Supplementary information

Ultrasensitive protein detection using lithographically defined Si multi-nanowire field effect transistors

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Device surface silanization and modification with anti-BSA

The device surface was silanized with 11-(triethoxysilyl) undecanal (TESU) by the dipping of devices in 1% toluene of TESU for about 10 hours, rinsed with plenty of toluene. Anti-BSA was immobilized by dipping TESU silanized smaple in a 50 µg/ml anti-BSA buffer solution (pH 8.4, 10 mM PBS, 10 mM NaCl, 4 mM NaBHCN) for 5 hours. The unreacted aldehyde groups were passivated with 50 mM ethanolamine in the presence of 4 mM $NaBH_3CN$, under similar condition for 5 hours. FTIR and contact angle measurement were used to characterize the surface modification. To facilitate the FTIR data collection, double-side polished floating zoom (FZ) silicon wafers with 3 cm by 2 cm sizes were used as control samples for the surface study. FTIR spectra were collected with a Thermo® 4700 FTIR spectrometer in the transmission mode under dry N_2 purge conditions with 4 cm^{-1} resolution. 74 degree incidence (Brewster angle) was used for the study of self-assembly silane layers. Fig. S1a† (i) shows the differential FTIR spectrum of TESU modified surface (TESU/SiO_2/Si) referencing to initial surface (SiO_2/Si). The positive peaks due to surface silanization are assigned as shown in the figure. Fig. S1a† (ii) shows the differential FTIR spectrum of anti-BSA/TESU/SiO_2/Si surface referencing to the surface before anti-BSA immobilization (TESU/SiO_2/Si). The positive peaks from amide I and amide II vibrations are clearly shown, indicating successful antibody attachment. The monolayer surface modification with TESU and the attachment of anti-BSA were also confirmed with AFM characterization (data not shown here).

Moreover, the stability of bare SiO_2 (without SAMs) and TESU/SiO_2 in buffer solution (10 mM PBS, pH 7.4) are compared. Fig. S1b† shows the comparison of differential FTIR spectra of SiO_2 and TESU/SiO_2 samples after immersion in buffer solution (10 mM PBS buffer solution, pH 7.4) for 4 hours. The FTIR spectra were collected with IR incidence perpendicular to the smaple surfaces. The negative TO photon peak at 1232 cm^{-1} indicates the dissolve of Si-O-Si bonds for bare SiO_2 sample. On contrast, TESU modified SiO_2 is stable and no Si-O-Si dissolution was observed indicating successful protection of gate oxide with TESU layer. The water contact angles of bare SiO_2 and TESU modified SiO_2 are largely different, <5° and >60°, respectively.

