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Response to "Comment on 'Electrospun hybrid organic/inorganic semiconductor Schottky nanodiode' " [Appl. Phys. Lett. 89, 176101 (2006)]

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Response to "Comment on 'Electrospun hybrid organic/inorganic semiconductor Schottky nanodiode' " [Appl. Phys. Lett. 89, 176101 (2006)]

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In his comment Lin agrees that the information provided in this letter was helpful in the fabrication of Schottky nanodiodes but disagrees on the interpretation of the results.[1] We thank him for his comment. He has analyzed our data using a modified model instead of the one that we presented. Some of Lin's comments are correct although it does not alter our conclusions, some are basically consistent with our interpretation, and some of his comments are incorrect.

(1) Lin argues that Eqs. (1) and (2) in Ref. 2 are incorrect and suggests revised equations. Lin correctly points out that we are missing the -1 in Eq. (1). Our equation is good to about 10% for $V > 8kT/q \sim 200$ mV. In calculating the saturation current density we have used the extrapolated value of I_s from the linear portion of the curve (see inset to Fig. 3 in Ref. 2) and not the intercept of the data on the current axis at $V=0$ thereby correctly using Eq. (1) in Ref. 2 to obtain J_s. Equation (2) given in the comment differs from ours because we define q as the absolute electronic charge. Lin includes a series resistance in his Eq. (1) which we have not. Our data indicate that the series resistance is relatively small. For example, from Fig. 4 in Ref. 2 the resistance of the 2 μm long polyaniline fiber is five to ten times smaller than the diode resistance in the voltage range below 1 V. When we make the diode, the series resistance is even smaller because the length of the polyaniline fiber is only 200 nm.

(2) We point out that the meaning of the words "contact resistance" in Ref. 2 differs from that of Lin. He refers to the contact resistance as the resistance of the polyaniline fiber/doped Si interface, i.e., he means the "resistance of the diode." We, however, mean that the contact resistance is that of the external electrical contacts to the doped Si and to the gold leads. That is, we attribute the deviation from linearity in the semilog plot of Fig. 3 in Ref. 2 to the resistance in the device that is not accounted for in our diode model.

(3) Our intention to include Fig. 5 in Ref. 2 was to demonstrate that the Schottky diode could also be used as a sensor. The sensing parameter we believe is the resistance of the polyaniline fiber upon exposure to ammonia gas. No device parameters were extracted from these data which is why no semilog plot of the forward bias current as a function of the forward bias voltage was given. Lin suggests that the series resistance (i.e., the resistance of the polyaniline fiber) dominates for $V > 0.4$ V. This appears to be related to our point (2) above where the words contact resistance are interpreted differently. Horowitz also relates the nonlinearity in the semilog plot of the current versus forward bias voltage (at high voltage) to the Ohmic losses in the semiconductor.[3] Our explanation for this nonlinearity basically agrees with Lin's.

(4) Equation (3) in the comment is incorrect—it needs a factor n, the ideality parameter, as can be seen by differentiating his Eq. (1) or our Eq. (1) in Ref. 2. This is important in his final point 4. Since Lin has a missing n ($n=4$ in our case) in his formula to extract the device parameters, it leads to the discrepancy in his results and ours. Thus we believe that part 4 of the comment is incorrect. Given the model that we are using, our values of the device parameters are correct and that Lin is incorrect in his calculations. Lin points out that a lower resistance Si would mean a lower series resistance, which is clearly true, but he does not consider that altering the Si might also alter the Schottky barrier, which could be helpful or harmful. We have used a highly n-doped Si/SiO_2 wafer ($\rho = 0.001-0.005\ \Omega$ cm) in a similar device construction as given in Ref. 2 and did not see the asymmetric Schottky diode characteristics. Lin suggests that an increase of the resistance of polyaniline (due to the ammonia gas) might lead to a shift of the Fermi energy and the occurrence of the dipole at the polyaniline/n-type Si interface. This study can be undertaken in the future; for the current paper it would not add to the central idea we wish to convey, viz., a simple technique to fabricate Schottky nanodiodes and also gas sensors. Lin is right that we have not provided a value for S, the effective area of the Schottky nanodiode. We give the diameter of the polyaniline nanofiber (70 nm) from which this area could be estimated if needed.

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In summary, while Lin suggests a modification of the thermionic emission model to interpret our data, we feel that his comments do not affect the general conclusions addressed in our letter.

[1]Y. J. Lin, Appl. Phys. Lett. **89**, 176101 (2006) (preceeding article).
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[3]G. Horowitz, Adv. Mater. (Weinheim, Ger.) **2**, 287 (1990).