n-type doping of MoS_2 with polyvinyl alcohol

César J. Lockhart de la Rosa[1,2], Amirhasan Nourbakhsh[1,2], Inge Asselberghs[1,2], Cedric Huyghebaert[1], Iuliana Radu[1], Stefan De Gendt[1,2], and Marc Heyns[1,2]

[1] imec, Kapeldreef 75, Leuven, Belgium
[2]KULeuven, Celestijnenlaan 200, B-3001 Leuven, Belgium
Email: lockhart@imec.be

Abstract

Molybdenum disulfide (MoS_2) is one of the main member of the semiconducting transition metal dichalcogenides family with promising potential applications in optoelectronics. However MoS_2 devices such as field effect transistors (FETs) have high sheet resistance (R_{SH}) and high metal-to-MoS_2 contact resistance (R_C) limiting the device performance. One of the most effective techniques to reduce R_{SH} and R_C is doping the MoS_2 thin films. Substitution doping of MoS2 with different atoms has been reported by several research groups [1-3]. However since this mechanism relies on covalent modification of MoS_2 it introduces severe structural defects. Alternatively, efficient doping of MoS_2 can be achieved by charge transfer from physisorbed species to MoS_2 [4-5].

This work reports on a reversible doping method to achieve highly stable *n*-type MoS_2, in which polyvinyl alcohol (PVA) serves as a non-covalent electron dopant layer. The chemically stable n-type characteristics of the PVA-doped-MoS_2 FETs were evaluated by electrical characterization. R_C and R_{SH} were extracted using the transfer length method (TLM) and four-point-probe (4PP) method, respectively. Figure 1 shows optical micrographs of 4pp and TLM back gated MoS_2-FETs with average thickness of about 5 nm. Thin films of PVA were obtained by spin coating from an aqueous solution onto the devices. The doping density of the MoS_2 FETs was controlled by changing the PVA concentration. Upon PVA coating, the ON current (I_{ON}) increases by a factor of 2 (figure 2-a) which can be further improved by a factor of 6 by dehydrating the PVA film. The I_{ON} improvement is due to the increase in the 2D carrier concentration (N_{2D}) resulting in a 30% reduction of R_C (figure 2-b). Moreover, a mobility increase from 20 to 422 $cm^2V^{-1}s^{-1}$ was observed (figure 2-c) after dehydration which can be attributed to charge impurity screening by PVA. The mobility boosting together with the increase of N_{2D} reduced the R_{SH} by more than one order of magnitude of its original value. After removal of the PVA film, all the parameters recovered to the pre-doping values indicating the reversibility of this doping process.

In conclusion, we have shown a strong *n*-type doping of MoS_2 FETs using PVA as dopant source. The significant improvement of device performance in I_{ON} and mobility is mainly attributed to the reduction of R_{SH} and R_C due to the strong doping from PVA coating.

References

[1] K. Dolui et al, Physical Review B, **88** (2013) 075420.
[2] M. Chen et al, Applied Physic Letters, **103** (2013) 142110.
[3] L. Yang et al, VLSI, T250 (2014).
[4] Y. Du et al, IEEE Electron Devices Letters, **10** (2013) 1328.
[5] D. Kiriya et al, J. Am. Chem. Soc. **113** (2014), 7853.

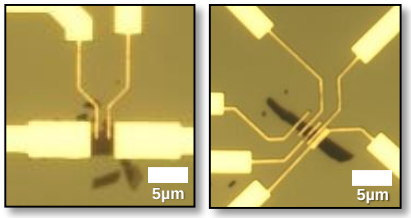

Figure 1: 4PP structure (right) and TLM structure (left).

Figures

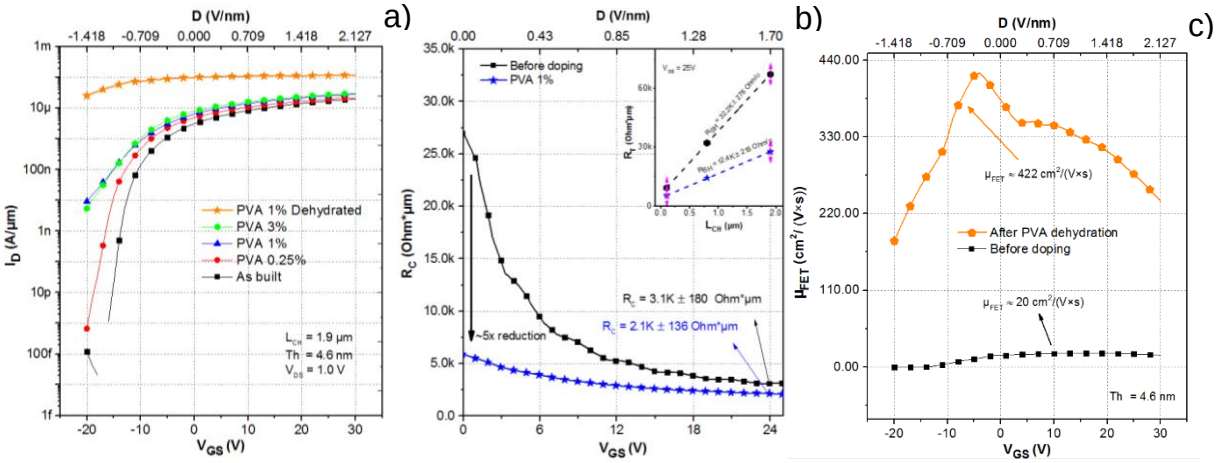

Figure 2: a) Transfer characteristics of the device, b) Contact resistance, c) Field-effect mobility