PRX Energy, vol.4, no.3, pp.033003-1-033003-10, September, 2025.

Large Tunable Thermoelectric Effects in Superconducting Spin Valves with Commercially Available Materials

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Abstract-

Recent studies have revealed magnetically controllable thermoelectric effects in superconductor/ferromagnet (S/F) structures. A tunable cryogenic thermoelectric generator needs not only a high conversion factor between electricity and heat, but also a large change in the thermoelectric output when switching the magnetic state of the device. However, the reported modifications in thermoelectric power are either minimal, involve superconductors with relatively low critical temperatures (below 1 K), or do not utilize commercially available spintronic materials. Here, we experimentally measure and numerically model thermoelectric effects in fully epitaxial ferromagnet/superconductor/ferromagnet (F/S/F) junctions based on commercially available easily grown materials, as well as their dependence on the magnetic configuration of the ferromagnetic (F) electrodes. We observe sizeable Seebeck coefficients for the parallel alignment of the F electrodes, reaching values of about 100 µV/K. Importantly, we find a decrease of the thermoelectric signal of more than an order of magnitude when switching from a parallel to an antiparallel configuration, constituting a large thermoelectric spin-valve effect. Theoretical modeling based on a self-consistent nonequilibrium Keldysh-Usadel Green's function theory, combined with micromagnetic simulations, qualitatively reproduce the experimental findings. The thermoelectric effect is optimized when there is a large spin-dependent electron-hole asymmetry in the superconductor combined with spin-dependent transmission through the interfaces. These findings pave the way for the development of efficient and versatile cryogenic thermoelectric heat engines.

Index Terms- Electrical conductivity; Electrical properties; Magnetism; Micromagnetism; Spintronics; Superconductivity; Thermoelectrics

Citation:
Tuero, P.; Tjernshaugen, J.B.; Sánchez, C.; González-Ruano, C.; Lu, Y.; Linder, J.; Aliev Kazanski, F. "Large Tunable Thermoelectric Effects in Superconducting Spin Valves with Commercially Available Materials", PRX Energy, vol.4, no.3, pp.033003-1-033003-10, September, 2025.