Supporting Information

High on/off ratio p-type field-effect transistor enabled by a single heavily Al-doped α-Si_3N_4 nanowire

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Experimental Procedure

The as-prepared Al-doped Si_3N_4 NWs in this study were grown by means of pyrolysis of a commercially available polysilazane.[1] First, the liquid precursor was solidified by heat treatment at 260 °C for 0.5 h in ultrahigh purity nitrogen. The obtained solid was then crushed into a fine powder by high energy ball milling. Then this powder mixture was transferred into a high-purity alumina crucible and pyrolyzed in a conventional tube furnace with a graphite resistance heater at 1350 °C for 30 min in flowing ultrahigh-purity nitrogen at 0.1 MPa, followed by furnace cooling to room temperature. The obtained products are hexagonal-phased α-Si_3N_4 nanowires, which are ~ 50−200 nm in diameter and up to several hundred micrometers long.[1]

Results and Discussion

<u>1. Structural characterization</u>

Fig. S1a is a typical SEM image of the pyrolyzed products of Al-doped Si_3N_4 NWs (sample 1) under a low magnification, showing relatively high-density nanowires, grown homogeneously on the top of the graphite matrix. Large amounts of products are due to that the pyrolysis of precursor in flowing ultrahigh-purity nitrogen

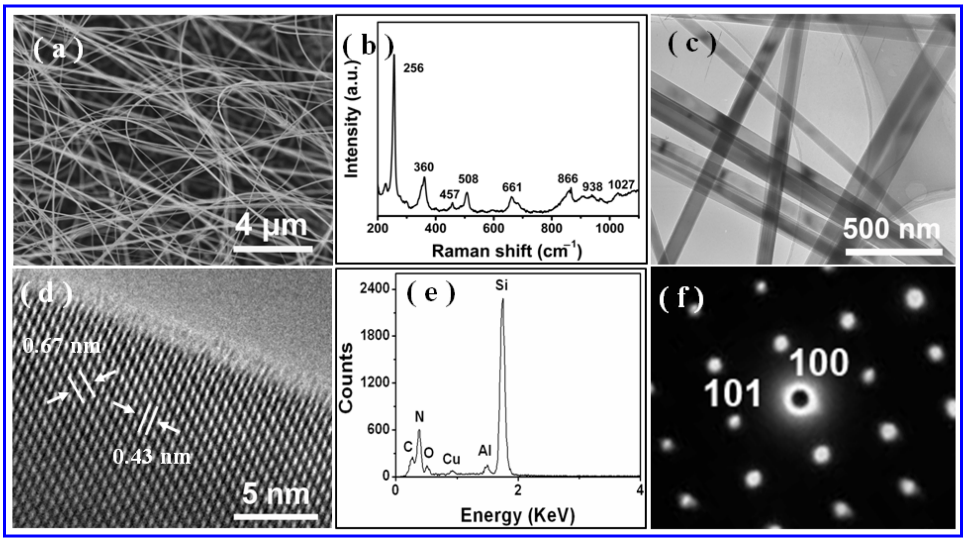

Fig. S1. Structural characterizations of the heavily Al-doped α-Si_3N_4 nanowires with the Al-doping concentration of ~1.5 atom %: (a) A typical SEM image under low magnification; (b) Raman pattern; (c) TEM image; (d) HRTEM imagine; (e) The EDS spectrum; (e) The corresponding SAED pattern.

yields after only half hour nearly ~ 80 wt% conversion of the raw materials into Si_3N_4 nanowires. They are ultra-long, having lengths of up to several centimeters and lateral sizes of 70 to 90 nm with mean diameter about 75 nm that could be useful connecting cables in circuits in nanodevices such as Junction FET (JFET). Fig. S1b shows a typical Raman pattern of the resultant products, suggesting α-Si_3N_4 is the only crystalline phase. As compared to the Raman spectra of bulk α-Si_3N_4 without doping,[2] its strong sharp peak at 250 cm^{-1} displays a slight blue shift of 3~7 cm^{-1} attributed to the phonon confinement effect or laser heating during the measurements.[3] The close-up TEM picture of representative nanowires under a high magnification, disclose a uniform shape of the nanostructure (Fig. S1c). The corresponding HRTEM image of the NWs is given in Fig. S1d, revealing that the NWs possess a perfect crystal structure with few structural defects such as dislocations and stacking faults. In general, the lattice fringe spacings of 0.67 and 0.43 nm compare well with those of the

(100) and (101) planes of bulk α-Si_3N_4, where a = 0.77541 nm and c = 0.56217 nm (JCPDS Card No. 41-0360). The selected area electron diffraction (SAED; Fig. S1f), which is identical over the entire wire, suggests the wires being α-Si_3N_4 and its single-crystalline nature. Both HRTEM imaging and SAED pattern suggest that the nanowires grow along [101] direction. Typical EDS spectra for the hints about elements contained inside wires (Fig. S1e), indicate Si, N, Al and a small amount of O, of which the latter is typically from the amorphous layer on the surfaces of the nanowires (Fig. S1d). The atomic ratio of Si to N, within the experimental limit, is close to 3:4. This result together with the combination of both XRD and SAED analysis rationalizes the nanostructure of Al-doped Si_3N_4. The Al concentration is estimated to be ~1.5 % by atom number with a uniformly spatial distribution along the nanowire axis.

