FIELD EMISSION FROM BORON-DOPING POLYCRYSTALLINE DIAMOND FILMS ON SILICON

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Abstract

This work deals with the study and development of the boron-doped diamond field emission cathodes. These cathodes have the aim to produce the primary and neutralizer electrons for an ion thruster prototype under development at the Laboratório Associado de Plasma (LAP) at Instituto Nacional de Pesquisas Espaciais (INPE). The prototype has been designed to produce 1mN thrust, using argon or xenon as propellant. The ion engine is intended to be used in the discharging and attitude control of the geosynchronous satellites, such as those under development by the Space Brazilian Program.

The apparent negative electron affinity (NEA) of diamond surface is interesting from both fundamental and applied perspectives. Well-understood requirements of surface chemistry and heavy p-type doping are variance with the observations of NEA characteristics from doped surface-hydrogenated diamond films. Technological interest, such as electron multipliers, cold cathodes, field emitters motivates a fundamental understanding of the mechanisms of electron emission. The unique surface chemistry of diamond emitters and environments where conventional material fail.

The field emission current from boron-doped polycrystalline diamond films grown by hot-filament-assisted chemical vapor deposition (CVD) was investigated. To this end, we have performed experiments on a set of parallel plane diodes with the cathodes consisting of diamond films doped with boron at boron/carbon (B/C) rations of 2,000 4,000, 8,000, 12,000, 16,000 and 20,000ppm. The current measurements were, taken at a distance of 50 μm, carried out as a function of voltage and indicate that the samples exhibit a negative electron affinity after exposure to hydrogen plasma and threshold voltages ranging from 30 to 40 Vμm. The film with the lowest work function was 4,000 ppm (B/C). This result is in concordance with the results achieved in electrochemical electrodes.

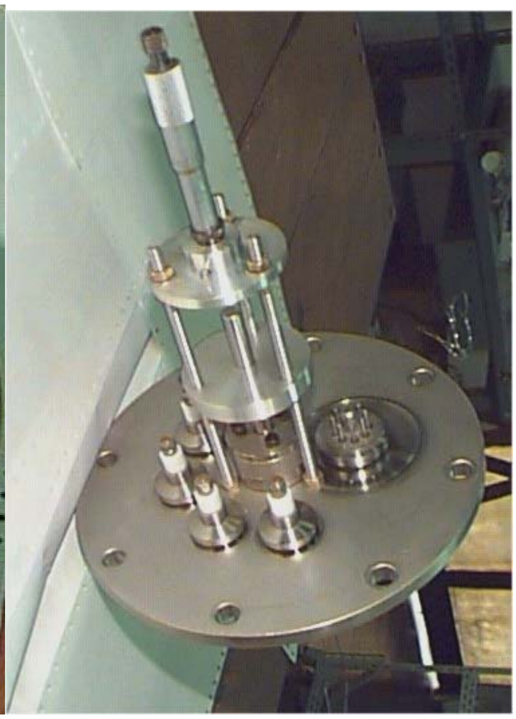
EQUAÇÃO DE FOWLER-NORDHEIM

$$I = K\left(\frac{V}{d}\right)^2 \exp\left[-B\frac{d\phi^{3/2}}{V}\right]$$

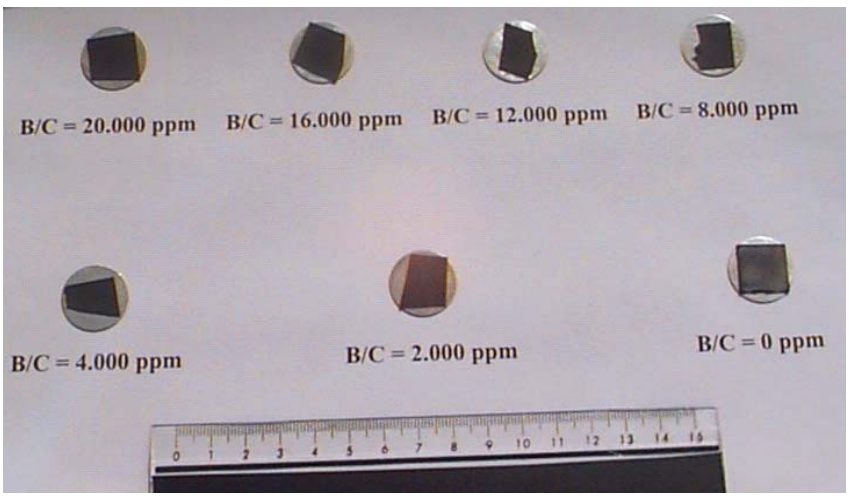
where I is the current (A), *k* is a constant related to the emission area ($6,2x10^{-6}$ for metals), V is the voltage applied, ϕ is the barrier height in *eV* and *d* is the distance, in μ*m*, from the anode to the cathode.
Plotting I/V^2 vs 1/V, the straight lines are fits to the bellow equation and are used to determine values for de effective barrier height and *k*.

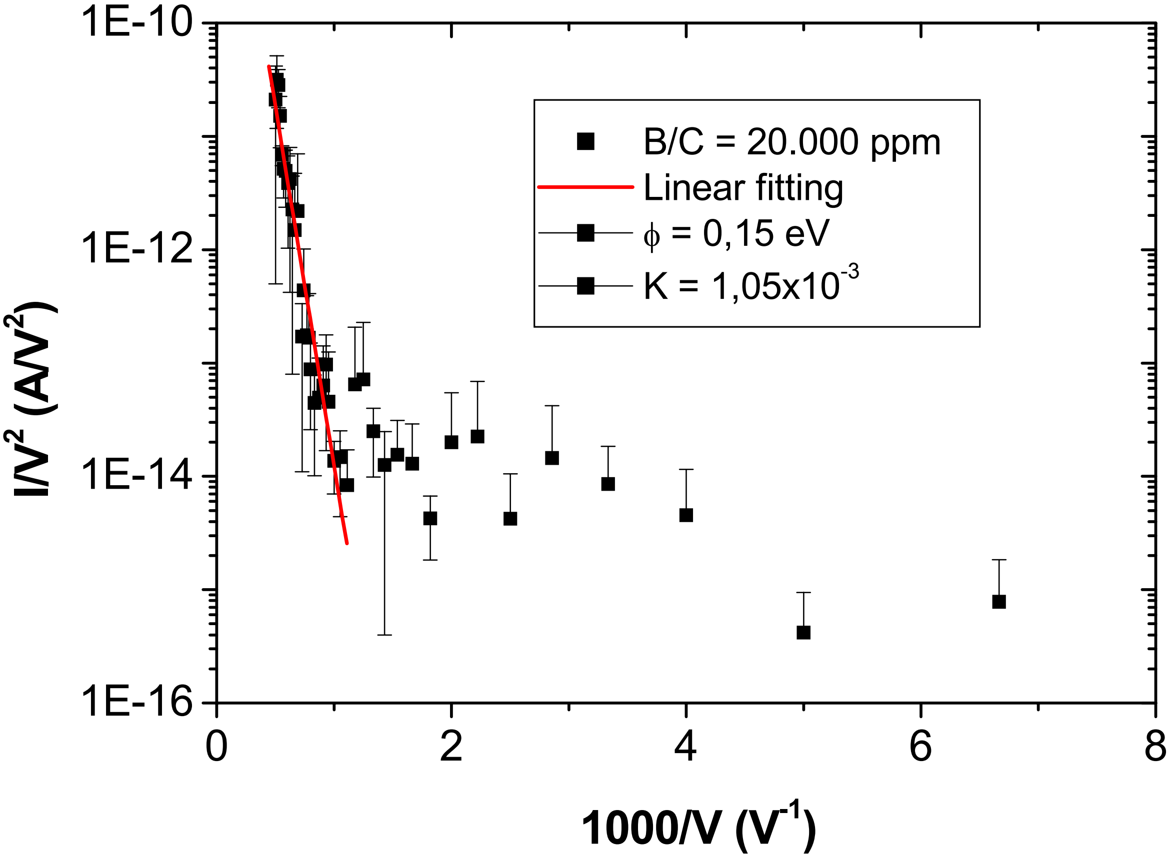
$$\ln\frac{I}{V^2} = \ln K\left(\frac{1}{d}\right)^2 - 6530 d\phi^{3/2} \cdot \frac{1}{V}$$

