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InAs/GaSb/AlSb Resonant Tunneling Spin Device Concepts

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We report device concepts for creating spin polarized current sources without external magnetic fields, using nonmagnetic 6.1 Å semiconductor resonant tunneling structures. These devices contain asymmetric quantum wells where quantized states are spin-split by the Rashba effect [1], and achieve spin filtering by exploiting the phenomenon that the spin of a resonantly transmitted electron aligns with that of the quasibound state traversed [2,3]. Achieving significant spin filtering using this approach is difficult because of the intrinsic properties of the spin-split quantum well states: the $\mathbf{k}_{\|}$-dependent spin splitting is typically small and vanishes at the zone center; states with opposite $\mathbf{k}_{\|}$ within a given spin-split subband have opposite spins so that there is no net spin when averaged over the subband. We use the properties of the 6.1 Å material system, such as large spin-orbit interaction in InAs and GaSb, the availability InAs and GaSb for building highly asymmetric quantum wells, and interband tunneling capability using the type-II broken-gap band offset, to provide effective strategies for overcoming these challenges. We have developed new concepts and also adapted existing ideas for designing InAs/GaSb/AlSb based spin devices. We will present modeling results on:

(1) ***Resonant Tunneling Spin Filter***. The asymmetric resonant tunneling diode (aRTD) is an implementation of the resonant tunneling spin filter [3] in the 6.1 Å semiconductors; it contains an InAs-GaSb quantum well with optimized Rashba coefficients.
(2) ***Spin-Blockade Device***. We designed an InAs/GaSb/AlSb triple-barrier spin filter based on the spin-blockade concept [4]. We clarify the idea of the one-sided collector [4].
(3) ***BIA (Bulk Inversion Asymmetry) Enhanced Spin Filter***. We present a simple method for enhancing spin filtering efficiency by properly combining the BIA and the SIA (structural inversion asymmetry) effects.
(4) ***Resonant Interband Tunneling Spin Filter*** [5]. The interband design exploits large valence band spin-orbit interaction to provide strong spin selectivity, without suffering from fast hole spin relaxation. Spin filtering efficiency is also enhanced by the reduction of tunneling through quasibound states near the zone center. The asymmetric resonant tunneling diode (aRITD) improves spin-filtering efficiency significantly (> 60% current spin polarization) over the aRTD.
(5) ***Bi-Directional Spin Pump***. In the spin filters we try to overcome the challenges presented by the spin configurations in Rashba-effect quantum wells. The spin pump, on the other hand, is designed specifically to take advantage of the Rashba spin configuration. It causes oppositely spin-polarized current components to flow in opposite directions, thereby providing a novel mechanism for spin separation.

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