Not many studies have been performed on the transparent SiC because it is a relatively new material and is still under development. A few samples of transparent SiC were fabricated and characterized for density, crystal structure, visible-infrared transmission, infrared absorption and emittance, hardness, fracture toughness, chemical purity, thermal expansion coefficient, thermal conductivity, electrical resistivity, elastic modulus, dielectric properties, refractive index, change of refractive index with temperature and microstructure. These data are summarized in Table 1, which is discussed in more detail in Section 4. From this table it can be seen that transparent SiC is a theoretical dense, fine grain, highly oriented (111) polycrystalline β-phase material with good transmission in the wavelength region 0.5 – 6 μm. Transparent SiC possesses a high value of thermal conductivity, elastic modulus and electrical resistivity. Currently the thermal conductivity of transparent SiC is 214 $Wm^{-1}K^{-1}$, which is about 43.7% of the single crystal value. The thermal conductivity of a material usually correlates quite well with its optical transmission. A large difference in thermal conductivity values of the transparent and single crystal SiC indicates that the CVD process potentially could be further optimized to enhance both these properties.

Table 2 shows the typical trace element concentration in a sample of transparent SiC. These measurements were performed at Northern Analytic Laboratory, NH. There are five metallic contaminants, Cr, Fe, W, Ni, and As with concentration ≥ 0.1 ppmw (parts per million by weight). Most of these contaminants are traceable to the raw material (CH_3SiCl_3) and the stainless steel injector. The total concentration of impurities in transparent SiC is about 3.2 ppmw. Thus transparent SiC is a high purity material.

Table 1: Important Properties of Transparent and Opaque CVD-SiC

Property	Average Value	
	Opaque CVD-SiC	**Transparent SiC**
Color	Dark gray	Yellow
Crystal Structure	FCC, polycrystalline, β-phase, Randomly oriented	FCC, polycrystalline, β-phase, Highly oriented, <111>
Density (g cm^{-3})	3.21	3.21
Average Grain Size (μm)	5 – 10	5 – 10
Trace Element Impurities (ppmw)	< 3.5	< 3.5
Transmittance, 0.6-5.6 μm (0.5-mm thick)	0%	> 40%
Attenuation Coefficient (cm^{-1}) @ 0.6328 μm 3 μm	 >100 >60	 6.9 2.2
Vickers Hardness (1 Kg load)	2540	2540
Fracture Toughness, K_{1C} (MN $m^{-1.5}$)	3.4	2.2
Elastic Modulus, GPa	466	466
Flexural Strength, MPa	421	---
Weibull Modulus, m	11.45	---
Coefficient of Thermal Expansion (10^{-6} K^{-1}) @ 293K	2.2	---
Thermal Conductivity (W m^{-1} K^{-1}) @ 27C	297	214
Heat Capacity ($Jkg^{-1}K^{-1}$)	640	---
Electrical Resistivity (ohm-cm)	1-50	$4.5x10^{4}$
Dielectrical Constant (35-50 GHz)	----	136
Dielectrical Loss (35-50 GHz)	----	75
Loss tangent	----	0.55
Refractive Index @ 633 nm 1152 nm 1523 nm	 2.635 2.576 2.566	 2.635 2.576 2.566
Thermo-optic Coefficient, dn/dT (10^{-6} K^{-1}) @ 2 - 4 μm	----	37

Table 2: Trace Element Analysis of Transparent SiC

Element	Concentration (ppmw)	Element	Concentration (ppmw)	Element	Concentration (ppmw)
Li	<0.01	Cl	0.3	Co	0.03
B	0.06	K	0.06	Ni	0.5
F	0.02	Ca	<0.1	Cu	0.03
Na	0.007	Ti	0.01	Zn	≤0.01
Mg	0.03	V	0.005	As	0.1
Al	0.04	Cr	0.3	Zr	≤0.05
P	0.05	Mn	0.01	Mo	≤0.1
S	0.06	Fe	0.5	W	0.8
Total					**≤3.27**

The refractive index of transparent SiC was measured with a prism coupling method at three wavelengths - 633-nm, 1152-nm and 1523-nm, and was determined to be the same as that of α-SiC. The refractive index inhomogeneity was determined by measuring refractive index at several locations. No difference in the refractive index was measured. Thus the refractive index inhomogeneity of one part per thousand is limited by the capability of the measurement technique.

Figure 3 shows a plot of visible-infrared transmittance of transparent SiC. The sample thickness was about 0.25 mm. The maximum transmittance is about 65%, which is close to the theoretical value for β-SiC. This transmittance corresponds to specular attenuation coefficient of about 2 and 6.9 cm^{-1} at wavelength 3 and 0.6328 μm, respectively. The specular attenuation coefficient at 1.06 μm is 1 cm^{-1}, and an attenuation coefficient of < 1 cm^{-1} is obtained at 2 μm. When the scatter contribution is subtracted from the attenuation coefficient, absorption coefficient is obtained. The absorption coefficient at two different temperatures, 291K (lower curve) and 912K (upper curve) as function of wavelength in the range of 2.5 - 6.67 μm is shown in Figure 4 (dotted line shows the data while solid line shows multi-phonon model calculations)[25]. At wavelength < 3 μm, the four phonon band is visible. We see that at 3 μm, the absorption coefficient is about 0.1 cm^{-1} at 291K and it is about 0.4 cm^{-1} at 912K. As the wavelength decreases, the absorption coefficient also decreases. The absorption coefficient values at other wavelengths are summarized in Table 3.