SET UP

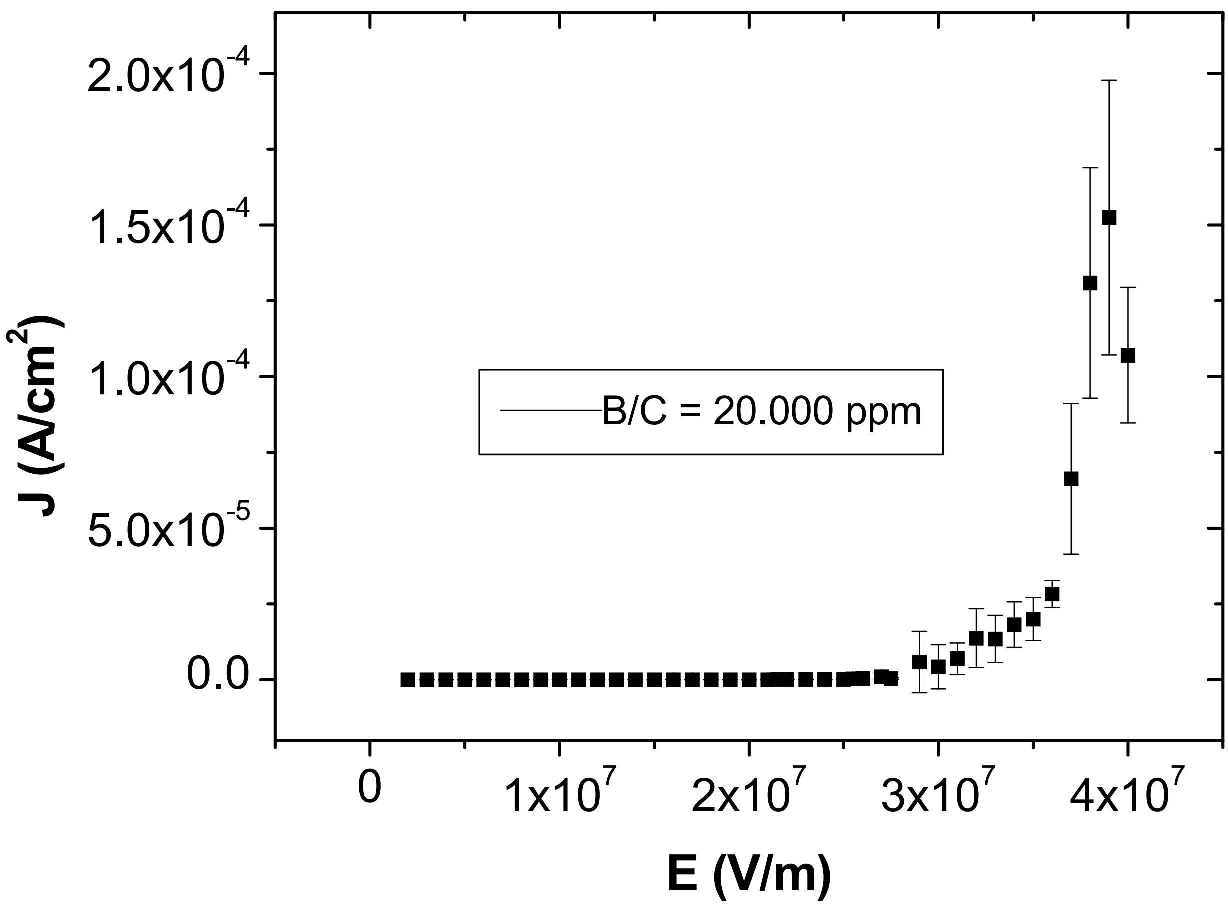


SAMPLES

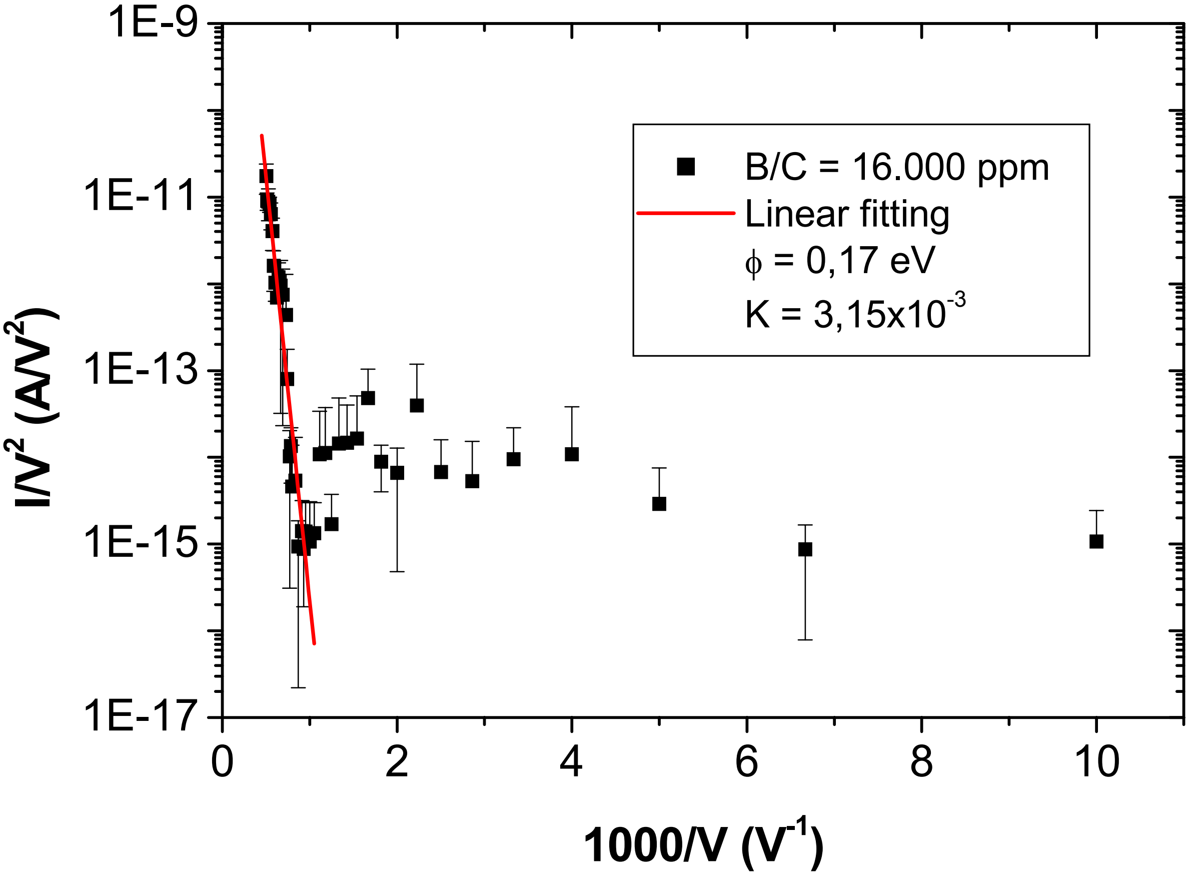




Fowler-Nordheim plot for 50 μm cathode-anode distance.



