InGaAs/GaAsSb based two-dimensional electron gases

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InGaAs/GaAsSb based two-dimensional electron gases


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The authors report on two-dimensional electron gases realized in the In_{0.53}Ga_{0.47}As/GaAs_{0.51}Sb_{0.49} material system. For different doping levels, the sheet carrier densities were measured to be between $8.4 \times 10^{10}$ and $8.3 \times 10^{11}$ cm$^{-2}$. A maximum electron mobility of $42700$ cm$^2$/V s was observed at a temperature of $60$ K. In addition to alloy scattering, remote ionized impurity scattering is a limiting factor for this material combination, as the GaAs_{0.51}Sb_{0.49} barriers have the same low effective mass as the In_{0.53}Ga_{0.47}As channel and therefore allow the wavefunction to protrude into the barrier more than in other established material systems. Angle resolved Hall measurements revealed a strong influence of the crystallographic directions on the carrier mobility and two-dimensional electron population. An additional feature of these two-dimensional electron systems, originating from the fact that In_{0.53}Ga_{0.47}As and GaAs_{0.51}Sb_{0.49} show a type-II band alignment and comparable bandgap energies, is spin splitting, due to the Rashba effect, with a Rashba-parameter of $0.42$ eVÅ. © 2014 Author(s). All article content, except where otherwise noted, is licensed under a Creative Commons Attribution 3.0 Unported License. [http://dx.doi.org/10.1116/1.4863299]

I. INTRODUCTION

Two-dimensional electron gases (2DEGs), where remote doping allows the separation of electrons in the channel from ionized donor atoms, opened the field for the discovery of quantum Hall physics.1–3 Most of these experiments were demonstrated in donor atoms, opened the field for the discovery of quantum Hall effects. The combination of In_{0.53}Ga_{0.47}As/GaAs_{0.51}Sb_{0.49} heterostructures, lattice-matched to InP,6,7 Structures, based on In_{0.53}Ga_{0.47}As/GaAs_{0.51}Sb_{0.49} heterostructures, lattice-matched to InP,6,7 Structures, based on In_{0.53}Ga_{0.47}As/GaAs_{0.51}Sb_{0.49} heterostructures, lattice-matched to InP,6,7 Structures, based on In_{0.53}Ga_{0.47}As/GaAs_{0.51}Sb_{0.49} heterostructures, lattice-matched to InP,6,7 Structures, based on In_{0.53}Ga_{0.47}As/GaAs_{0.51}Sb_{0.49} heterostructures, lattice-matched to InP,6,7 Structures, based on In_{0.53}Ga_{0.47}As/GaAs_{0.51}Sb_{0.49} heterostructures, lattice-matched to InP,6,7

II. HETEROSTRUCTURE DESIGN AND GROWTH

All samples discussed in this work were designed and grown with the lattice-matched compositions In_{0.53}Ga_{0.47}As and GaAs_{0.51}Sb_{0.49} for InP substrates. The In_{0.53}Ga_{0.47}As/GaAs_{0.51}Sb_{0.49} interface, which forms the 2D channel, was formed on top of a 1 μm thick In_{0.53}Ga_{0.47}As buffer. Then, an undoped GaAs_{0.51}Sb_{0.49} spacer with a thickness of 20 nm was grown, to separate the electrons in the channel from the ionized donors. The remote doping was provided by Si atoms in a 5 nm thick GaAs_{0.51}Sb_{0.49} layer. In this work, four different doping levels between $5.5 \times 10^{11}$ and $4.3 \times 10^{12}$ cm$^{-2}$ were used. Finally, the structure was capped with 40 nm GaAs_{0.51}Sb_{0.49} and 5 nm In_{0.53}Ga_{0.47}As on the surface.