The emittance of 1-mm thick sample of CVD-SiC is computed based upon the above absorption coefficient and is plotted in Figure 5 as function of wavelength. The mean emittance at 4-5 μm is about 0.3 at room temperature and 0.5 at 815K. However, in the 3-4 μm range, the mean emittance is about 0.05 at room temperature and about 0.1 at 815K. These data show that transparent SiC is a good candidate window material for high temperature applications, particularly at wavelength < 4 μm. In the 4-5 μm wavelength region, the high emissivity values make the transparent SiC less attractive for window applications. However, since there is an absorption band at 4.3 μm due to the presence of CO_2 in the atmosphere, in principle, emittance contribution to the detector can be reduced by blocking the radiation at 4.3 μm with a filter.

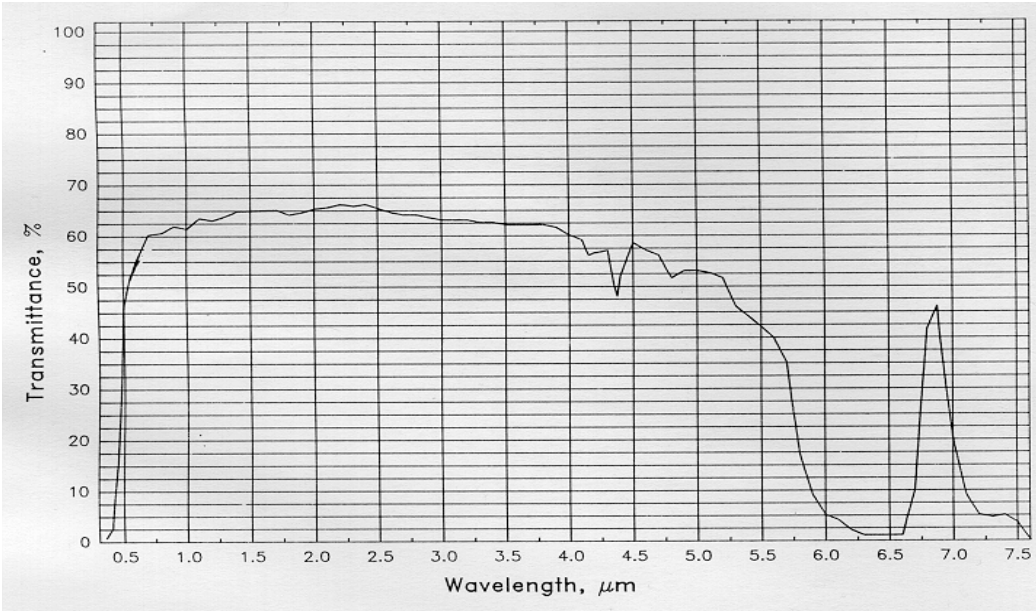


Figure 3: Visible-infrared transmittance of a transparent SiC sample of thickness = 0.25 mm

