ELECTRICAL TRANSPORT THROUGH SELF ASSEMBLED HYDROPHOBIN PROTEIN MONOLAYER

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Activity on investigation of possibilities to realize molecular electronics has been high recently (see e.g. refs [1-3]). Furthermore, especially biomolecule, e.g. protein, based molecular electronics has gained recently special interest due to their possibility to combine also biological functions to nanoelectronics [4,5]. However, the combining of proteins with non-biological "nanoworld" is often challenging, because even thought proteins often bind to surfaces there is usually little or no control of their packing arrangement neither their orientation on the surface. Our approach relies on the use of hydrophobin proteins whose natural function is to bind to hydrophobic surfaces and further, they are self-aligning to ordered monolayer with know orientation [6,7].

In this work, we present electrical transport studies of the ordered HFBI hydrophobin protein monolayer. Hydrophobins are small (mass is app. 10 kDa) special type of proteins which have certain unique bio- and physicochemical properties. Due to their strong surface activity they are extremely promising candidate for nanobioelectronic purposes. They are amphilic entities, i.e. they have both hydrophilic and hydrophopic patches. Futhermore, they self-assembly to stable monolayer films to surfaces and to nanoscale structures [7]. This work focuses on both the wild type HFBI and genetically tailored HFBI with attached gold nanoparticles (Au-HFBI). Used gold nanoparticles were 1.4 nm in diameter.

Electrical transport properties were investigated at molecular level by conducting atomic force microscope (C-AFM). In C-AFM measurements the bias voltage is introduced between a conducting (e.g. PtIr coated) AFM-tip and the sample and the induced current is measured. The set-up is enabling to perform current-voltage measurements at desired places on a surface or to measure a conduction (or current) map of surface. Additionally, the system was modified to enable the compensation of electrostatic force and thus to allow one to perform electrical characterisation in large voltage scale with constant contact force.

The protein film was deposited onto a hydrophopic (highly orientated pyroletic graphite (HOPG) or silicon) substrate by a drop-surface transfer method as in Ref. [7] and then a clean conductive tip is brought in contact with formed crystallized protein monolayer. The main advantages of this approach are that the measurement is done through monolayer and thus transport properties are measured through single proteins (several in parallel, but only one in series) and that the orientation of each individual proteins is well defined and known.

In Fig 1. is presented the first preliminary results from transport measurements through a single ordered protein membrane. The results from bare HFBI and Au-HFBI are shown. Previously, the assumption was that hydrophobins do not conduct. However, the IV-curves are rich of resonances. The attachment of the gold nanoparticles is generally increasing measured conductivity. The general trend is that the resonances in the IV-characteristics appear with smaller voltages and the resonant currents are several orders of magnitude larger with tailored protein films.

To summarize, we have performed the transport characterization of hydrophobin proteins with known orientation under constant contact pressure. Both samples exhibit current-voltage

characteristics with rich of resonances. Additionally, the gold nanoparticles are in indeed improving the electrical contacting between the AFM-tip and the protein, yet the intrinsic electrical properties of the HFBI protein are not changed dramatically. Furthermore, our interpretation is that the electrical transport of self assembled HFBI monolayer is predominantly determined by the protein internal properties instead of direct tunneling throught the monolayer.

References:

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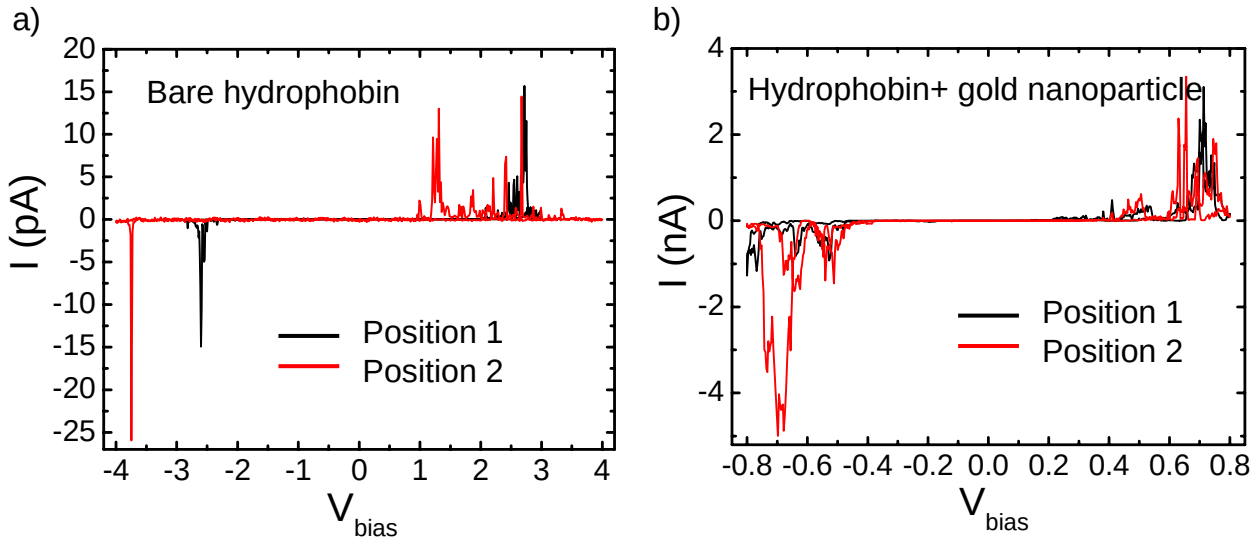

Figure 1. *A measured current-voltage characteristics from bare hydrophobins (a) and from hydrophobins with gold nanoparticles (b). Figures are presenting typical examples of the IV-characterisictics measured at different surface positions. Note that scales are different in (a) and (b).*