QuasiSchottky barrier diode on nGa0.47In0.53As using a fully depleted p+ Ga0.47In0.53As layer grown by molecular beam epitaxy


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Quasi-Schottky barrier diode on n-Ga$_{0.47}$In$_{0.53}$As using a fully depleted $p^+$- Ga$_{0.47}$In$_{0.53}$As layer grown by molecular beam epitaxy

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A quasi-Schottky barrier diode made on n-Ga$_{0.47}$In$_{0.53}$As has been demonstrated. This device utilizes a fully depleted ultrathin $p^+$-Ga$_{0.47}$In$_{0.53}$As layer grown by molecular beam epitaxy to increase the barrier height. An increase in the barrier height of 0.27 V, making the total barrier height 0.47 V, has been obtained. A low reverse leakage current and a hysteresis-free capacitance-voltage characteristic suggest that this structure should be useful as a current control gate for high speed field-effect transistors.

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Recent studies have suggested that Ga$_{0.47}$In$_{0.53}$As is a promising material for high speed field-effect transistor (FET) applications. First, experimental study shows that n-Ga$_{0.47}$In$_{0.53}$As has the highest low field mobility among the quaternary system that can be grown lattice matched to promising material for high speed field-effect transistor (FET) applications. First, experimental study shows that n-Ga$_{0.47}$In$_{0.53}$As has the highest low field mobility among the quaternary system that can be grown lattice matched to

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**Diagram:**

![Diagram of the quasi-Schottky barrier diode](image)

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scan, for example, is needed to pinpoint the mechanisms comparable to that of the oxide-enhanced Schottky diode. This can be caused by thermionic emission or tunneling. A detailed study using temperature dependence of the effective barrier height \( \phi'^* \). This is not surprising for this quasi-Schottky structure in which the applied voltage is dropped across a depleted \( p^+ \) layer as well as the depletion region in the \( n \)-type layer. While Schottky barriers with nonunity ideality factors can generate excessive shot noise in mixer diode applications, this is somewhat immaterial for the field-effect transistor application. If we arbitrarily define the cut-in voltage as the forward bias voltage to reach a current of 10 \( \mu A \), then the quasi-Schottky barrier diode has a cut-in voltage of 0.005 V. On the other hand, a Ga\(_{0.47}\)In\(_{0.53}\)As \( p-n \) junction diode of the same area shows a cut-in voltage of 0.14 V. The fact that a quasi-Schottky barrier diode has a smaller cut-in voltage than a \( p-n \) junction diode is consistent with our expectation.

The current-voltage characteristic of a plain Au/\( n \)-Ga\(_{0.47}\)In\(_{0.53}\)As Schottky diode (without the \( p^+ \) layer) is shown in Fig. 2(b) for comparison. It can be seen that the \( p^+ \)-layer quasi-Schottky barrier reduces the reverse leakage current significantly, more than three orders of magnitude at 0.6-V bias.

In light of the discussion presented so far and the energy band diagram shown in Fig. 1(b), we can estimate the free-hole concentration in the \( p^+ \) layer. The hole concentration will be greatest at the location where the potential energy reaches its maximum. The maximum free-hole concentration is estimated to be 1.6 \( \times 10^{17} \) cm\(^{-3}\) from the known separation between the Fermi level and the valence band. This number is indeed negligibly small compared to \( N_s \), satisfying the condition of depletion, \( p < N_s \), where \( p \) is the free-hole concentration.

We also measured the capacitance-voltage (C-V) characteristic of the diode. C-V measurement at 1 MHz shows no hysteresis, as expected. In contrast, hysteresis is usually observed in the oxide-enhanced Schottky diode. A C \( -2 \) vs \( V \) plot suggests a uniform carrier concentration of 1.2 \( \times 10^{17} \) cm\(^{-3}\) in the \( n \)-type layer and a barrier height of 0.51 V, in good agreement with the Hall measurement and I-V measurement, respectively.