Although remote doping of GaAs_{0.51}Sb_{0.49} with Si atoms is not as straightforward as for Al_{1–x}Ga_{x}As or In_{1–x}Al_{x}As, it leads to n-type carriers. Compared to pure arsenides, only a fraction of the free electrons are reached in the bulk material, depending on the doping level between 17.4 and 52.6%. In this work, doping levels from $1.10 \times 10^{11}$ to $8.53 \times 10^{18}$ cm$^{-3}$ were used, where the doping efficiency can be estimated to be around 40–50%. Part of the Si atoms is believed to form deep levels or show acceptor like behavior. Due to the type-II band-alignment of In_{0.53}Ga_{0.47}As/GaAs_{0.51}Sb_{0.49} heterostructures, electrons and...
holes would accumulate at the interface, which forms the 2D channel, leading to both, electron-hole recombination, a loss of electrons in the channel, and additional scattering for the 2D electrons. At first sight, the type-II band alignment appears to be detrimental for 2DEGs, but it enables spin splitting experiments, which are discussed in Sec. VI.

The conduction band profile for the different doping levels was modeled with a self-consistent Schrödinger–Poisson solver, utilizing the envelope function approximation. Band nonparabolicity, even though significant in this low-bandgap type-II heterostructure, was neglected in this model, as the main emphasis was put on the position of the charge carriers, not on the actual energy of the quantized states. Even though Si atoms are known to cause deep levels in GaAs$_{0.51}$Sb$_{0.49}$, these effects are not included in this simplified model, as only few parameters were published up to date. In all calculations, the conduction band edge of In$_{0.53}$Ga$_{0.47}$As on the surface was assumed to be pinned 0.20 eV above the Fermi energy ($E_F$). The conduction band profiles, obtained from this model with the four different doping levels, are plotted in Fig. 1. From this model, the 2DEG with the lowest doping level appears depleted, as the ground state is calculated to be 48 meV above the $E_F$. For the next higher doping level of $1.1 \times 10^{12}$ cm$^{-2}$, the lowest quantized state in the 2DEG is approximately 10 meV above $E_F$. In both cases, the number of carriers in the channel is underestimated. According to the model, a nominal sheet carrier density of $2.1 \times 10^{12}$ cm$^{-2}$ leads to the ideal case, with one filled state, localized in the In$_{0.53}$Ga$_{0.47}$As layer. However, the lowest level in the GaAs$_{0.51}$Sb$_{0.49}$ barrier is just 9 meV above the Fermi energy, which shows the onset of a parasitic channel around this doping level. This is even more expressed for the highest sheet carrier density, where already two quantized states in the GaAs$_{0.51}$Sb$_{0.49}$ barrier are filled, compared to only one level below $E_F$, located in the In$_{0.53}$Ga$_{0.47}$As layer.

The structures were grown by solid-source molecular beam epitaxy, where both group V compounds were supplied from valved cracker cells. Tetrameric As was supplied with a beam-equivalent-pressure of $1.5 \times 10^{-5}$ Torr throughout oxide desorption, growth, and cooling of the samples. For reliable lattice-matching, Sb was cracked at 1000 °C to reach a higher sticking coefficient. Switching between the different compounds was done by In and Sb shutter operations only. After the native oxide was thermally desorbed, the substrates were brought to a growth temperature of 480 °C, measured by a pyrometer, calibrated for GaAs. The samples were then grown on compensation-doped InP:Fe substrates at a combined growth rate around 0.8 lm/h for In$_{0.53}$Ga$_{0.47}$As, leading to a Ga-limited growth rate of approximately 0.4 lm/h for GaAs$_{0.51}$Sb$_{0.49}$, and finally cooled, while still under As$_4$ flux to stabilize the surface.

III. VARIATION OF SHEET CARRIER DENSITY

Basic Hall measurements were performed on $5 \times 5$ mm sized pieces following the van der Pauw method. For electrical contacts, In:Sn pellets were annealed in the corners of the samples at 520 °C for 3 min, while under reducing H$_2$/N$_2$ atmosphere. For the electrical measurements, the samples were placed in a cryostat, shielded from ambient light. Conductivity and Hall voltage were performed for the temperature range from 300 to 8 K, applying 0.1 mA DC and a magnetic field of 0.1 T.

