INFRARED TO VACUUM-UV OPTICAL PROPERTIES OF 3C, 4H AND 6H SILICON CARBIDE

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Motivation

To obtain both the ordinary and extra-ordinary components of the dielectric function of SiC polytypes.

To extend the scope of existing measurements of 4H- and 6H-SiC dielectric functions to the infrared energy region (~300-7000 cm^{-1}) of these dielectric functions.

To show the effect of phonon modes and anisotropy.

Samples

3C samples from several suppliers. 3C-SiC on Si were also investigated.

Two sets of samples for each polytype (4H and 6H) were measured: with the [1010] or the [1120] direction normal to the surface. Additionally, vicinal c-plane samples with different doping concentrations were measured.

Ordinary [<e> ⊥ (0001)] and extra-ordinary [<e> ∥ (0001)] components of <e> were measured.

Data were mathematically corrected for ~2 nm of SiO$_2$ using a 3-phase model and low energy data (0.7-3 eV).

Instrumentation

IR-ellipsometer with photon energy range 200-7000 cm^{-1} from J.A. Woollam Co. was used.

Measurements in the 0.7-6.5 eV range were performed with a V.A.S.E system from J.A. Woollam Co.

WVASE 32 software from J.A. Woollam Co. used for analyzing the data.

Measurements in the 3.5-9 eV photon energy range were performed using a Sentech Instruments ellipsometer in Nitrogen ambient.

For the critical points, additional Fourier transform analysis were performed together with real space analysis.

3C-SiC

The dielectric function of all the polytypes are dominated by a strong TO-phonon resonance near 800 cm^{-1}.

4H-SiC A$_1$ modes seen in ε
— c-cut, experimental data, vicinal sample
— ε perpendicular to the c-axis, experimental data
— ε perpendicular to the c-axis, model data
— ε parallel to the c-axis, model data
— ε parallel to the c-axis, experimental data
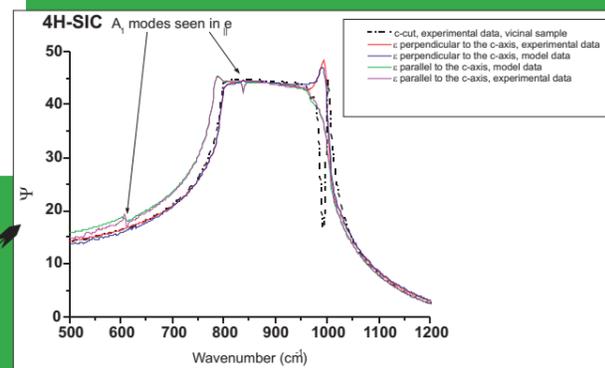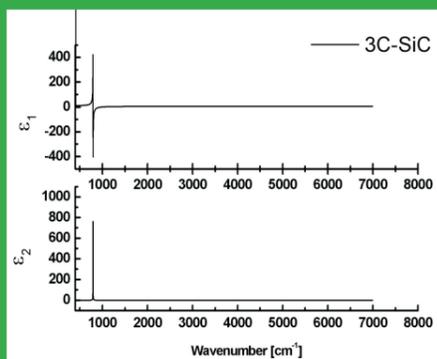
Anisotropy in the phonon modes is affecting the reststrahlen band.

6H-SiC, ordinary ε
6H-SiC, extra-ordinary ε

4H-SiC, ordinary ε
4H-SiC, extra-ordinary ε

6H 2-phonon summation bands

All polytypes investigated show higher lying modes. The picture shows the 2-phonon summation bands of 6H-SiC. Similar modes are seen for 3C and 4H SiC as well.
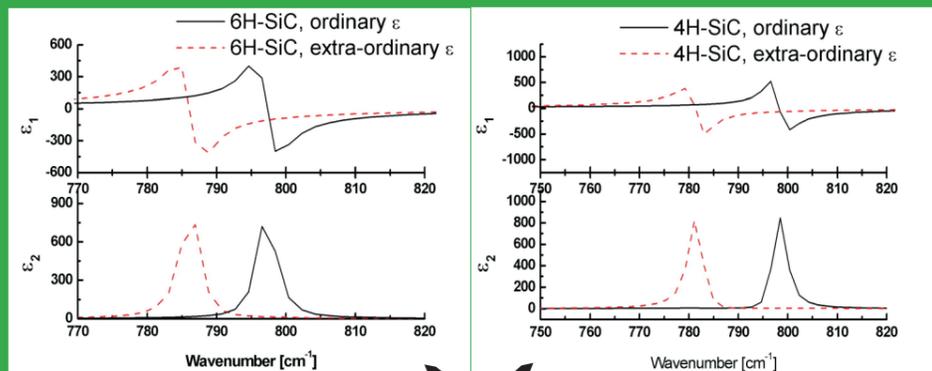
The anisotropy for the hexagonal polytypes is clearly visible in the position of the main one-phonon peak.
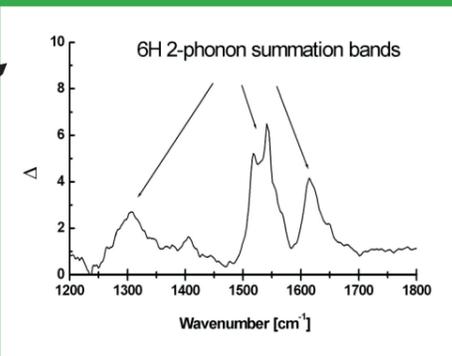
Why SiC?

