Parallel electron-hole conducting gases in monoxide/mononitride multilayers

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An unexplored class of materials for the realization of a two dimensional (2D), two carrier (electron+hole) gas is proposed: heterostructures of a rocksalt oxide (MgO) and nitride (ScN or CrN) grown along the polar (111) direction. For thinner nitride blocks of four unit cells or less, the heterostructures (designed as a superlattice) remain insulating with the band gap defined by states residing at the two separate interfaces. For thicker blocks, the band gap collapses as an insulator-to-metal transition takes place at a critical thickness of 5 layers. First principles calculations indicate that each of the metallic electron and hole layers is confined to its own interface, with negligible overlap, constituting a periodic array of alternating electron and hole 2D gases. Use of the N anion should promote robust two carrier 2D conduction compared to oxides, where holes are prone to localization – recall that most bulk transition metal nitrides are metallic. We additionally propose experimental tests for detecting this peculiar bi-conducting system, i.e. thermopower and Hall effect measurements. Both should display considerable electron-hole compensation, especially for the (essentially vanishing) thermopower that could enable the use these superlattices as a reference material for thermoelectric measurements at the nanoscale.