Current-voltage at room temperature



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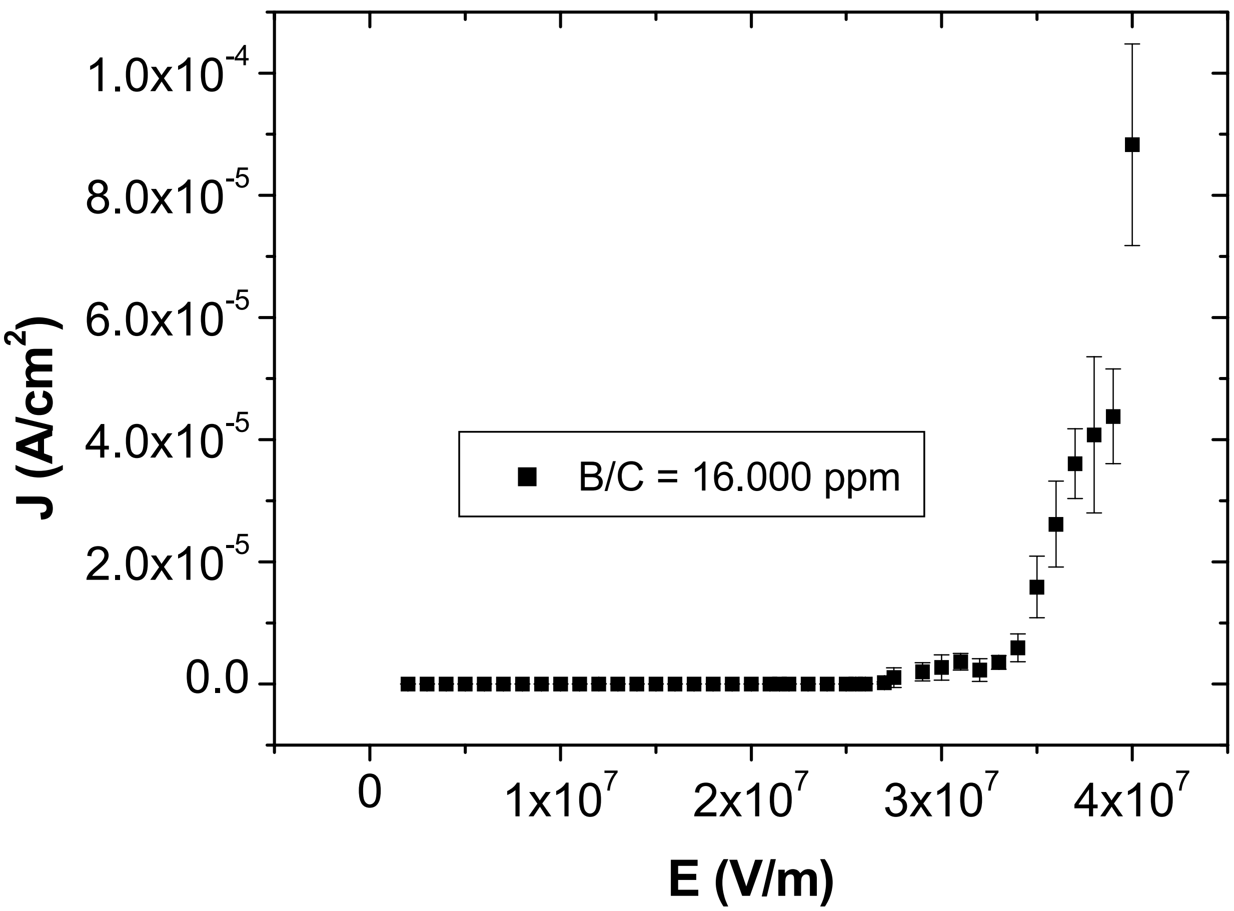

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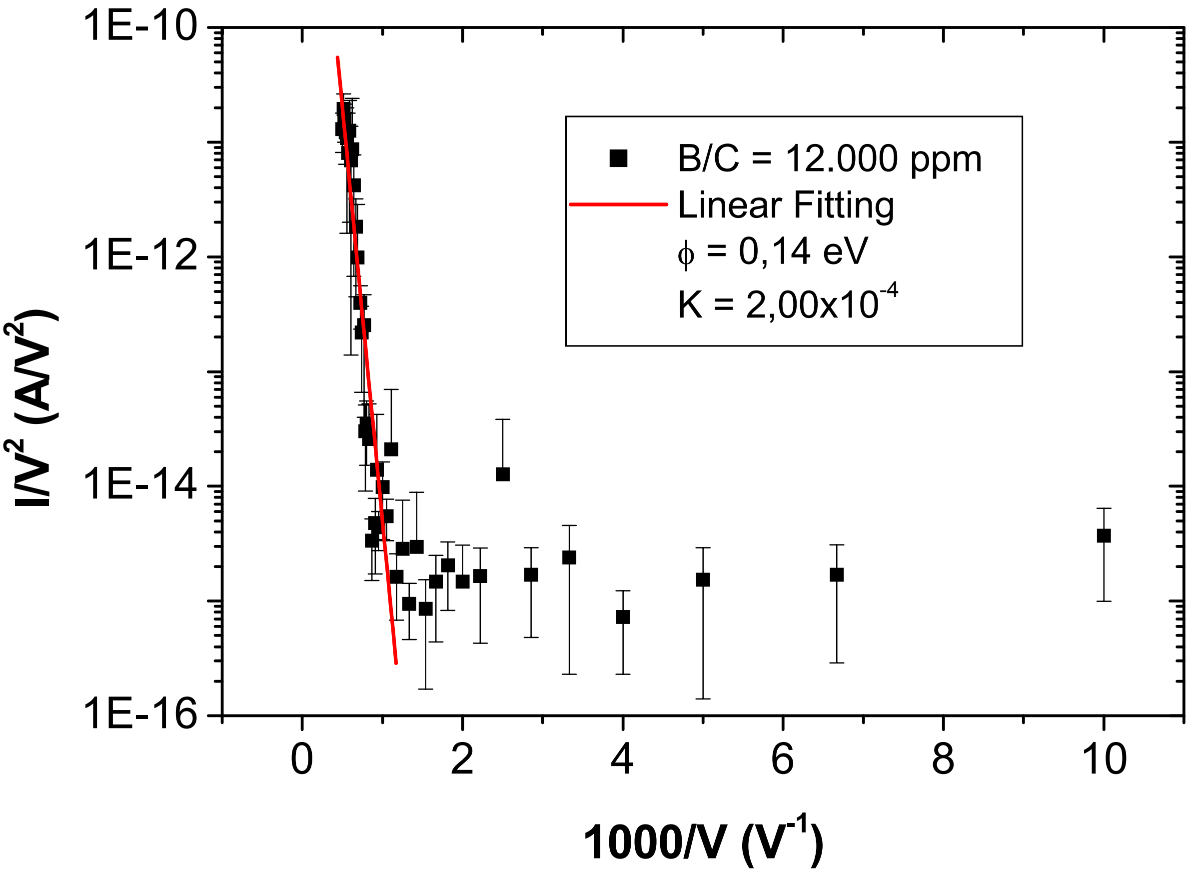