Temperature dependent electron mobilities for the different doping levels are plotted in Fig. 2. Starting from 300 K, the mobility for the different doping levels is increasing as expected. The maximum mobility of 42 700 cm$^2$/V s, is

![Fig. 1. (Color online) Calculated conduction band profiles and quantized states of In$_{0.53}$Ga$_{0.47}$As/GaAs$_{0.51}$Sb$_{0.49}$ 2DEGs with different doping levels between $5.5 \times 10^{11}$ and $4.3 \times 10^{12}$ cm$^{-2}$. The Fermi energy ($E_F$) is fixed at 0 eV.](image1)

![Fig. 2. (Color online) Temperature dependent Hall mobilities for structures with a common spacer thickness of 20 nm and different sheet carrier densities. The open symbols represent datapoints, obtained after illumination.](image2)
reached at 60 K for a sheet carrier density of $1.07 \times 10^{12}$ cm$^{-3}$. However, another common feature is the decrease in the mobility for lower temperatures, which could be caused by ionized dopants or carrier freeze out, where the ohmic contacts are diffused through the GaAs$_{0.51}$Sb$_{0.49}$ barrier material. Scattering due to remote impurities is expected to be more pronounced than in other material systems, as discussed in detail in Sec. IV. On the other hand, Sn doping in GaAs$_{1-x}$Sb$_x$ is known to cause self-compensation at compositions around $x = 0.15$ already. In addition, the open datapoints were measured after exposing the sample to light. This procedure frees additional carriers and in turn increases the mobility slightly.

Both, room temperature and maximum mobilities depending on the sheet carrier density are summarized in Fig. 3(a). While the mobility at 300 K remains more or less constant, there is a clear trend toward higher mobilities for lower doping levels. This behavior is in clear contrast to GaAs/Al$_{x}$Ga$_{1-x}$As and In$_{0.53}$Ga$_{0.47}$As/In$_{0.52}$Al$_{0.48}$As-based 2DEGs, where the mobility directly scales with the sheet carrier density in the channel. This dependence suggests that alloy scattering in the barrier material GaAs$_{0.51}$Sb$_{0.49}$ plays an important role. However, the lowest doping leads to a sharp drop in the mobility, which suggests that a certain amount of carriers is needed to saturate trap states in the undoped GaAs$_{0.51}$Sb$_{0.49}$ spacer, until a high mobility 2D-channel can be formed at the interface between In$_{0.53}$Ga$_{0.47}$As and GaAs$_{0.51}$Sb$_{0.49}$. A summary of deep traps related to bulk GaAs$_{0.51}$Sb$_{0.49}$ as well as In$_{0.53}$Ga$_{0.47}$As/GaAs$_{0.51}$Sb$_{0.49}$ heterojunctions can be found in Ref. 30.

From previous works, we estimate the doping efficiency for bulk GaAs$_{0.51}$Sb$_{0.49}$ to be approximately between 40 and 50% for doping concentrations between $1.1 \times 10^{18}$ and $8.5 \times 10^{18}$ cm$^{-3}$. This is known to be further reduced in the case of remote doping, as the dopant atoms are placed in the barrier and electrons need to tunnel to the 2D channel, while potentially being trapped in the undoped spacer. The relation between nominal doping and measured sheet carrier density in the channel is plotted in Fig. 3(b). Both datasets, for 300 K and for the temperature with the maximum mobility, follow a linear fit, which shows that 19.5% of the charge carriers make it into the channel at 300 K. The reduced doping efficiency in combination with the type-II band alignment explains the decreasing mobility with increasing sheet carrier densities between $1.07 \times 10^{12}$ and $4.27 \times 10^{12}$ cm$^{-2}$. Extrapolating the linear fit from Fig. 3(b), leads to a probably overestimated, trap density of $1.5 \times 10^{13}$ cm$^{-3}$, which needs to be saturated in order to form a 2DEG. For the lowest dopant sample, this density is already on the same order of magnitude as the nominal doping. Qualitatively, this explains the low mobility of the lowest doped sample, lying even below room temperature mobilities of the higher doped samples.