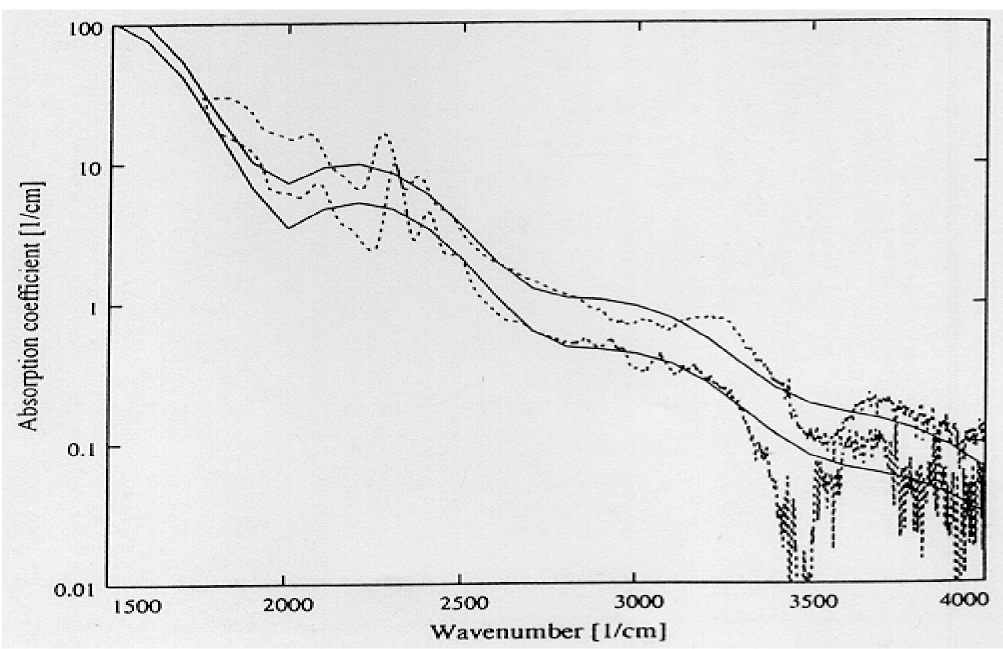


Figure 4: Absorption coefficient of transparent SiC as function of wavelength at two different temperatures, 291K (lower), 912K (upper). Data (dotted lines) are compared with multi-phonon model[25].

Table 3: Absorption Coefficient of Transparent SiC

Wavelength (μm)	Absorption Coefficient (cm^{-1}) 291K	609K	912K
5.4	14.42	16.84	28.09
4.89	6.0	7.72	16.2
4.47	2.4	3.0	10.11
3.96	1.38	1.53	2.6
3.49	0.52	0.56	0.92
3.22	0.31	0.38	0.65
2.95	0.51	0.17	0.27

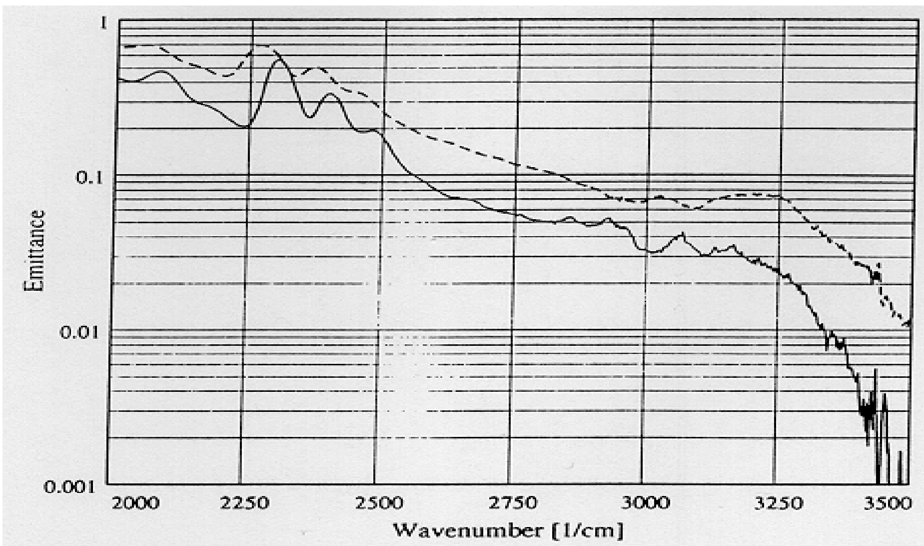


Figure 5: Calculated emittance of transparent SiC at 291K (solid line) and 912K (dashed line). The material thickness was assumed to be 1 mm.

The change in refractive index with temperature, dn/dT for transparent SiC as function of wavelength in the region of 2-4 μm is shown in Figure 6[25]. We see that dn/dT value is fairly constant in this wavelength range and equal to about 37 x 10^{-6} K^{-1}.

It will be of interest to compare the infrared transmission of Morton transparent SiC with that of single crystal α-SiC. In recent years, significant advances in the crystal growth technology has resulted in producing single crystal SiC wafers, which have minimal doping, and excellent infrared transmittance. Figure 7 shows a plot of transmission versus wavenumbers for a semi-insulating sample of 4H SiC. Other α-SiC also show similar transmission behavior. The thickness of this sample was 0.35 mm. We see that the transmission in the 3-4 μm range is about 68%, which is close to the theoretical value. Further, the attenuation coefficient in 4-5 μm wavelength range for this material is close to the absorption coefficient as calculated in Reference 25.