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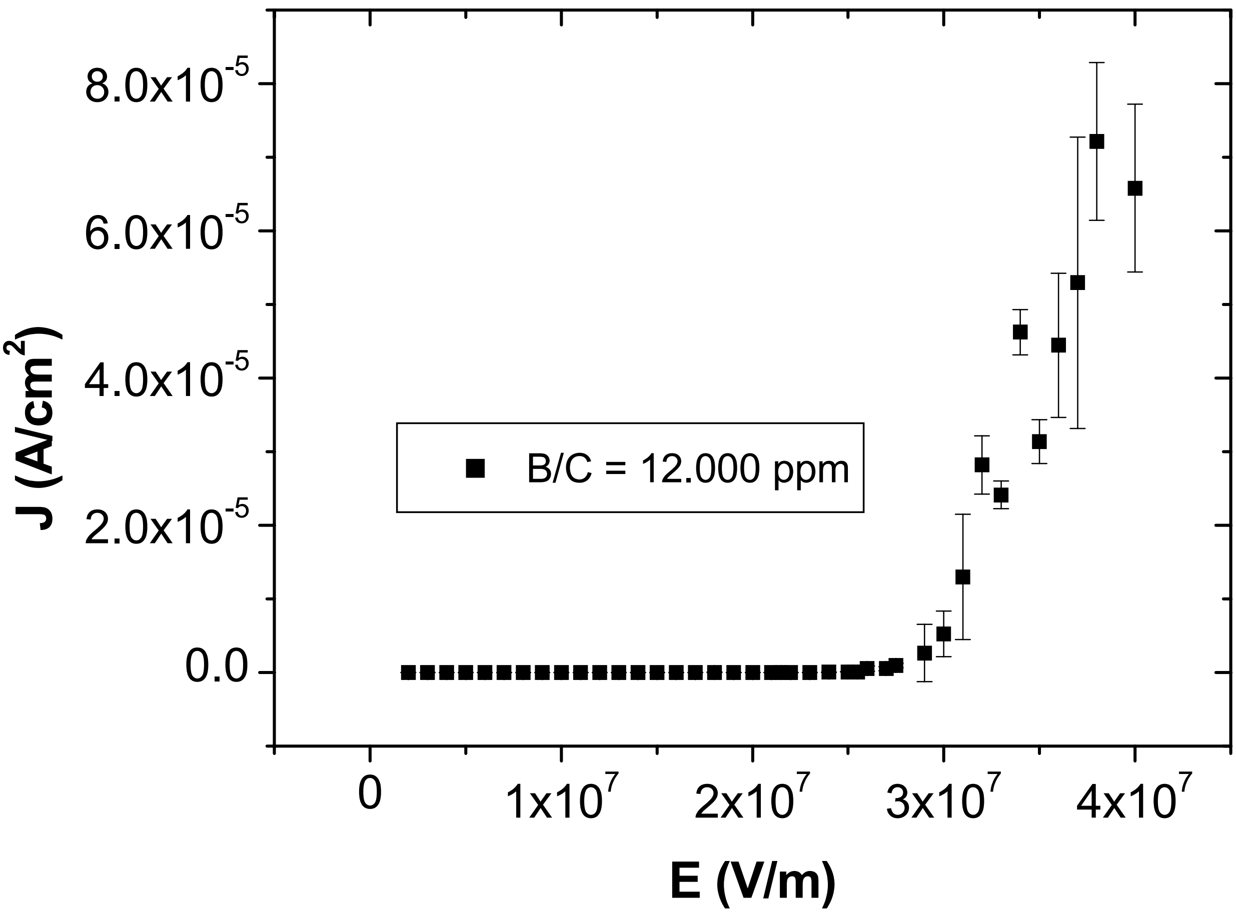

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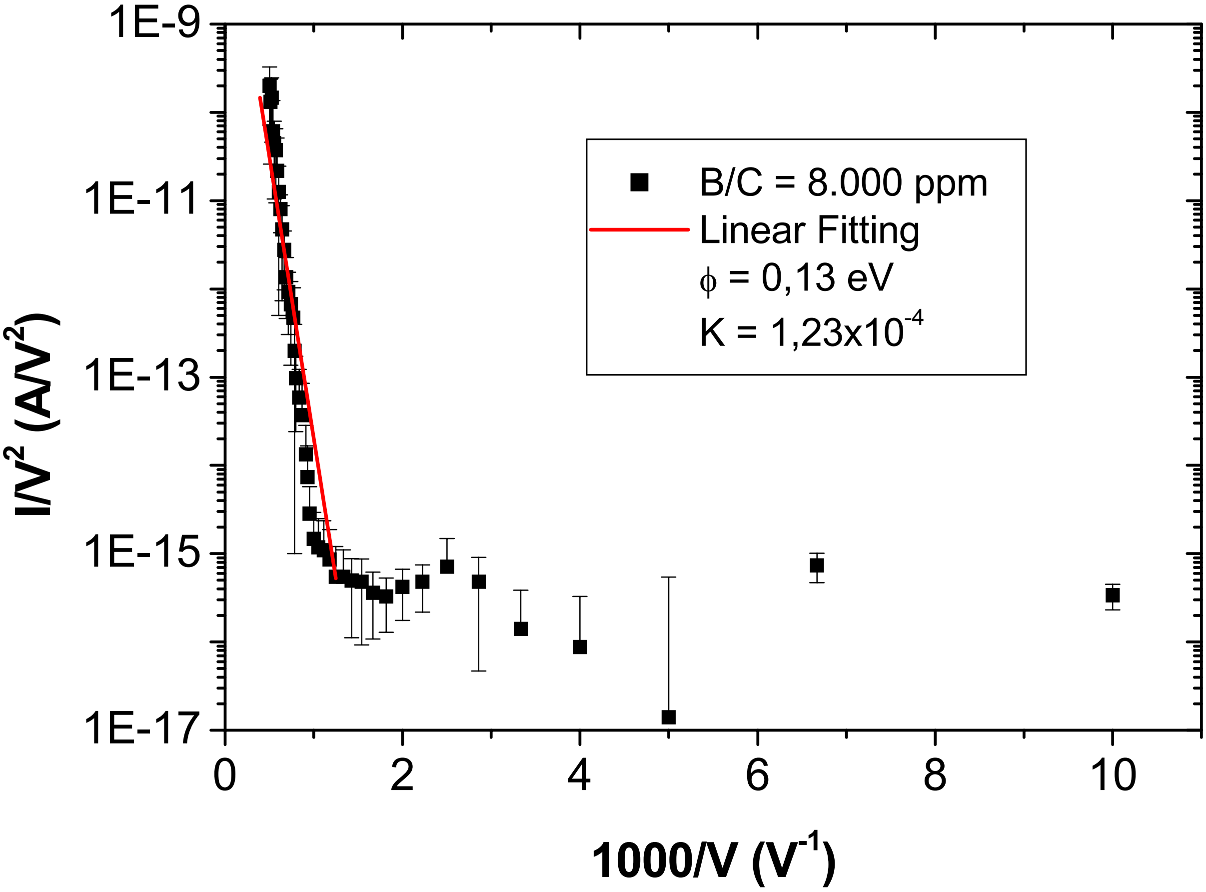