In conclusion, we have demonstrated a quasi-Schottky barrier diode on \( n \)-Ga\(_{0.47}\)In\(_{0.53}\)As substrates using a \( p^+ \)-Ga\(_{0.47}\)In\(_{0.53}\)As layer grown by MBE. The barrier height is enhanced by a \( p^+ \) layer which is fully depleted at thermal equilibrium. An effective barrier height of 0.47 V, representing an enhancement of \(-0.27\) V, has been obtained. A low

\[ \Delta \phi'^* \approx V_0 N_p/N_A, \]

where \( N_p \) is the doping level of the \( n \)-type layer and \( V_0 \) is the built-in potential of the \( p^-n \) junction. The thickness and doping levels in the present structure satisfy this condition. As a result, the Schottky barrier enhancement is calculated to be 0.3 V, making a total effective barrier height of 0.5 V. This agrees reasonably well with the result inferred from Eq. (1).

The current-voltage characteristic shown in Fig. 2(a) fits the standard equation for a Schottky barrier diode, with an ideality factor of 1.3. This nonunity ideality indicates a strong voltage dependence of the effective barrier height \( \phi'^* \). In light of the discussion presented so far and the energy band diagram shown in Fig. 1(b), we can estimate the free-hole concentration in the \( p^+ \) layer. The hole concentration will be greatest at the location where the potential energy reaches its maximum. The maximum free-hole concentration is estimated to be 1.6 \( \times 10^{17} \) cm\(^{-3}\) from the known separation between the Fermi level and the valence band. This number is indeed negligibly small compared to \( N_s \), satisfying the condition of depletion, \( p < N_s \), where \( p \) is the free-hole concentration.

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\[ \Delta \phi'^* \approx V_0 N_p/N_A, \]
leakage current and a hysteresis-free capacitance-voltage characteristic suggest that this structure should be of excellent quality for use as a gate in high speed FET applications.


Collection length of holes in a-Si:H by surface photovoltage using a liquid Schottky barrier

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In a recent article Dresner, Szostak, and Goldstein (DSG) described the use of the surface photovoltage (SPV) method for measuring the ambipolar diffusion length in the photoconductive semi-insulator hydrogenated amorphous silicon. In this method the surface is illuminated with monochromatic light at various wavelengths near the absorption edge. A photovoltage is developed between the surface and the bulk due to the back diffusion of minority carriers to a surface barrier and the subsequent charge separation in the barrier field. The light intensity at each wavelength is adjusted for a constant photovoltage. The photovoltage was detected by a Kelvin probe. In the present letter we wish to demonstrate that the surface photovoltage can alternatively be detected by a liquid Schottky barrier in direct contact with the surface. A significant improvement in signal-to-noise and convenience is achieved.

In the original SPV method as applied to crystalline Si and GaAs, the light beam was chopped at some fast rate and the signal picked up capacitively by a closely spaced transparent conducting electrode. This approach was not suitable for a-Si because the ac coupling is best at high chopping rates which are precluded by relatively slow trapping effects at the surface. Instead, DSG used unmodulated light and detected the dc photovoltage with a vibrating Kelvin probe. The measurements were performed in an ultrahigh vacuum system in which the surface could be prepared by ion sputtering, annealing, etc. Careful stabilization of the probe and complete shielding are necessary.

It has long been known that the interface between a semiconductor and a suitably chosen electrolyte can be used to make a photoelectrochemical cell. Much effort has been expended in attempts to use an oxidation-reduction (redox) reaction in the electrolyte solution with a platinum counter-electrode to form a self-regenerating solar cell. In particular, with regard to a-Si Williams has shown that Schottky barriers form at the interface with a number of redox systems whose normal potentials are in the range $-0.1$ to $-1.5$ V (the sign is according to the convention of Latimer). These attempts are spurred by the obvious advantages of the liquid contact: no complicated technology or high-temperature processes are required and the light can easily pass through the electrolyte into the space-charge region to form a conceptually simple solar cell. Regardless of how one views the future of such devices, it is a fact that problems of stability arise especially when current is drawn from the cell. In the case of an illuminated $n$-type semiconductor there is a com-