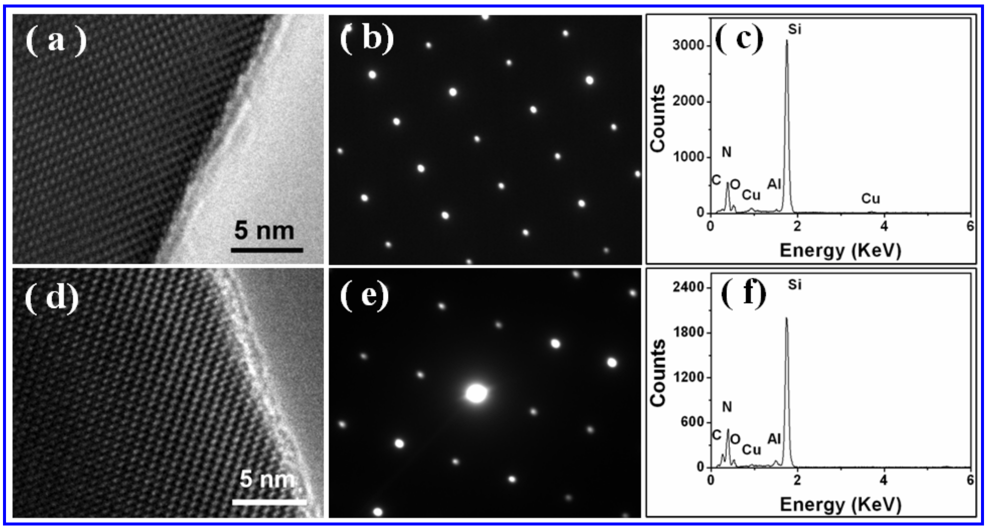

Fig. S2. Structural characterizations of the Al-doped α-Si_3N_4 nanowires with the doping concentration of ~0.5 atom %: (a) HRTEM imagine; (b) The corresponding SAED pattern; (c) The EDS spectrum. Structural characterizations of the Al-doped α-Si_3N_4 nanowires with the doping concentration of ~1 atom %: (d) HRTEM imagine; (e) The corresponding SAED pattern; (f) The

EDS spectrum.

The results obtained from the structural characterizations for the other two different Al-doped α-Si_3N_4 nanowire samples are similar to those of sample 1 that have been previously noted, except for the EDS elemental analysis. Their Al concentrations are determined to be ~0.5 and ~1 atom %, respectively.

2. Electrical transport data

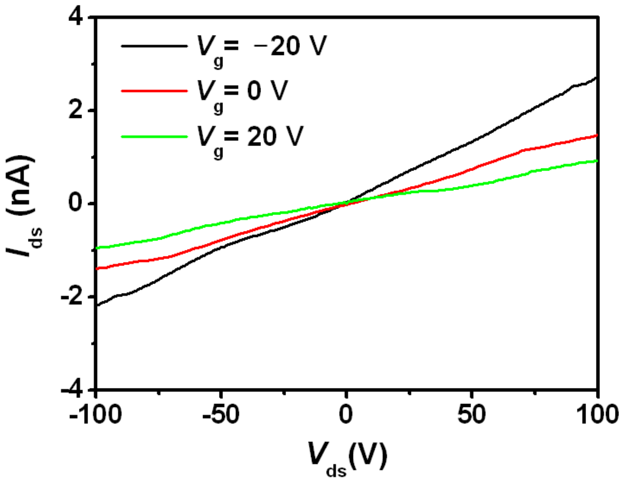

Fig. S3. I_{ds}−V_{ds} characteristic curve as a function of V_g (−20, 0 and 20 V) for the device C with the Al-doping concentration of ~ 0.5 atom %.

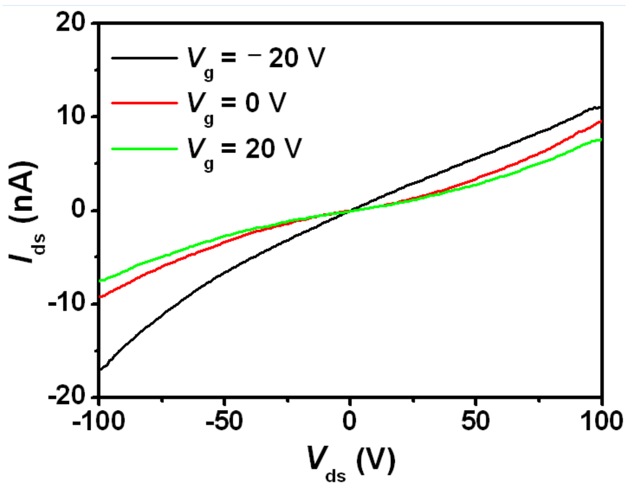

Fig. S4. I_{ds}−V_{ds} characteristic curve as a function of V_g (−20, 0 and 20 V) for the device B with the Al-doping concentration of ~ 1 atom %.

References

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