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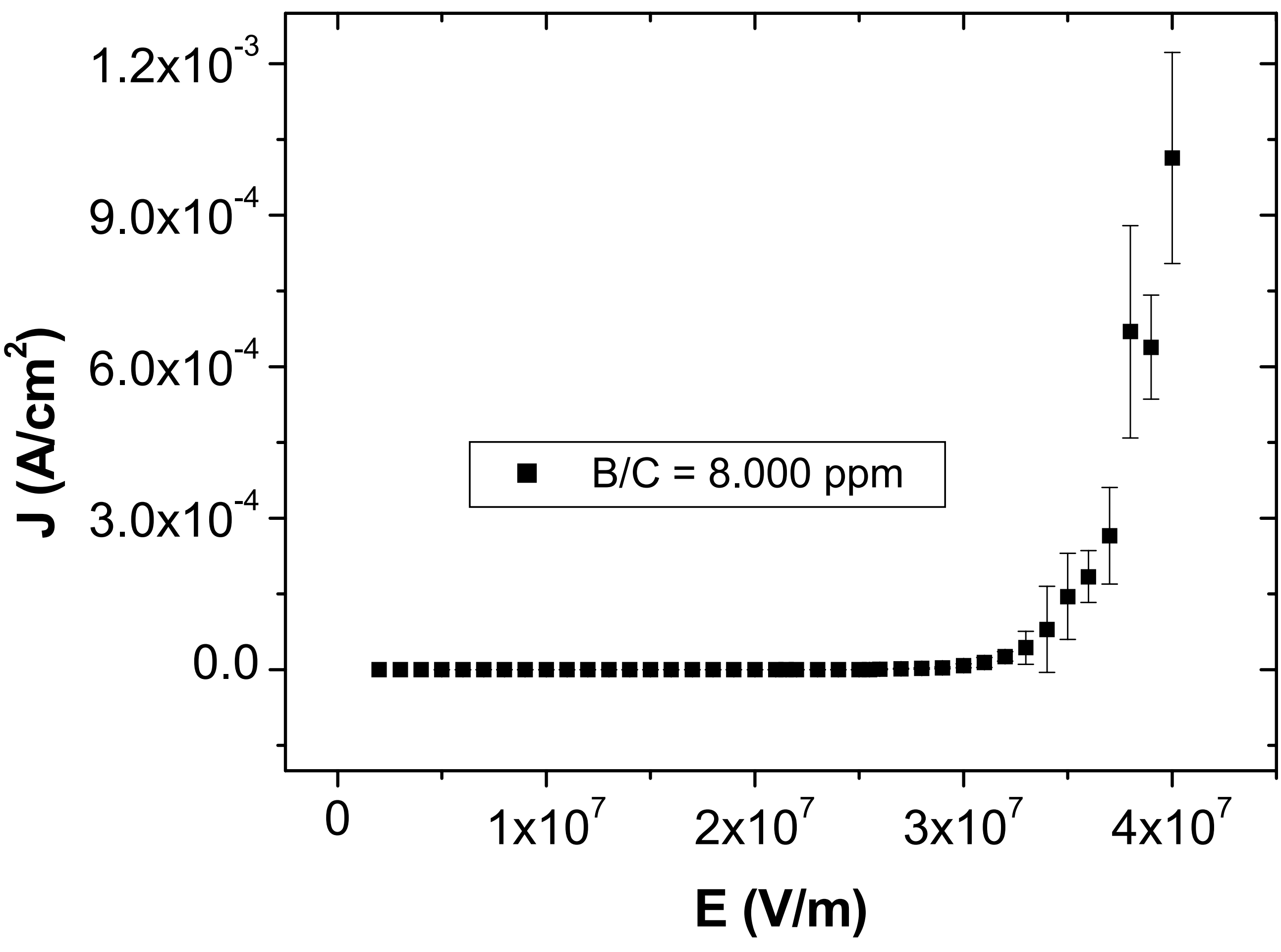

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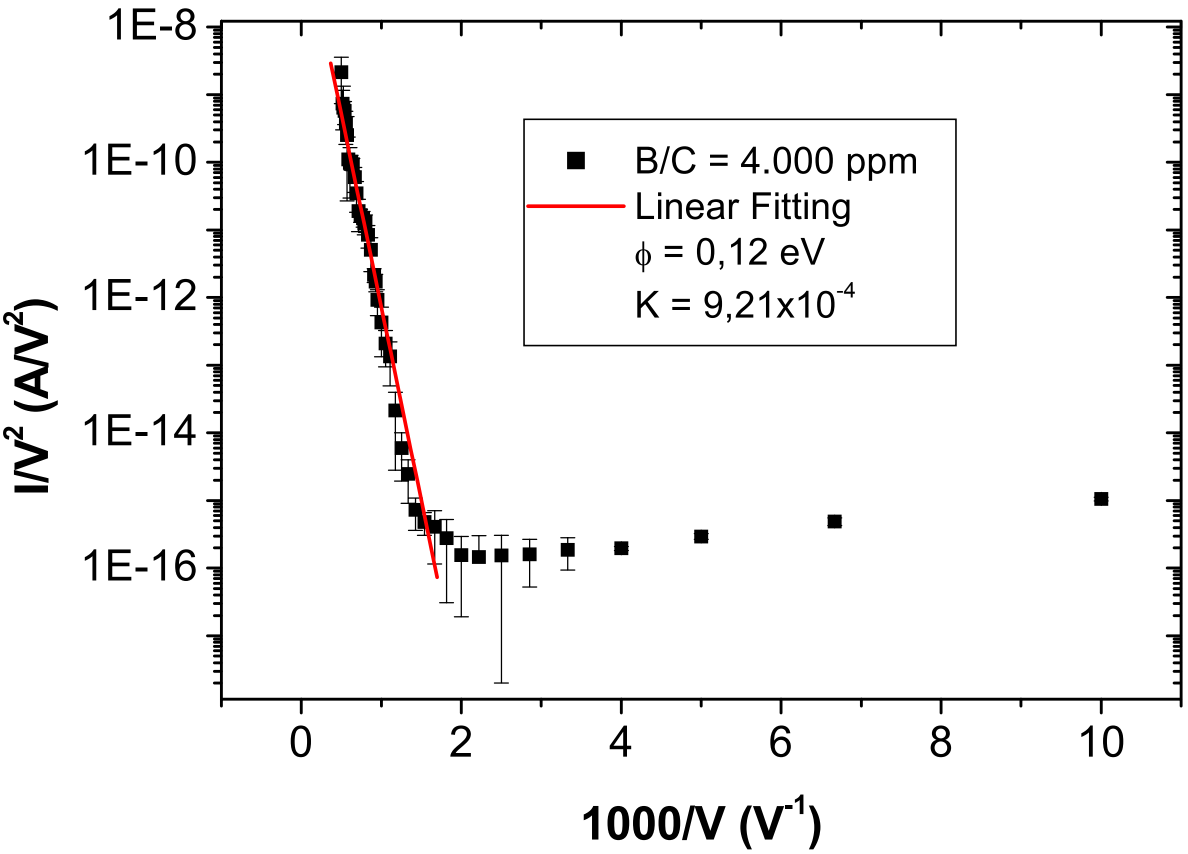