### IV. INFLUENCE OF MATERIAL PARAMETERS

The following paragraphs will provide a comparative overview of 2DEGs in different III-V materials. Despite their technological importance, nitride-based materials are omitted here for simplicity, due to their polar bonding nature. Important features to distinguish the individual materials are the number of alloy constituents of well and barrier material, the effective masses in both compounds, and the conduction band offset (CBO). The fact that alloy scattering limits the 2DEG mobility at low temperatures clearly favors the combination of the binary GaAs wells with Al$_{0.3}$Ga$_{0.7}$As barriers, as the electron wavefunction is mostly confined in the binary alloy. The other InGaAs based combinations feature a lower electron effective mass with the disadvantage of alloy scattering due to almost equal Ga and In fractions in the cation sublattice.

For the following analysis, conduction band profiles and quantized electron states were calculated for heterostructures composed of the different material combinations (GaAs/Al$_{0.3}$Ga$_{0.7}$As, In$_{0.53}$Ga$_{0.47}$As/In$_{0.52}$Al$_{0.48}$As, In$_{0.53}$Ga$_{0.47}$As/InP, and In$_{0.53}$Ga$_{0.47}$As/GaAs$_{0.51}$Sb$_{0.49}$) but with identical layer thicknesses, as described in Sec. II and a fixed doping of $4.26 \times 10^{18}$ cm$^{-2}$. The individual conduction band profiles are plotted in Fig. 4. Obviously, all structures lead to the formation of a 2DEG at the heterointerface. In addition, the combination of In$_{0.53}$Ga$_{0.47}$As with InP or GaAs$_{0.51}$Sb$_{0.49}$ barriers exhibits a parallel channel due to states in the barrier for lower doping levels, compared to the other material systems. However, this does not influence the following comparison of 2DEG structures. Electrons in the 2D channel are assumed to only populate the lowest energy level, which is located at the interface.

Scattering processes are not only limiting the carrier mobility in 2DEGs, but are also known to influence the device characteristics of QCLs. In particular, interface roughness scattering was found to reduce the carrier lifetime in the upper laser level of QCLs. The wavefunction in a QCL at the alignment field spreads over two quantum wells,
including the barrier with two interfaces in between. Since symmetric active regions still showed asymmetric behavior, we conclude that the scattering must be sensitive to \( \Psi^2 \) at the interface, which therefore serves as one figure of merit. Alloy scattering, although potentially present in both layers, is commonly attributed with the channel material due to the small fraction of the wavefunction, which is penetrating into the interface, which therefore serves as one figure of merit. Alloy scattering in the barrier material.

Table I. Comparison of the same 2DEG structure, realized in different material combinations. Figures of merit are the overlap of the electronic wavefunction with the barrier material, the amplitude squared at the interface, and the effective spacer thickness \( (d_{\text{eff}}) \), given by the distance between the dopant atoms and the expectation value for the position of the 2D electron wavefunction. To allow better comparison of the different materials, also the CBO and the ratio of effective electron masses in channel and barrier material are listed.