Advantages:

- Wide bandgap
- High thermal conductivity
- High electron saturation drift velocity
- Chemically inert
- Mechanically hard
- Fairly high mobility
- Excellent substrate material for growth of III-Nitride material due to its similar lattice constant and thermal expansion coefficient
  good candidate for high power, high temperature and high frequency devices

Disadvantages:

- Very expensive
- Micropipe defects, can destroy the device performance
- Fairly difficult to control doping accurately, especially p-type

4H-SiC
<ε> parallel to (0001)
Critical point energies
<ε> perpendicular to (0001)

6H-SiC
<ε> parallel to (0001)
Critical points
<ε> perpendicular to (0001)
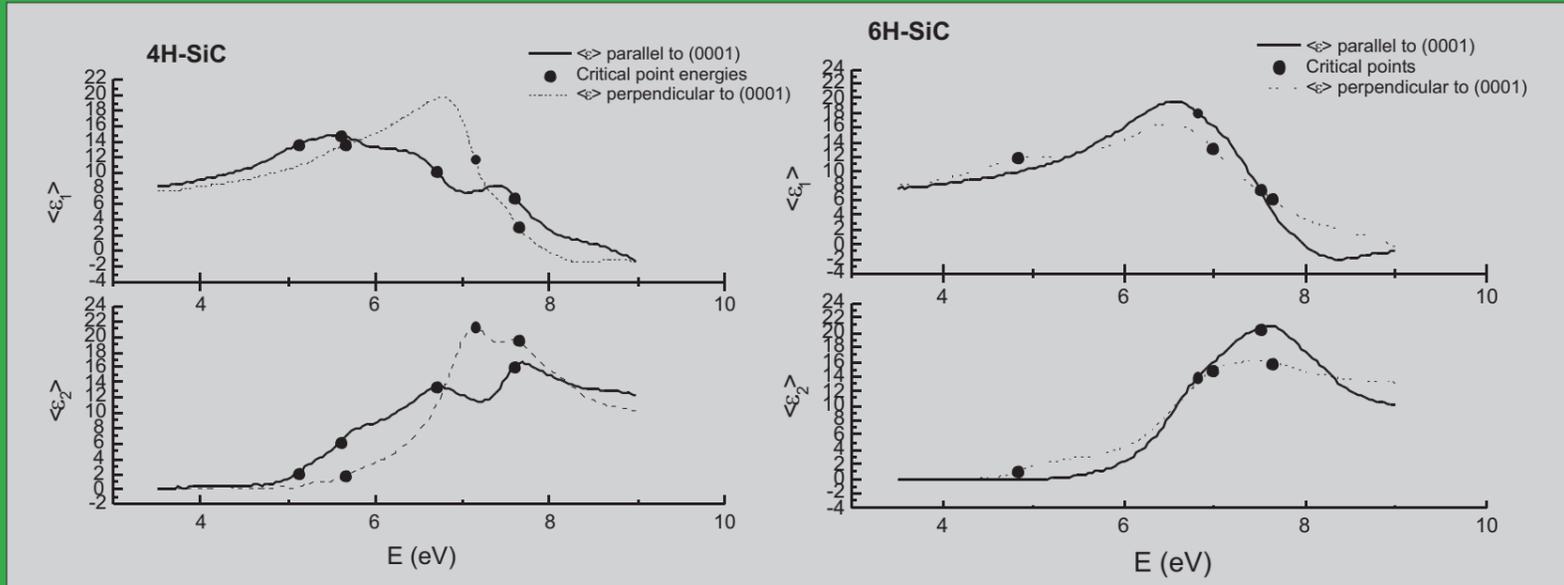
CRITICAL POINT ENERGIES (eV)

	Visible-Near UV		UV	
4H∥	5.11 ± 0.1	5.61 ± 0.1	6.68 ± 0.1	7.60 ± 0.1
4H⊥		5.65 ± 0.15	7.115 ± 0.044	7.615 ± 0.044
6H∥	4.82 ± 0.1		6.95 ± 0.2	7.65 ± 0.2
6H⊥			6.80 ± 0.2	7.49 ± 0.2

Conclusions

Dielectric functions of 3C, 4H and 6H-SiC have been obtained for the energy region 0.03-9 eV.

Anisotropy, free carrier effects, phonon mode frequencies are addressed in the IR region.

Phonon modes with A$_1$ symmetry are seen when measuring a-plane material

The derivative like feature near the LO-phonon frequency is explained.

Critical point energies in the VIS-UV region are found using both real and reciprocal space analysis.

The main reason for the anisotropy in the UV part of the spectra is the different amount of hexagonal lattice sites in 4H and 6H-SiC and the number of possible band-to-band transitions.

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