Full band Monte Carlo study of bulk and surface transport properties in 4H and 6H-SiC

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Introduction

The degree of anisotropy differs widely between the silicon carbide polytypes 4H and 6H. In this work, Monte Carlo simulation has been used for the study of bulk and surface transport properties in 4H and 6H-SiC when the transport direction is neither along the c axis nor within the plane perpendicular to it.

Surface scattering model

We have used an extension of the semi-empirical model proposed by E. Sangiorgi and M. R. Pinto, which uses a combination of diffuse and specular scattering. A constant (*C*) defines the probability of diffuse scattering. Our model is based on the reflection in two perpendicular planes, see Fig. 1.

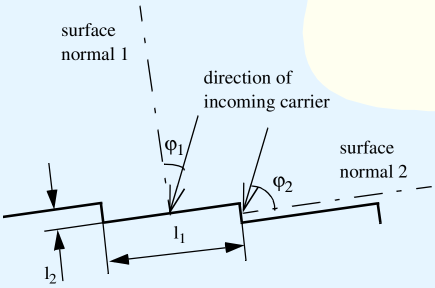

Fig. 1. Illustration of principle for semiconductor-insulator interface model.

The probability for scattering in each surface is proportional to $l \cdot \cos\varphi$. The reflection in a plane is excluded if φ exceeds 90 degrees. We consider this model as reasonable for interface surfaces tilted up to 15 degrees. A *C*-factor of 1.0 was used for the surface parallel to the c axis and 0.2 for the perpendicular surface.

Bulk mobility results

In Fig. 2 the simulation results for bulk drift mobility are shown for a donor doping of 7.0 x 10^{15} cm^{-3}. The bulk mobility has two components, one parallel to the electric field direction and one perpendicular to it. Due to the high anisotropy, 6H-SiC has a large range of angles, where the component perpendicular to the field is of the same magnitude as the component parallel to it. This phenomenon is similar to the Hall effect, but does not require any magnetic field.

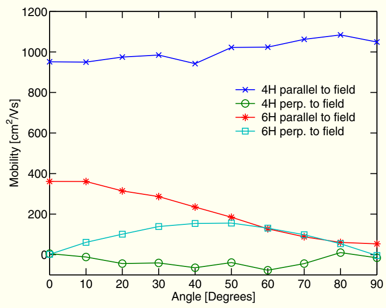

Fig. 2. Bulk drift mobility parallel and perpendicular to the field direction as a function of field angle from the plane perpendicular to the c axis.

Surface mobility results

The surface diffusion mobilities are shown in Fig. 3. They decrease with increasing angle and are much lower perpendicular to the surface steps than parallel to them.

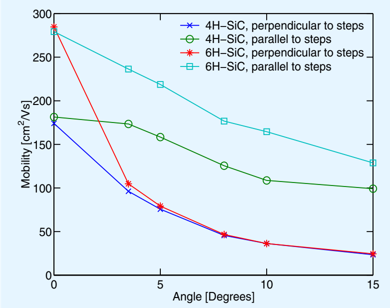

Fig. 3. Surface diffusion mobility as a function of interface angle from the plane perpendicular to the c axis, $E_{\perp} = 500$ kV/cm.

It is interesting to compare the 6H mobility at 3.5 degrees with the 4H mobility at 8 degrees, since the crystals generally are cut at these angles for the respective polytype. Then, 6H has approximately twice the mobility of 4H irrespective of the orientation of the transport relative to the steps.

In Fig. 4 and 5 the electron mean velocity at the tilt angles 3.5 and 8 degrees is shown as function of the field in the plane. Positive field means transport against the steep side of the steps, i.e. to the left in Fig. 1.

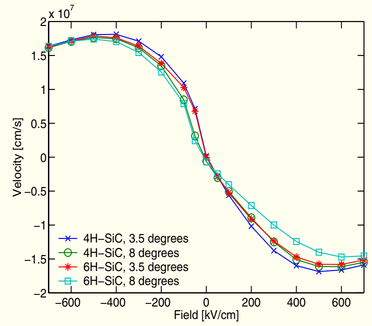

Fig. 4. Mean electron velocity as a function of field perpendicular to the steps in the interface, $E_{\perp} = 500$ kV/cm.

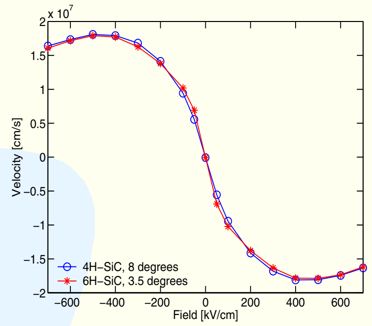

Fig. 5. Mean electron velocity as a function of field parallel to the steps in the interface, $E_{\perp} = 500$ kV/cm.

The characteristics are symmetrical for transport parallel to the steps, while it is asymmetrical perpendicular to the steps with considerably lower velocities for positive field. For negative field, the 6H velocity at 3.5 degrees is higher than the 4H velocity at 8 degrees.

Conclusions

Bulk mobility in 6H-SiC has a large component perpendicular to the field direction over a large range of angles. This causes an effect that may be compared to the Hall effect, but without any magnetic field.

The surface mobility in 6H-SiC is about twice the mobility in 4H-SiC for the angles generally used when cutting the crystal. Both polytypes have much higher mobility parallel than perpendicular to the steps. The high-field drift in both 4H and 6H-SiC is slower in the direction against the steep side of the surface steps.