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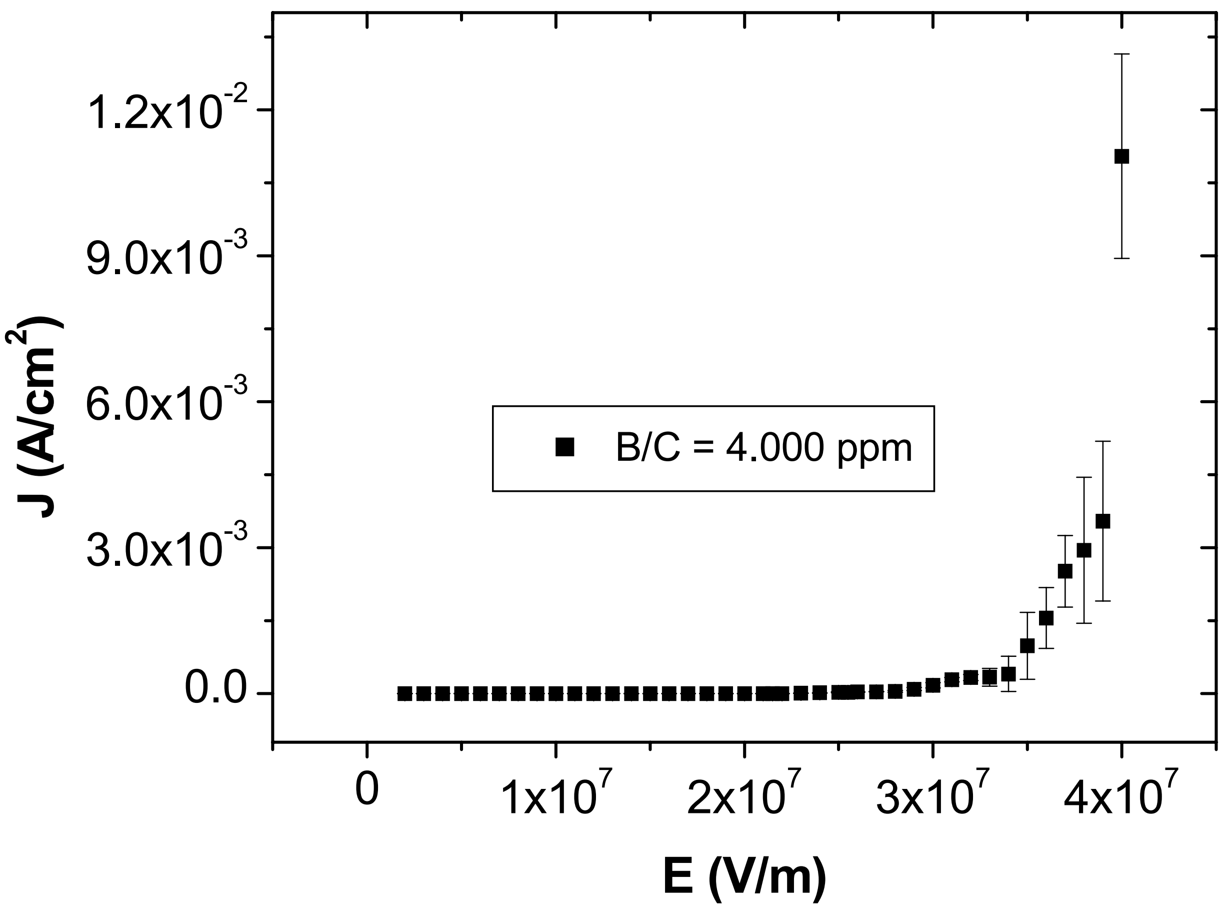
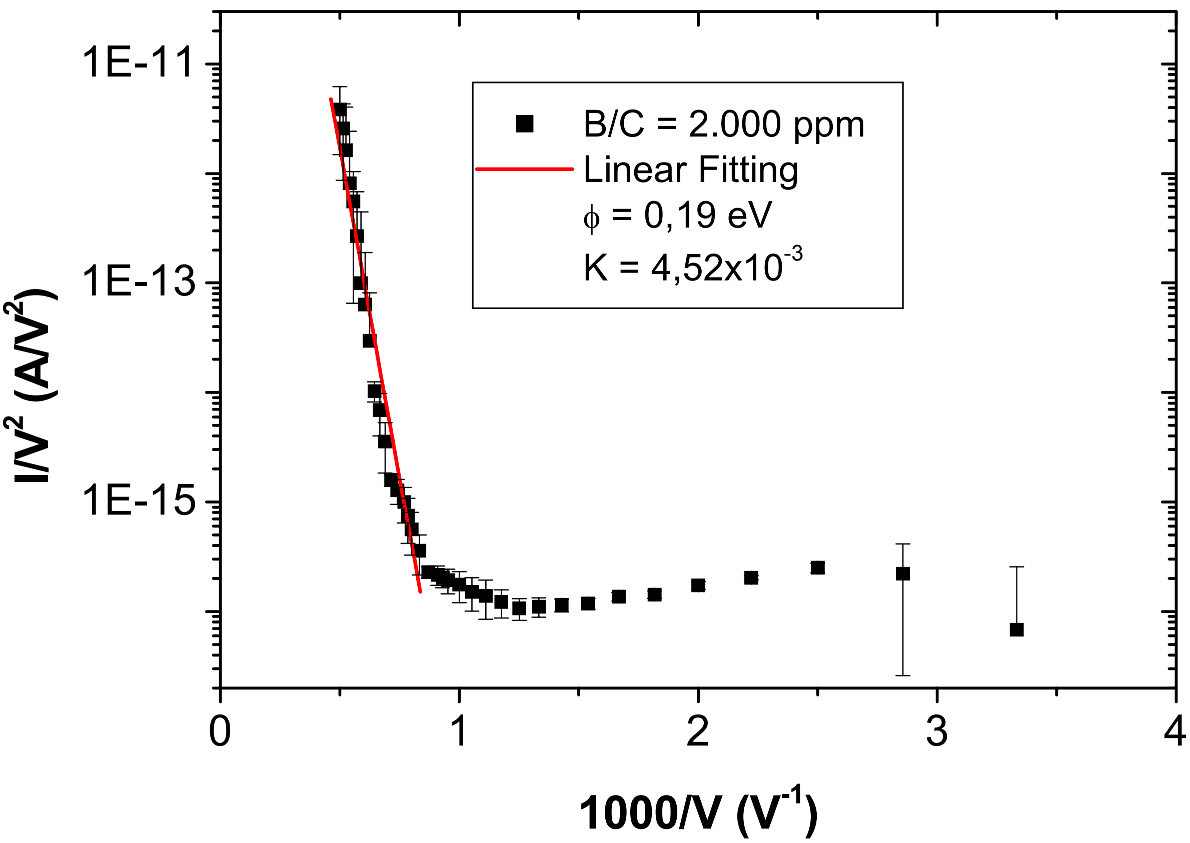