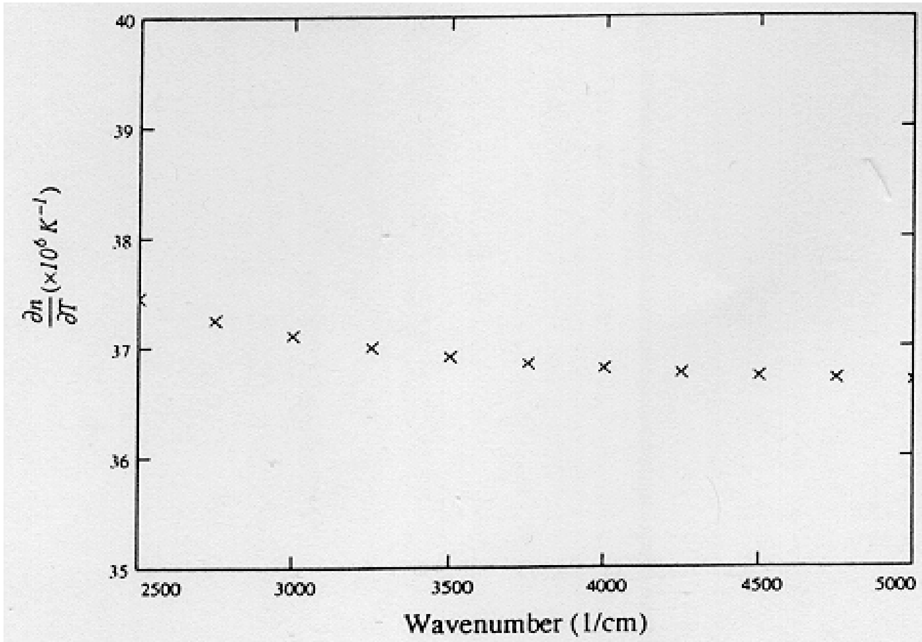


Figure 6: Thermo-optic coefficient, dn/dT of transparent SiC as function of wavelength.

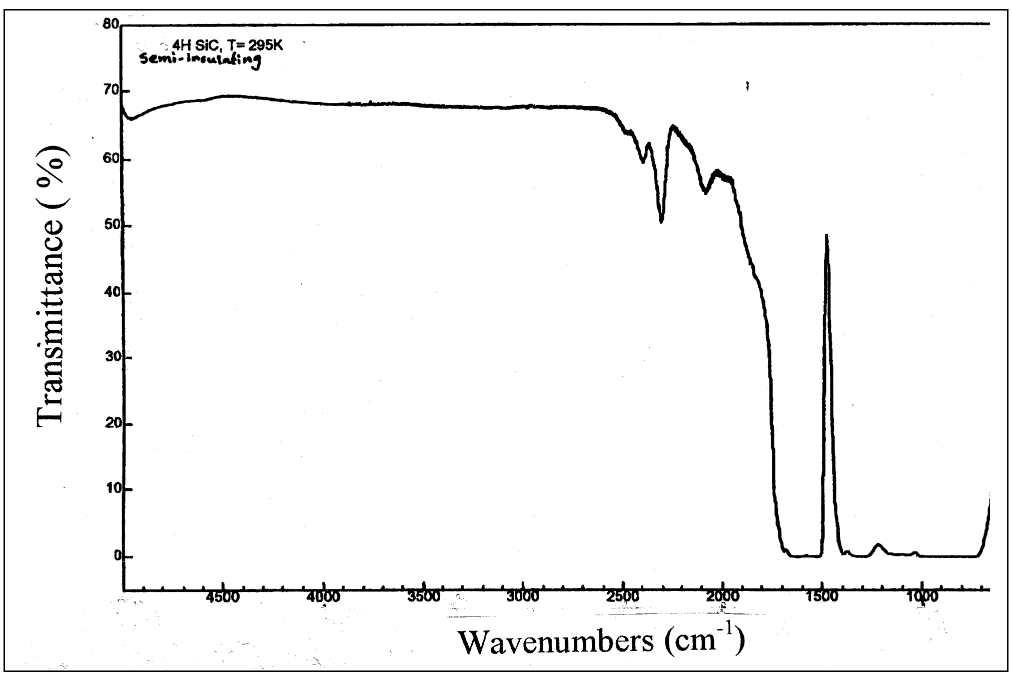
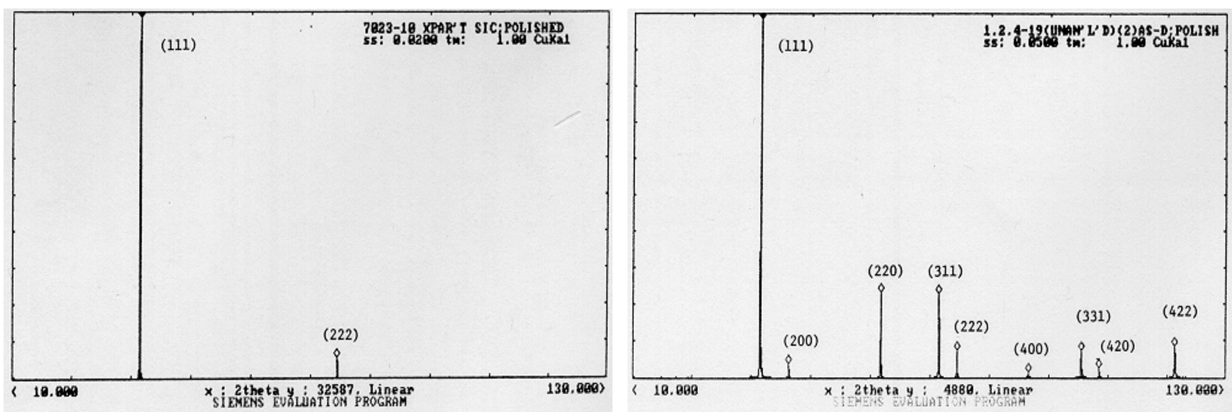


Figure 7: Infrared transmittance of a semi-insulating 4H single crystal SiC sample. Thickness = 0.35 mm (Courtesy Gail Brown, AFRL/MLPO, Wright Patterson Air Force base, Ohio).

