Electric field effect in few layers antiferromagnetic CrSBr

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Low dimensional magnetic material with weak interlayer electronic coupling and high electrical field tunability provide a great platform for developing modern spintronic technologies. Van der Waals materials CrSBr has been recently reported to be an A-type antiferromagnetic structure below 132 K with each layer aligned ferromagnetically in plane yet coupled antiferromagnetically along the stacking direction [1–4]. To investigate its magnetic tunability with field-effect, we report the in-plane transport and optical study on first successfully fabricated 6–12 layers CrSBr field effect transistor (FET). The FET devices show n-type semiconducting behavior with on/off current ratio of 10^3 to 10^5 from room temperature down to liquid Helium temperatures respectively. The field effect mobility evaluated from the gate capacitance is around 8 cm^2/Vs, comparable to the previously reported 2D magnetic van der Waals materials, such as $NiPS_3$ [5]. Furthermore, we found the finite density of states even at zero backgate voltage which could possibly be attributed to impurity doping with density around 8×10^{12} cm^{-2}. Meanwhile, based on thermally activated model, the activation energy at different silicon back gate voltages is estimated and experience a change from 33 to 277 meV, revealing the appearance of impurity in gap states below the conduction band. This is consistent with the photoluminescence (PL) spectra, which show the direct gap recombination at 1.35 meV and a low energy peak (1.25 meV) attributed to the presence of impurities in the materials. To explore the magnetic tunability of CrSBr, the magnetic phase diagram versus temperature and magnetic field is studied in detail. Further investigation also reveals a close relation between negative magnetoresistance and applied gate voltage. These results demonstrate the great potential of semiconducting CrSBr as a promising candidate for exploring electrical field effect on 2D magnetism down to low temperature with defects playing a role.

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