<table>
<thead>
<tr>
<th>Channel/barrier material</th>
<th>( \Psi^2 ) at int. ((\times 10^{-3}) )</th>
<th>( \Psi^2 ) at barrier ((\times 10^{-3}) )</th>
<th>( d_{\text{eff}} )</th>
<th>CBO</th>
<th>( m_{\text{eff}}/m_{\text{0}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>GaAs/Al(<em>{0.3})Ga(</em>{0.7})As</td>
<td>2.55</td>
<td>7.40</td>
<td>26.9</td>
<td>0.237</td>
<td>1.37</td>
</tr>
<tr>
<td>In(<em>{0.53})Ga(</em>{0.47})As/In(<em>{0.52})Al(</em>{0.48})As</td>
<td>0.82</td>
<td>1.00</td>
<td>26.9</td>
<td>0.52</td>
<td>1.64</td>
</tr>
<tr>
<td>In(<em>{0.53})Ga(</em>{0.47})As/InP</td>
<td>1.09</td>
<td>1.23</td>
<td>28.6</td>
<td>0.22</td>
<td>1.75</td>
</tr>
<tr>
<td>In(<em>{0.53})Ga(</em>{0.47})As/GaAs(<em>{0.51})Sb(</em>{0.49})</td>
<td>13.1</td>
<td>156</td>
<td>25.6</td>
<td>0.36</td>
<td>1.00</td>
</tr>
</tbody>
</table>

V. ORIENTATION DEPENDENT 2D ELECTRON POPULATION

Angle-resolved measurements of the mobility and the sheet carrier density were performed using 100 × 300 \( \mu \)m sized Hall bars, rotated in 15° steps from 0° to 90° with respect to the major flat of the wafer. The structures were defined by standard optical lithography and SiCl\(_4\) reactive ion etching. Evaporated Ge/Au/Ni contact pads, annealed at 520 °C for 3 min, were used for the electrical measurements. A current of 1 \( \mu \)A and magnetic fields from 0 to 8 T were used to record Shubnikov-de-Haas (SdH) oscillations, as well as the electrical conductivity and Hall voltage.

Experimental values for the angled Hall bars are plotted in Fig. 5. For these measurements, the sample was kept at a temperature of 4 K. For a Hall bar, which is oriented inline with the major flat sheet, carrier densities of 5.05 \( \times 10^{11} \) cm\(^{-2}\) (Hall) and 4.56 \( \times 10^{11} \) cm\(^{-2}\) (SdH) were obtained. This
obtained for 0 switch in the group V sublattice. Alternatively, CuPt-ordered originate from a change in the surface reconstruction due to a responsible for orientation dependent scattering.33,34

rably low bandgaps, these structures are ideal to probe spin mobilities. Due to the type-II band alignment and the comparable physical properties, despite their relatively low electron levels, as well as the carrier mobility with respect to the orientation of the Hall bars. The angle is defined between the Hall bar orientation and the (110) direction. The experimental values were obtained at a temperature of 4 K.

deviation can be explained by the fact that the Hall voltage includes all free carriers, while the SdH oscillations only depend on carriers in 2D levels. This measurement therefore suggests that almost 10% of the carriers occupy some 3D level above the 2D gas or parasitic levels in the barrier.

If the Hall bars are tilted about the (100) axis of the wafer, the obtained sheet carrier densities decrease for both techniques. It is notable that the decrease of the 2D electron density is more influenced by the orientation on the wafer than the total number of carriers. In the case of a Hall bar that is tilted by 60°, only 23% of the carriers are found to be in the 2DEG.

Consequently, the measured mobility follows the trend of the 2D densities. The maximum value of 64 000 cm²/Vs is obtained for 0°, while at 45°, the mobility drops below 11 000 cm²/Vs. The deviating mobilities between the Hall bar and van der Pauw measurements can be explained by the different contact materials or by the smaller, lithographically defined, area of the Hall bars.