4. COMPARISON BETWEEN TRANSPARENT AND OPAQUE SiC

It will be illuminating to see how other important properties compare between the transparent and opaque SiC. Silicon carbide samples were characterized for density, refractive index, fracture toughness, grain size, thermal expansion coefficient, thermal conductivity, electrical resistivity, chemical purity, crystallographic structure, and secondary ion mass spectroscopy (SIMS), Auger and transmission electron microscopy (TEM) analysis. Table 1 shows this comparison. We see that density, thermal expansion coefficient, average grain size and chemical purity of transparent SiC are either the same or close to those of the opaque SiC. However, the thermal conductivity and fracture toughness of transparent SiC are less than those of the opaque SiC.

The crystallographic structure of both forms of SiC, as determined from the x-ray diffraction is cubic, β-phase. However, the transparent SiC is highly oriented along the (111) direction, while the opaque material is randomly oriented[16]. This can be seen in Figure 8. The transparent SiC shows only two peaks, (111) and its reflection, (222). On the other hand the opaque SiC shows nine peaks, which are all assigned to β-phase SiC. The relative intensities of these peaks are close to those of the β-SiC powder pattern[16].

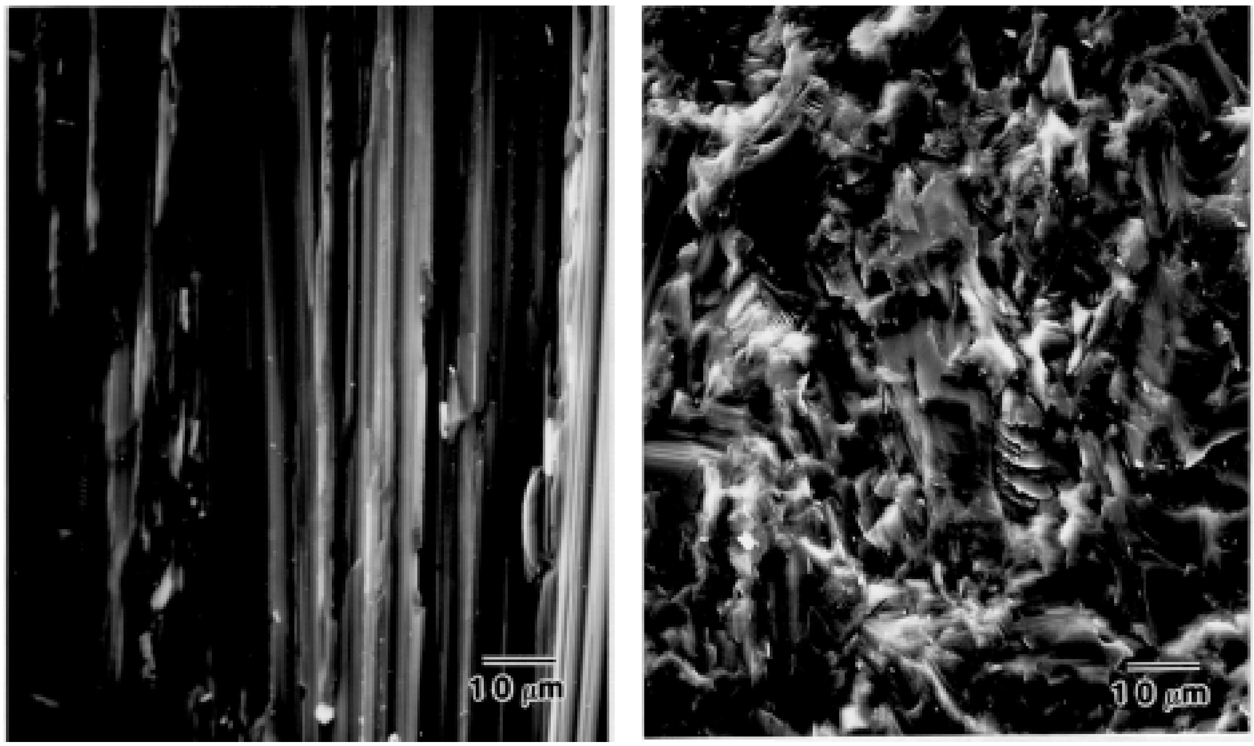


(a) **(b)**

Figure 8: X-ray diffraction scan of (a) transparent SiC, (b) opaque SiC

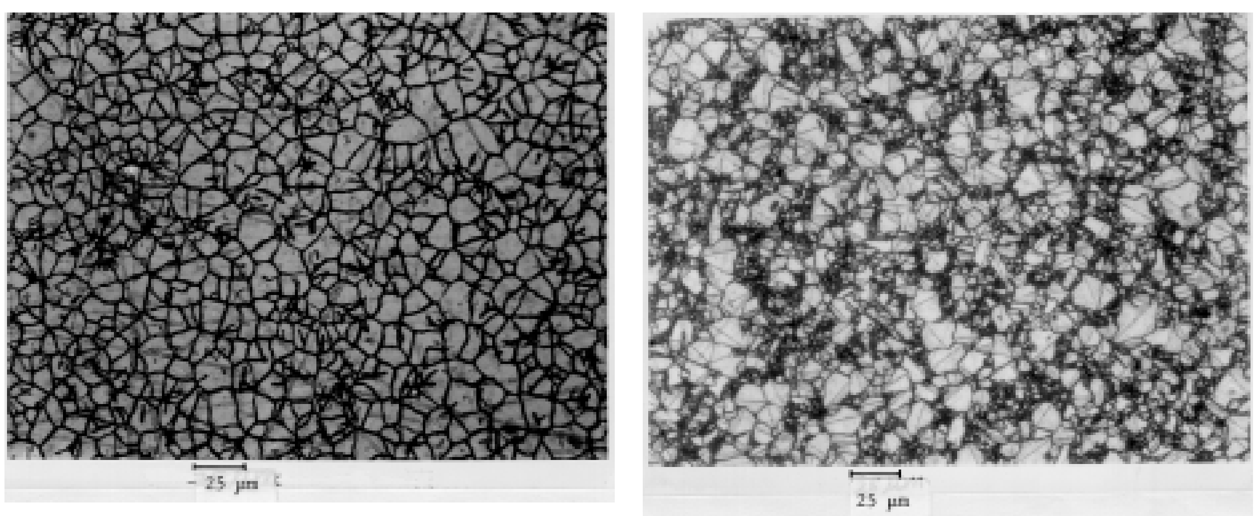
In order to obtain the microstructure of the two types of SiC, samples were fractured manually perpendicular to the deposition surface and the cross-sections were examined with scanning electron microscope (SEM). Figure 9 shows the observed microstructure. We see that the transparent sample exhibits the columnar growth pattern while the opaque material shows the random growth pattern confirming the results of x-ray analysis. Thus the preferred orientation may be the key to reducing scattering in the material and thus obtaining high transmittance SiC.