Current-voltage at room temperature



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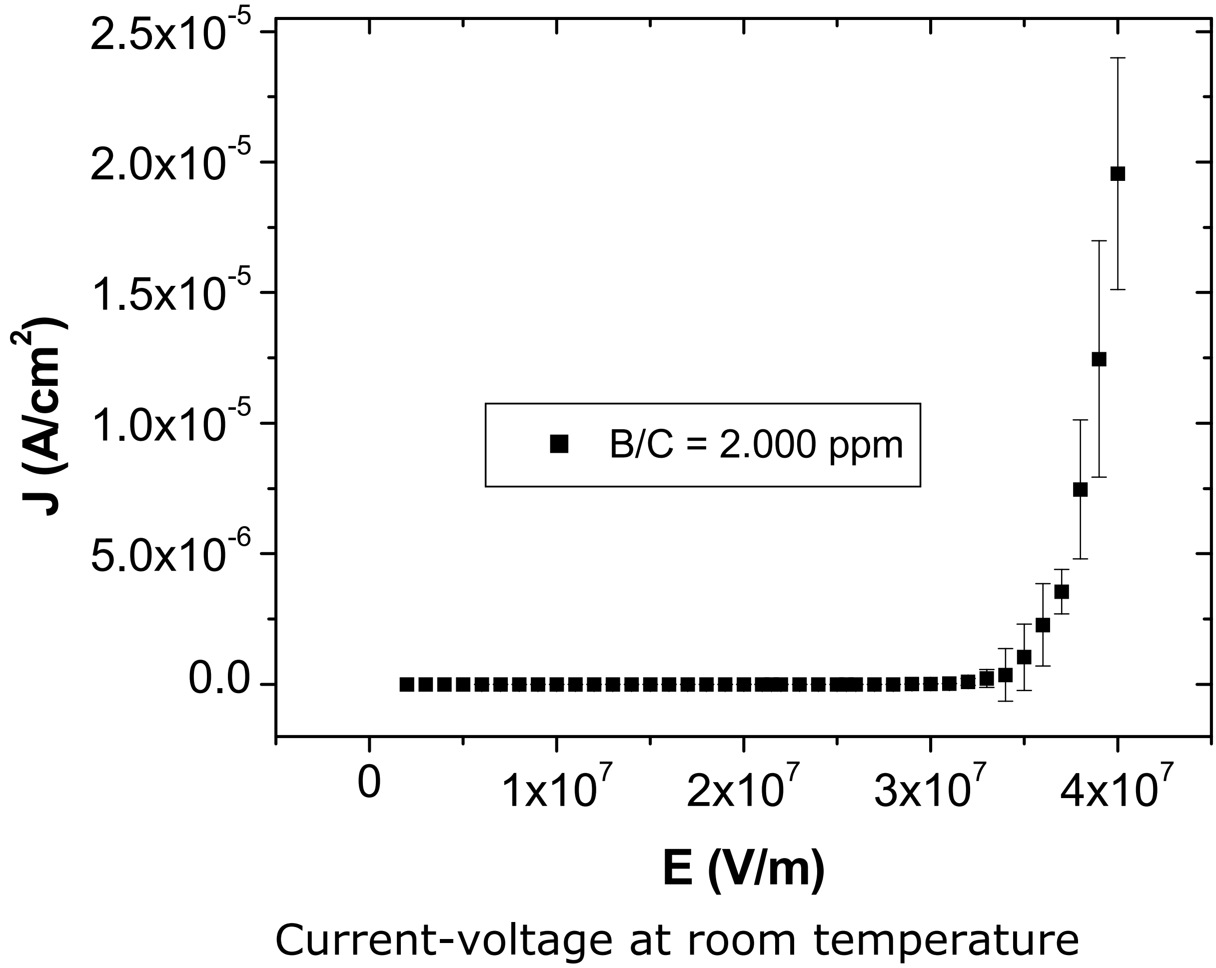
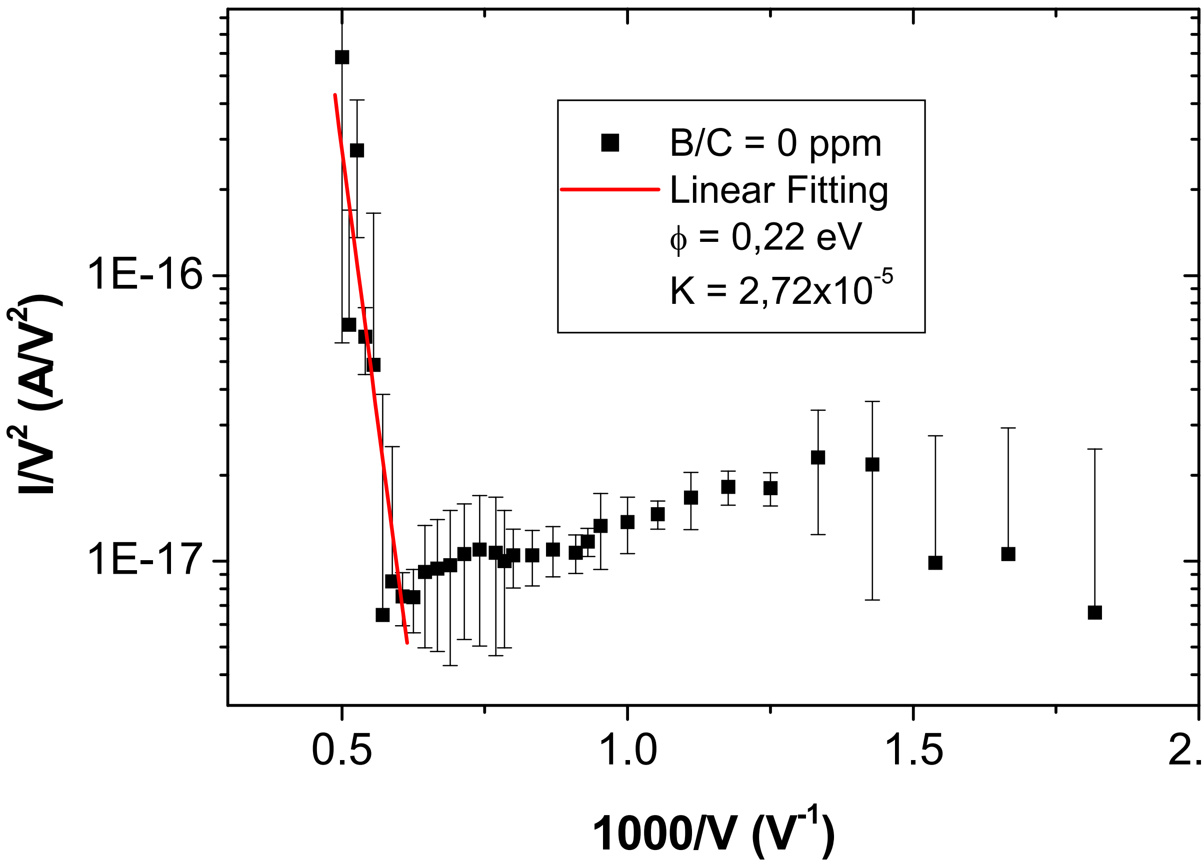