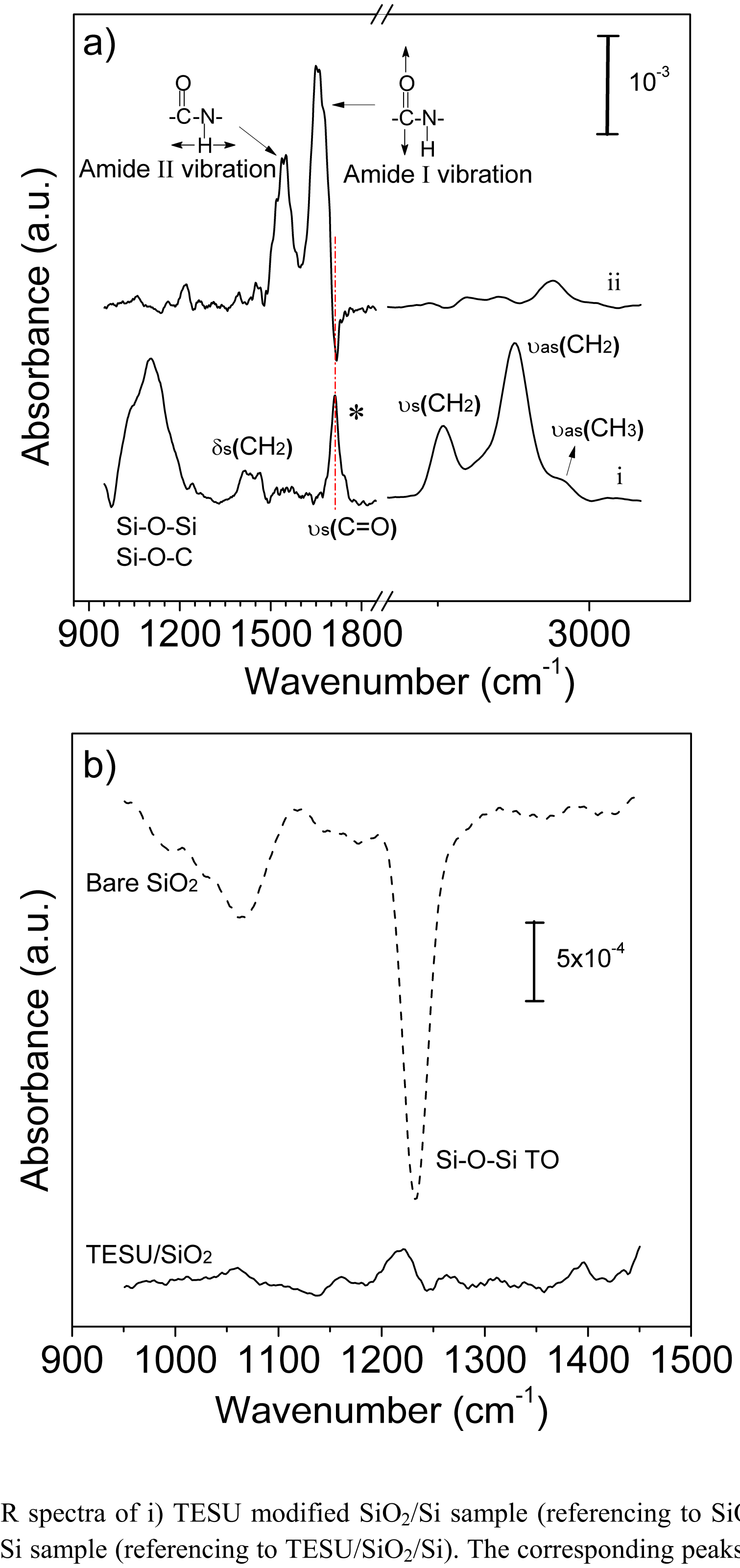

Fig.S1† a) Differential FTIR spectra of i) TESU modified SiO_2/Si sample (referencing to SiO_2/Si) and ii) anti-BSA modified TESU/SiO_2/Si sample (referencing to TESU/SiO_2/Si). The corresponding peaks are marked in the spectra b) Differential FTIR spectra of SiO_2/Si and TESU/SiO_2/Si samples after immersion in buffer solution (10 mM PBS, pH 7.4) for 4 hours. The negative peak at 1232 cm^{-1} indicates dissolve of Si-O-Si bonds. In comparison, the TESU/SiO_2/Si sample shows good stability without negative Si-O-Si TO photon modes.

BSA sensing with device without SAMs treatment.

Control experiment of BSA sensing with bare multi-SiNW FETs (without surface modification) was carried out. Fig. S2† shows the conductance of a bare multi-SiNW FET in response to solutions of different concentrations of BSA sequentially. The BSA concentration was varied from 1fM to 1pM and no current change was observed. This result demonstrates that without anti-BSA functionalization, the nanowire sensor does not respond to BSA proteins.

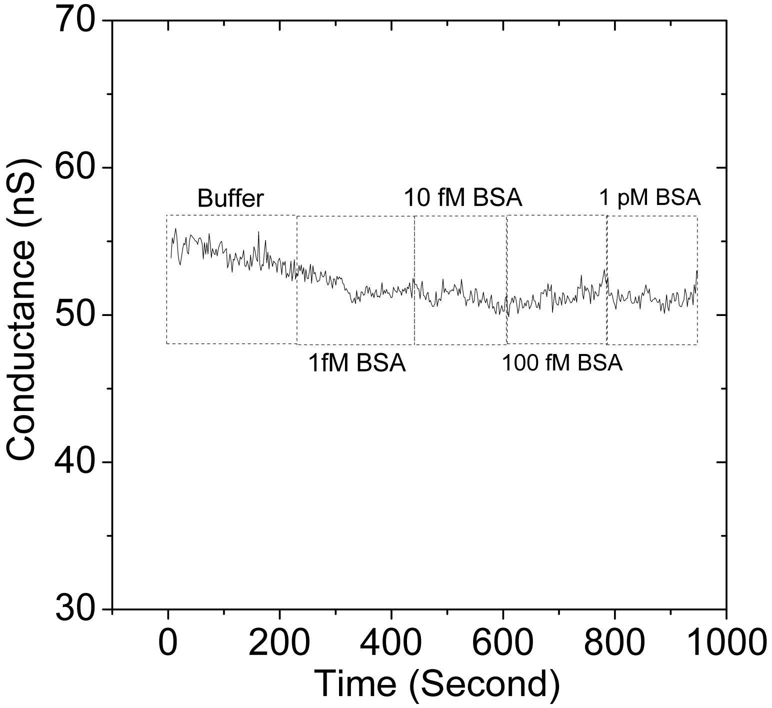

Fig. S2†. Time-dependent conductance curve of a bare multi-SiNW FET exposed to solutions (10 µm PBS, 10 µm NaCl, pH 7.4) of varying BSA concentrations sequentially. The device contains 50 nanowires with length of 80 µm and width of 19 nm.