The microstructure parallel to the deposition surface was examined with an optical microscope for both types of SiC. The SiC samples were prepared by first polishing the surface followed with etching them with KOH pellets at about 700°C. The microstructures are shown in Figure 10. It can be seen that the transparent SiC has relatively more uniform grains than the opaque material. However, the average grain size of both the materials is the same i.e. 5–10 μm. A wider range of grain size can also lead to an increase in scattering resulting in loss of transmission.



(a) (b)

Figure 9: SEM micrograph of fractured surfaces perpendicular to deposition surface (cross-section), (a) transparent SiC , (b) opaque SiC.



(a) (b)

Figure 10: Microstructure parallel to deposition surface for (a) transparent SiC, (b) opaque SiC.

The two types of SiC were also characterized with TEM and high resolution electron microscopy (HREM). For this analysis, the samples were prepared by first slicing parallel to the deposition surface, then grinding, followed by mechanical dimpling and finally, two-sided milling was performed with an argon ion source. At least two samples of each type were examined. These results, which are discussed in more detail in Reference 16 are summarized below.

TEM images showed that some transparent SiC grains were totally free of defects, while others contained a low density of dislocations. Grains were about 5-10 μm in size, and were almost always found to have one of these (111) directions perpendicular to the sample surface. In many cases, the preferred orientation was nearly "perfect" in several abutting grains. Figure 11 shows two such grains, and their corresponding (111) superimposed selected area diffraction pattern (SADPs) indicating a pure cubic structure.

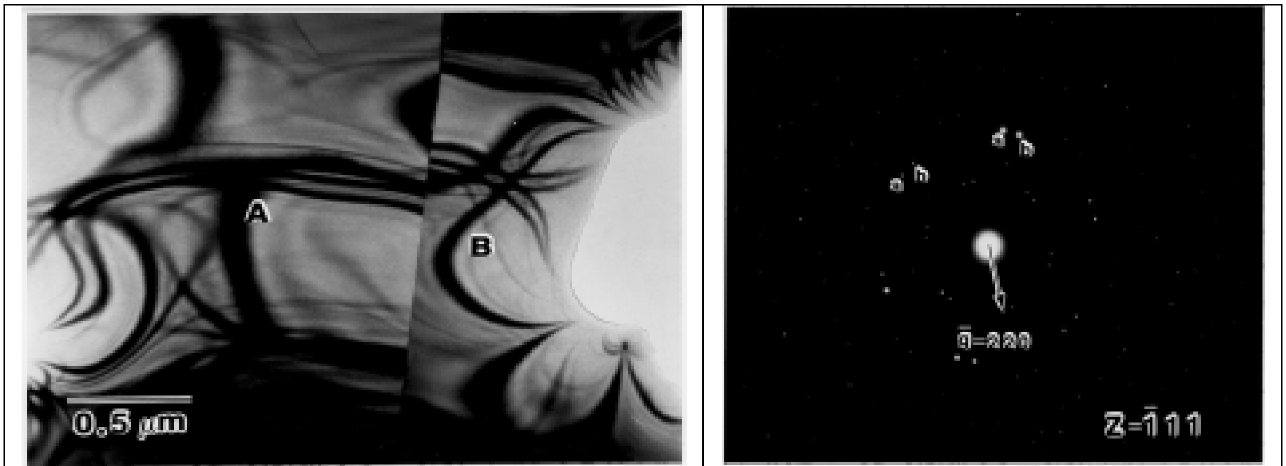
The opaque SiC has a totally different microstructure. The grain size was up to 10 μm. Grains were heavily faulted, but typically not with twins, but rather with stacking faults and high densities of dislocations. In fact many grains lost their cubic symmetry and exhibited hexagonal symmetry with one directional disorder as seen in Figure 12.