Current-voltage at room temperature



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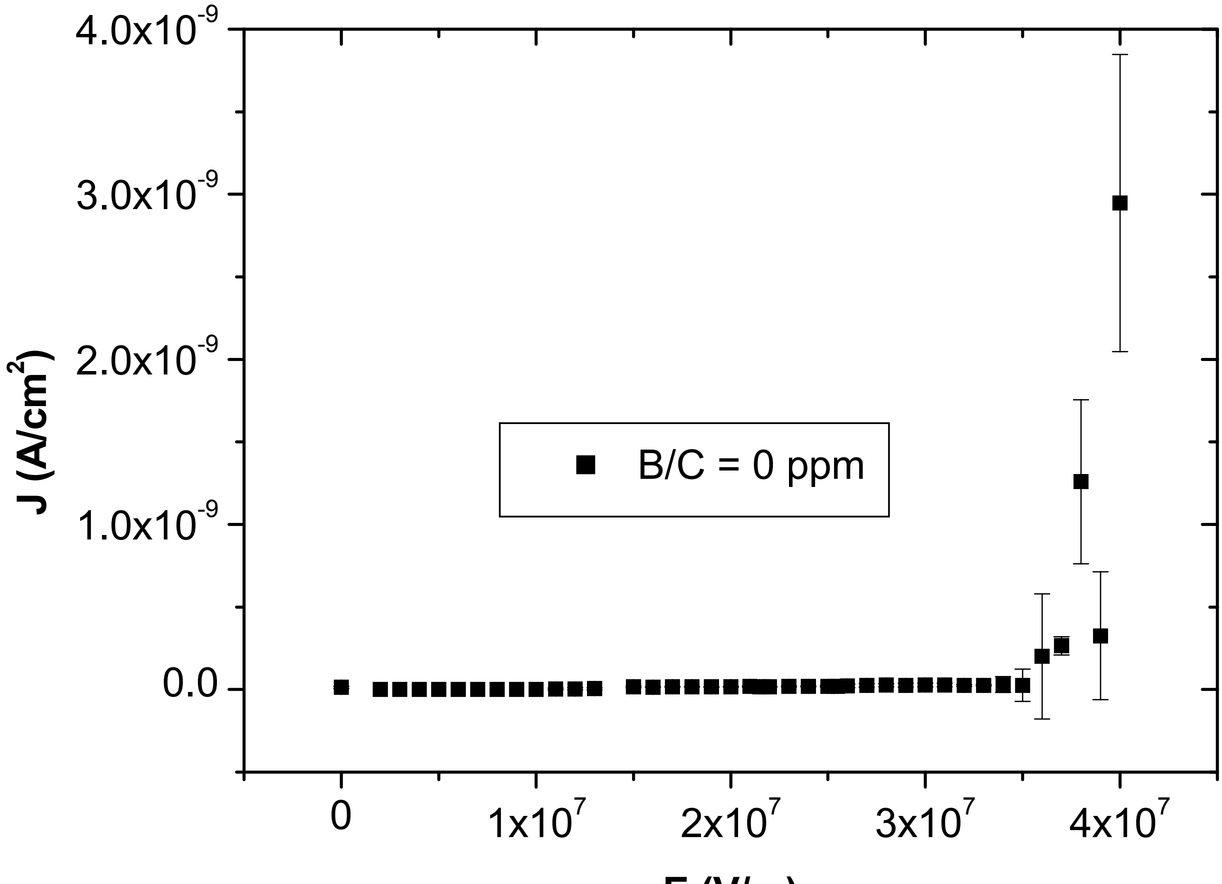
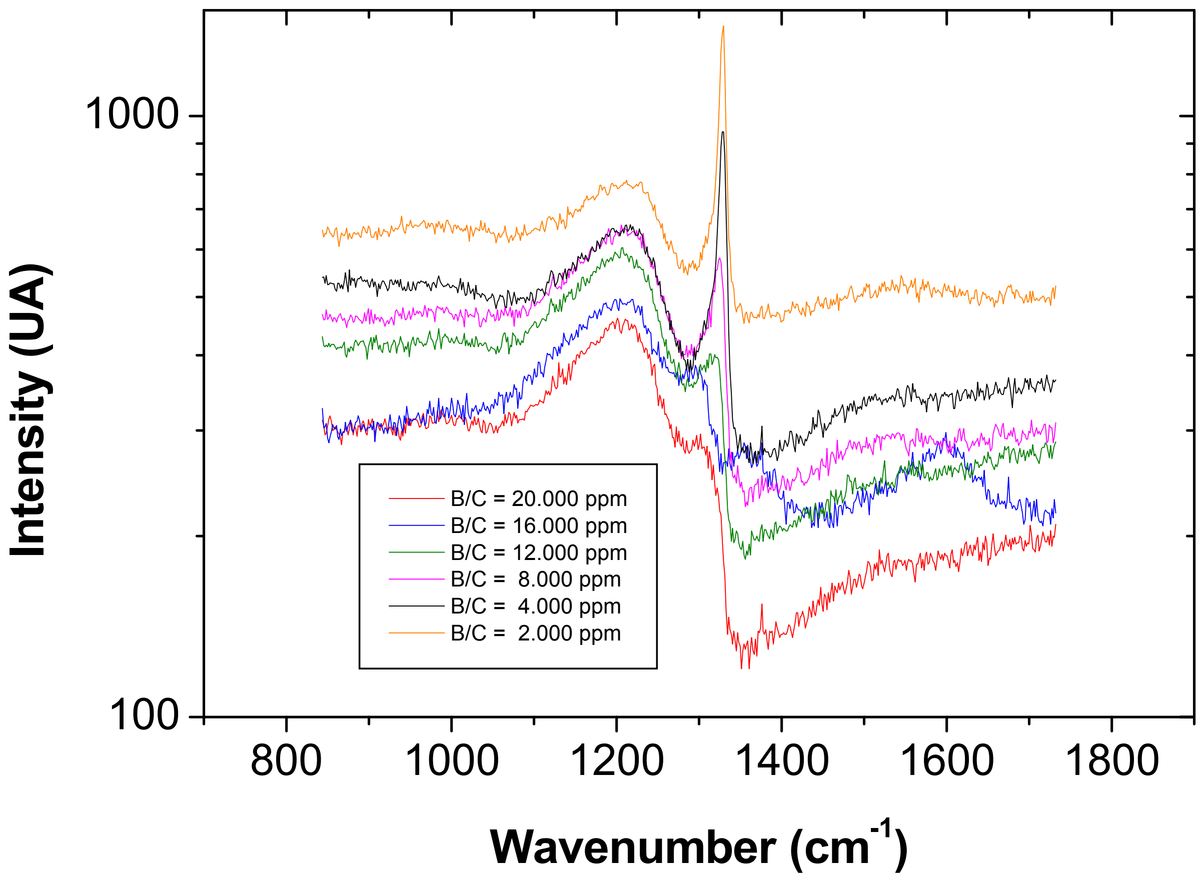
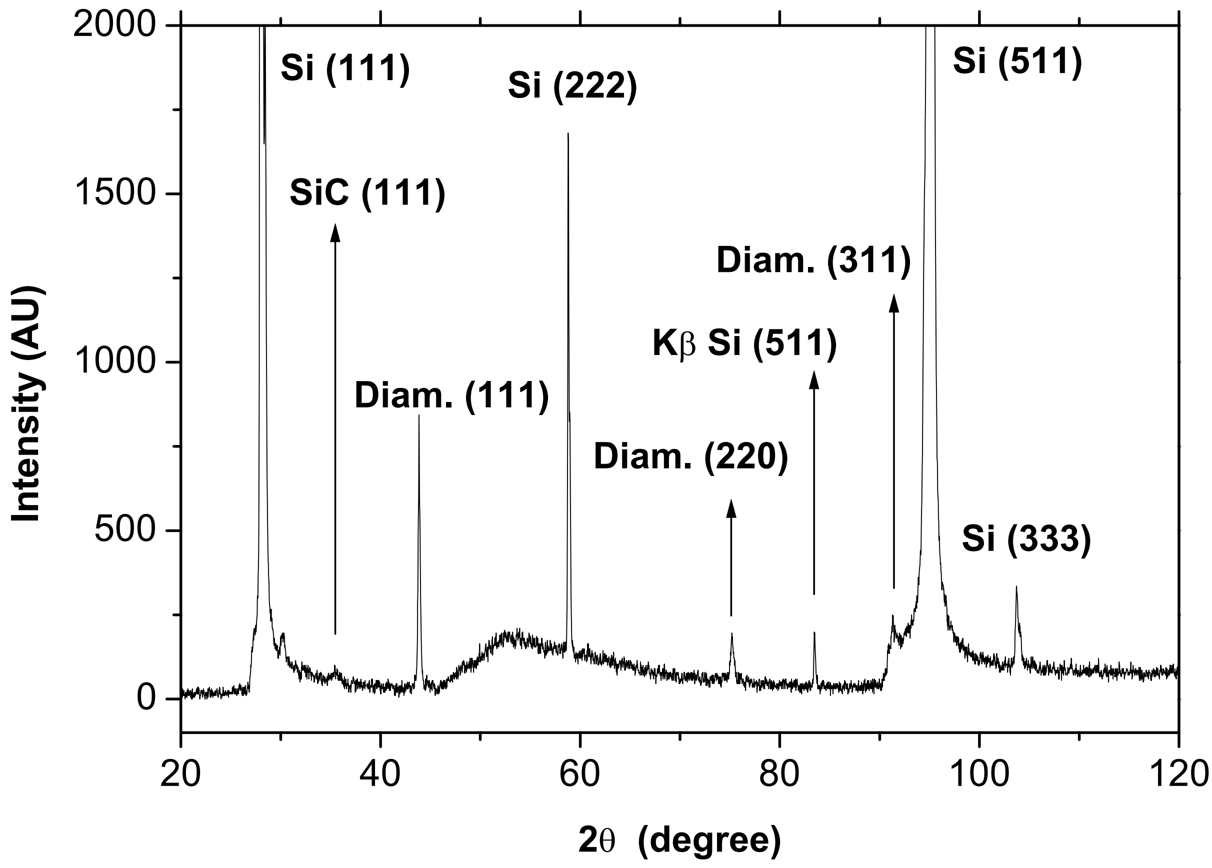


Current-voltage at room temperature



Raman spectroscopy of diamond films



Typical XRD diffraction of diamond films

Conclusions

The downshifts of diamond peaks from Raman at 1332 *cm*$^{-1}$ are attributed to the boron incorporation in the diamond film. The investigations by X-ray diffractometry have revealed the occurrence of *SiC* in the diamond film and the growing process occurs preferentially at plane (111).

When an intense electric field is applied in the diamond films, the work function assumes values from 0.12 to 0.22 *eV* conform boron-doped level.

This fact shows that the boron-doped diamond films exhibits negative electron affinity (NEA) comportment with threshold voltages about 3.5×10^{7} *V/m* for the cathode/anode distance of 50 μm.

Acknowledgement

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