We attribute these orientation-dependent effects to a difference in the interface roughness along the (110) and (110) directions. Similar effects were observed in GaAs/AlₓGa₁₋ₓAs and InₓGa₁₋ₓAs/InₓAl₁₋ₓAs 2DEGs.31,32 This could potentially originate from a change in the surface reconstruction due to a switch in the group V sublattice. Alternatively, CuPt-ordered domains in the GaAsₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐₐ}_{\text{02C104-5 Detz et al.: InGaAs/GaAsSb based two-dimensional electron gases 02C104-5}}

VI. RASHBA SPIN SPLITTING

Two-dimensional electron systems based on In₀.₅₃Ga₀.₄₇As/GaAs₀.₅₁Sb₀.₄₉ heterostructures show interesting physical properties, despite their relatively low electron mobilities. Due to the type-II band alignment and the comparably low bandgaps, these structures are ideal to probe spin splittings based on the Rashba effect.20

The Rashba parameter can be decomposed into two parts:35,36 One material dependent part, which can be calculated from the bandgap and the spin-orbit gap, as well as the effective mass and which is constant for a particular material. Due to the lack of reliable data for the ternary alloy GaAs₀.₅₁Sb₀.₄₉, the energy of the spin-orbit gap is assumed to be 0.75 eV, identical to GaSb. As the second contribution, this term must be multiplied with the electric field at the interface. Both terms are stronger for In₀.₅₃Ga₀.₄₇As/GaAs₀.₅₁Sb₀.₄₉ heterostructures compared to GaAs/AlₓGa₁₋ₓAs, which leads to the Rashba parameter being one order of magnitude larger.36

Spin-splitting due to the Rashba effect has already been demonstrated in In₀.₅₃Ga₀.₄₇As/GaAs₀.₅₁Sb₀.₄₉ resonant tunneling diodes,20 Rashba parameters between 0.38 and 0.78 eVÅ were calculated from the experimental data. Shubnikov-de Haas oscillations were observed in Hall bar samples, where a magnetic field was applied inline with the direction of quantization. Corresponding data, recorded for magnetic fields up to 8 T at a constant current, are plotted in Fig. 6(a). For further analysis, a fast Fourier transformation was applied to the first derivative of the experimental data. The resulting spectral distribution is shown in Fig. 6(b). Two distinct peaks, corresponding to two carrier populations in different states can be clearly observed for temperatures up to 4 K. Contributions from a potential parallel channel in the GaAs₀.₅₁Sb₀.₄₉ barrier can be excluded as these carriers would have a much lower mobility and therefore would not lead to SdH oscillations. Furthermore, the existence of a second populated 2D level in the channel can be ruled out from the modeling, presented in Fig. 1, where the second bound state in the In₀.₅₃Ga₀.₄₇As channel is calculated to be well above the Fermi energy.

![Graph showing carrier densities obtained from Hall and SdH measurements](image)
From these data, a Rashba parameter of 0.42 eVÅ for the In0.53Ga0.47As/GaAs0.53Sb0.49-based 2DEGs could be extracted. Resonant tunneling diodes of the same material system showed values in the range of 0.38–0.78 eVÅ.20 Rashba spin-orbit coupling of the same order of magnitude (0.64–0.74 eVÅ) was reported for highly strained In0.53Ga0.47As/InP 2DEGs, which were patterned into quantum wires.37 Furthermore, similar values, around 0.5 eVÅ are predicted for InSb/InAs quantum wells.38

VII. SUMMARY

This work provides a comprehensive study on 2DEGs, realized in In0.53Ga0.47As/GaAs0.53Sb0.49 heterostructures. Hall measurements in the van der Pauw geometry revealed a maximum electron mobility of 42 700 cm²/V s for a sheet carrier density of 1.07 × 10¹² cm⁻². Compared to other material systems, the mobility is limited by alloy scattering, both in the In0.53Ga0.47As channel and to a lesser extent in the GaAs0.53Sb0.49 barrier. Furthermore, the low effective mass in the barrier leads to an up to five times higher fraction of the wavefunction, protruding into the barrier, which makes the 2DEGs more sensitive to remote ionized impurity scattering and interface roughness. Nevertheless, these structures are attractive for spintronics. The bandgaps in combination with a type-II band alignment lead to large Rashba parameters, which allow to observe pronounced spin splitting effects.

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