The attenuation coefficients of the transparent and opaque SiC samples were measured to be 7 cm^{-1} and > 103 cm^{-1} at 633 nm, respectively. Higher defect density and α-SiC grain disorder in β-SiC can lead to increased scattering, resulting in loss of transmission.

5. APPLICATIONS FOR IR WINDOWS AND DOMES

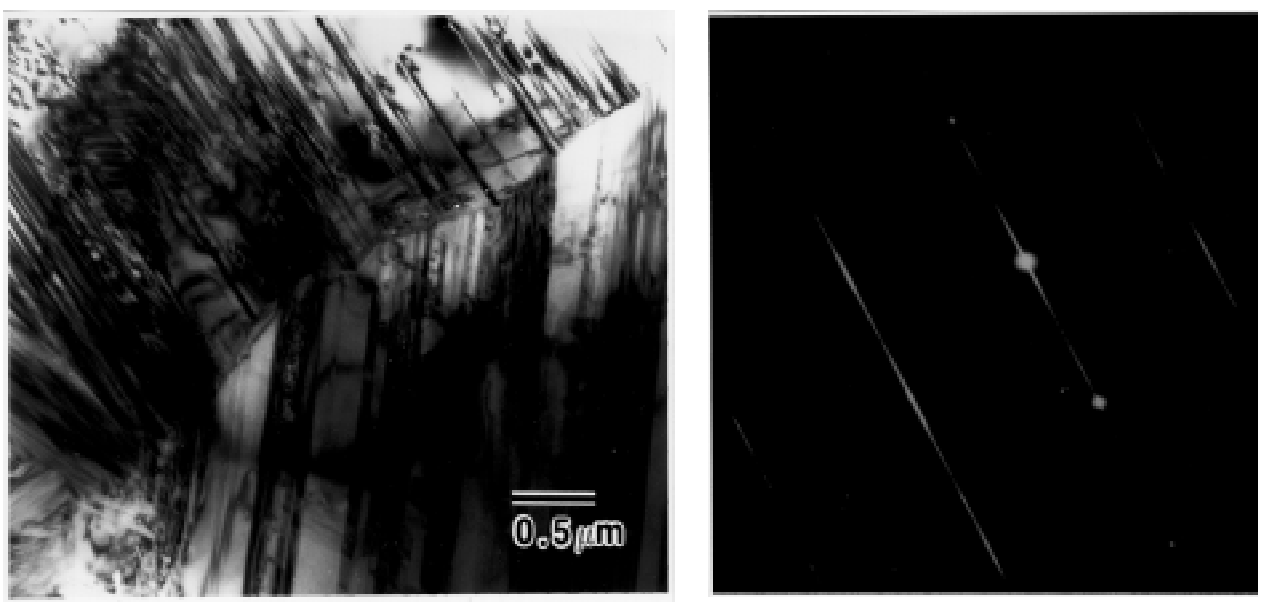
The most important application of transparent SiC is its use as windows and domes for severe environments associated with high speed missiles, combustion, space and laser systems. An important parameter that is used to compare the performance of different candidate window materials is the thermal shock resistance. The thermal shock parameter, R is defined as $\sigma\kappa(1-\nu)/\alpha E$, where σ is the flexural strength, κ is the thermal conductivity, ν is the Poisson's ratio, α is the thermal expansion coefficient, and E is the elastic modulus. This parameter provides a relative indication of thermal shock resistance of materials when Biot number, $B_I = hL/\kappa \leq 12$[26-28] . Here h is the heat transfer coefficient and L is the characteristic dimension, which could be thickness of the window or dome. Table 4 compares the thermal shock parameter of CVD-SiC with that of several competing materials[26-28]. We see that CVD-SiC provides thermal shock parameter value, which is significantly greater than those of all other materials except diamond. However, diamond is a relatively expensive material, is difficult to polish and obtain in large sizes. Further CVD diamond grown in thick layers exhibits growth in grain size with thickness which results in considerable thermal conductivity variation along the thickness of the material. Comparing SiC to sapphire, which is currently a leading candidate material of choice in the 3-5 μm wavelength region, we see that transparent SiC is better because it (i) is a polycrystalline and isotropic material, (ii) has the potential to be fabricated rapidly, efficiently and in a cost-effective manner directly in a CVD chamber as a consequence of the near-net-shape and precision replication technologies, and (iii) possesses a thermal shock parameter, R, which is better by a factor of 45.

