



Physical Sciences

Resonant Tunneling Spin Pump

Electrons in opposite spin states would flow in opposite directions across a spin filter.

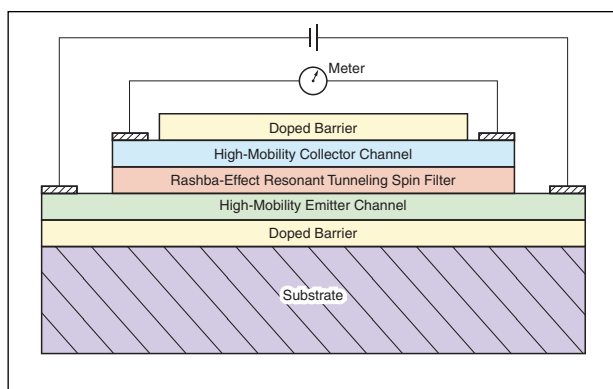
NASA's Jet Propulsion Laboratory, Pasadena, California

The resonant tunneling spin pump is a proposed semiconductor device that would generate spin-polarized electron currents. The resonant tunneling spin pump would be a purely electrical device in the sense that it would not contain any magnetic material and would not rely on an applied magnetic field. Also, unlike prior sources of spin-polarized electron currents, the proposed device would not depend on a source of circularly polarized light.

The resonant tunneling spin pump would have some features in common with other, similarly named devices, including resonant tunneling spin filters described in a previous *NASA Tech Briefs* article: "Electron-Spin Filters Based on the Rashba Effect" (NPO-30635), Vol. 28, No. 10 (October 2004), page 58.

To recapitulate: Proposed semiconductor electron-spin filters would exploit the Rashba effect, which can induce energy splitting in what would otherwise be degenerate quantum states, caused by a spin-orbit interaction in conjunction with a structural-inversion asymmetry in the presence of interfacial electric fields in a

semiconductor heterostructure. The magnitude of the energy split is proportional to the electron wave number. Theoretical studies have suggested the possibility of devices in which electron energy states would be split by the Rashba effect and spin-polarized currents would be extracted by resonant quantum-mechanical tunneling.



In the **Resonant Tunneling Spin Pump**, the lateral electric field applied to the emitter channel would induce a lateral current in the collector channel and spin-polarized currents across the spin filter.

The resonant tunneling spin pump (see figure) would include a spin filter between two reservoirs of initially unpolarized electrons. Like the devices of the cited prior article, the resonant tunneling spin pump would be designed and fabri-

cated in the InAs/GaSb/AlSb material system. One reservoir would be a high-mobility InAs emitter channel and the other a high-mobility InAs collector channel. The spin filter would comprise an InAs/GaSb/AlSb asymmetric resonant tunneling structure.

The application of a lateral electric field in the emitter channel would cause current of one spin state to flow from the emitter channel to the collector channel and a current of the opposite spin state to flow from the collector channel to the emitter channel, thereby inducing spin polarization in both reservoirs. This mode of operation would differ somewhat from that of a spin filter: In a spin filter, component currents containing spins of both states would flow from the emitter to the collector and spin polarization in the collector would be achieved by choosing the design and the operating conditions of the device

to make one of the spin component currents larger than the other.

This work was done by David Z. Ting of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-30885

Enhancing Spin Filters by Use of Bulk Inversion Asymmetry

Current spin polarization could be maximized through appropriate choice of collection angle.

NASA's Jet Propulsion Laboratory, Pasadena, California

Theoretical calculations have shown that the degrees of spin polarization in proposed nonmagnetic semiconductor resonant tunneling spin filters could be increased through exploitation of bulk inversion asymmetry (BIA). These enhancements would be effected through suitable orientation of spin collectors (or spin-polarization-inducing lateral electric fields), as described below.

Spin filters — more precisely, sources of spin-polarized electron currents — have been sought for research on, and development of, the emerging technological discipline of spintronics (spin-transport electronics). Proposed nonmagnetic semiconductor electron-spin filters were described in a prior *NASA Tech Briefs* article: "Electron-Spin Filters Based on the Rashba Effect" (NPO-30635), Vol. 28, No. 10 (October 2004),

page 58. To recapitulate: The proposed spin filters were to be based on the Rashba effect, which is an energy splitting of what would otherwise be degenerate quantum states, caused by a spin-orbit interaction in conjunction with a structural-inversion asymmetry (SIA) in the presence of interfacial electric fields in a semiconductor heterostructure. The magnitude of the energy split is proportional to the electron wave num-