Klein and Gentilman[27] have ranked important materials for use as windows and domes when they are suddenly exposed to a supersonic flight environment. This environment leads to intense convective heat loads due to rise in temperature of the boundary layer. For thermally thick case ($B_i > 1$), transparent SiC ranked second after Si_3N_4, but ahead of diamond, sapphire and AlN. For thermally thin case ($B_i < 1$), the transparent SiC also ranked second, behind diamond, but ahead of AlN, Si_3N_4 and sapphire.



(a) (b)

Figure 11: TEM micrographs and SADP of transparent SiC (a) bright field micrograph of two grains of transparent SiC with essentially parallel (111) zone axis; (b) SADP of (a) showing rotation around zone axes but no significant deviation between these axes.



(a) (b)

Figure 12: TEM micrograph and SADP of opaque SiC: (a) opaque SiC grain showing stacking faults and dislocations; (b) SADP of an area of (a) with hexagonal symmetry and one dimensional disorder.

Table 4: Comparison of Thermal Shock Resistance of Important Window Materials

Material	Flexural Strength σ (MPa)	Elastic Modulus E (GPa)	Poisson Ratio ν	Thermal Conductivity κ ($Wm^{-1}K^{-1}$)	CTE α (10^{-6} K^{-1})	Thermal Shock Parameter R
CVD-SiC	470	466	0.21	330	2.2	119.5
Sapphire	400	380	0.27	24	8.8	2.1
Spinel	160-190	190	0.26	14.6	8.0	1.2-1.39
ALON	300	315	0.24	12.6	7.8	1.02
Yttria	116	164	0.3	14	7.1	0.94
MgF_2	100	115	0.3	16	11.0	0.89
Diamond	2000	1050	0.16	2000	0.8	4000
GaP	100	103	0.31	97	6	10.8
GaAs	60	86	0.31	53	6	4.3
CVD-ZnS	103	75	0.29	16.7	7	2.3

Transparent SiC was evaluated as window material for use in laser welding systems that operate at a wavelength of 1.06 μm. Table 5 shows the results of high power CW Nd:Yag laser irradiation of a sample of transparent SiC for laser welding applications. The Yag laser was passed through a fiber optics cable to produce a spot size of 750 μm. The sample thickness was 0.54-mm. The input power was varied in the range 55-550 watts. We see that even at very high energy densities the transmittance of transparent SiC did not degrade appreciably. Further, after laser irradiation was completed, no visible damage to transparent SiC sample was observed. In comparison, other competing materials such as sapphire, AlON, CLEARTRAN® and quartz did not survive the extreme thermal shock.

Table 5: CW Nd:Yag Laser Irradiation Results

Laser wavelength = 1.06 μm Spot size = 750 μm Sample thickness = 0.54 mm

Input Power (W)	On Time (s)	Power Density (KW cm^{-2})	Energy Density (KJ cm^{-2})	Output Power (W)	Transmittance (%)
55	5	12	60	34	62
58	5	13	65	37	64
82.5	5	19	95	52	63
290	5	66	330	177	61
550	3	125	375	--	--

In addition to the windows and domes, the transparent SiC also has applications in semiconductor and electronic industries. The high purity and transparency of transparent SiC makes it a good candidate material for fabricating semiconductor furnace furniture, such as wafer carriers, furnace support tubes and paddles. The transparency of the material provides not only a perception of high purity, but also the capability to see the wafers without taking them off the support components. Transparent SiC can also be used for fabricating high temperature luminous sources. Finally, high thermal conductivity and electrical resistivity makes transparent SiC a preferred material for electronic packaging applications. The transparency of the material can be used to provide optical connection in electronic circuits.

6. SUMMARY AND CONCLUSIONS

The current status of research work on the transparent SiC has been reviewed. Transparent SiC is a superior window material in the wavelength region covering from the visible to about 4 μm. In this region the material has high transmittance, low absorption and excellent physical, optical, thermal and mechanical properties of interest to windows and domes. In the 4-5 μm wavelength region however, the material exhibits a high value of emissivity. For many defense applications, this region is very critical. Consequently, it is important that the emissivity of transparent SiC is reduced in this wavelength region. Since the atmospheric CO_2 has an absorption band at 4.3 μm, one method of effectively reducing the SiC emittance contribution on the detector is to block the 4.3 μm radiation using a filter. Future analytical work will be focussed in the 4-5 μm wavelength region to reduce SiC emissivity to an acceptable level.

The transparent SiC CVD process is currently in the development stage. Although preliminary results are very encouraging, additional work is required to develop this process further. This development effort should be focussed on optimizing process parameters, reducing its attenuation coefficient, performing a detailed material characterization, exploring scaling issues and determining its full potential as an infrared optical material.

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