Quartz crystal microbalance, an efficient tool to design supramolecular structure on solid substrate

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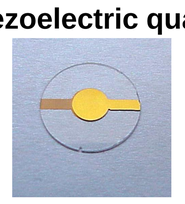
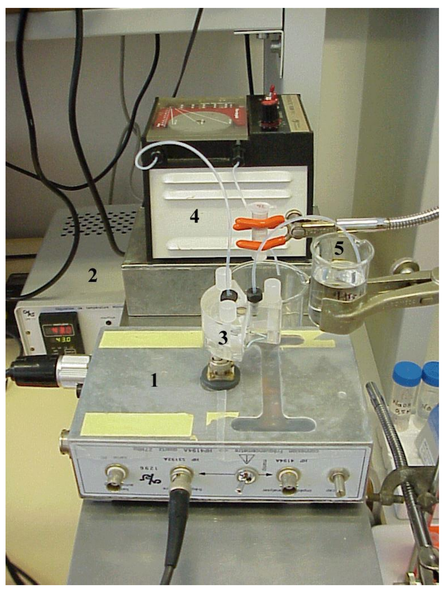
Quartz crystal microbalance

piezoelectric quartz



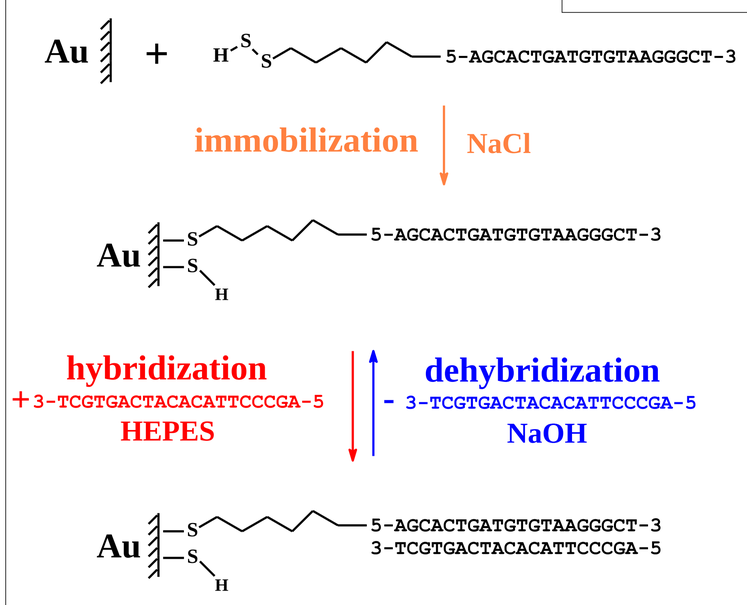
sensitivity = 350 pg/Hz

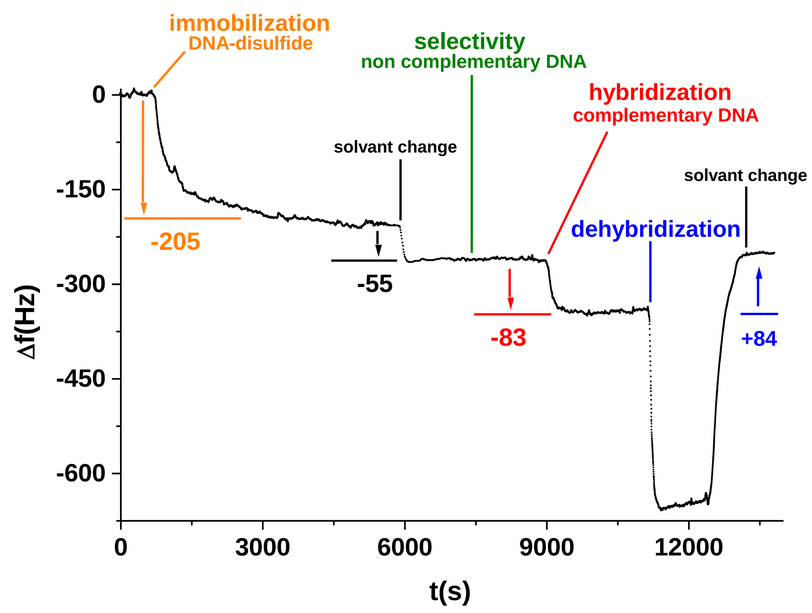
microbalance apparatus



The microbalance resonator was a piezoelectric quartz (∅ 14 mm) covered with two identical gold electrodes (2000 Å thick, ∅ 5 mm). A home-made oscillator (1) temperature controlled (2) was designed to drive the crystal at 27 MHz. There is a linear relationship between mass and frequency change of the quartz: $\Delta f = -s.\Delta m$. The sensitivity s is 350 pg/Hz. The crystal was inserted in a home-made plexiglass cell (3) and frequency shift during circulation with a peristaltic pump (4) of different solutions (5) can be correlated to mass change of the quartz due to phenomena like as adsorption or crystalisation that occur on the gold quartz surface.

DNA-biosensor[1]

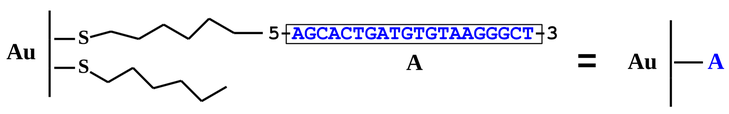




A DNA-biosensor is designed with the quartz microbalance apparatus: there is a **-205 Hz** frequency change during circulation of a DNA-disulfide solution attributed to chemical adsorption of the DNA-disulfide probe on the gold surface of the quartz **(immobilization)**. There is no frequency shift during circulation of non-complementary DNA solution indicating that there is no hybridization of the non-complementary DNA strand **(selectivity)**. There is a **-83 Hz** frequency change during circulation of a complementary DNA HEPES solution attributed to hybridization of the complementary DNA target **(hybridization)**. There is a **+84 Hz** frequency change during circulation of a NaOH solution indicating that the biosensor is renewable **(dehybridization)**. This sensitive, selective and renewable quartz crystal microbalance DNA-biosensor was used to study thermodynamic and kinetic of 45-base and 70-base DNA polymerizations.

45-base DNA polymerization

DNA-biosensor



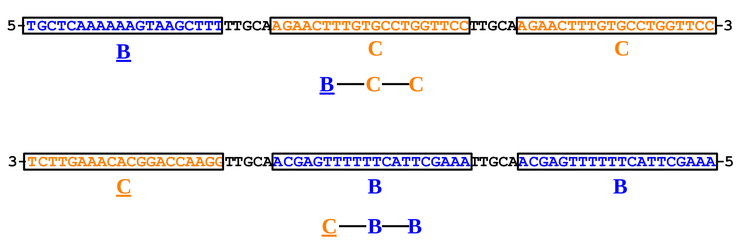
45-base DNA monomers

45-base DNA polymerization

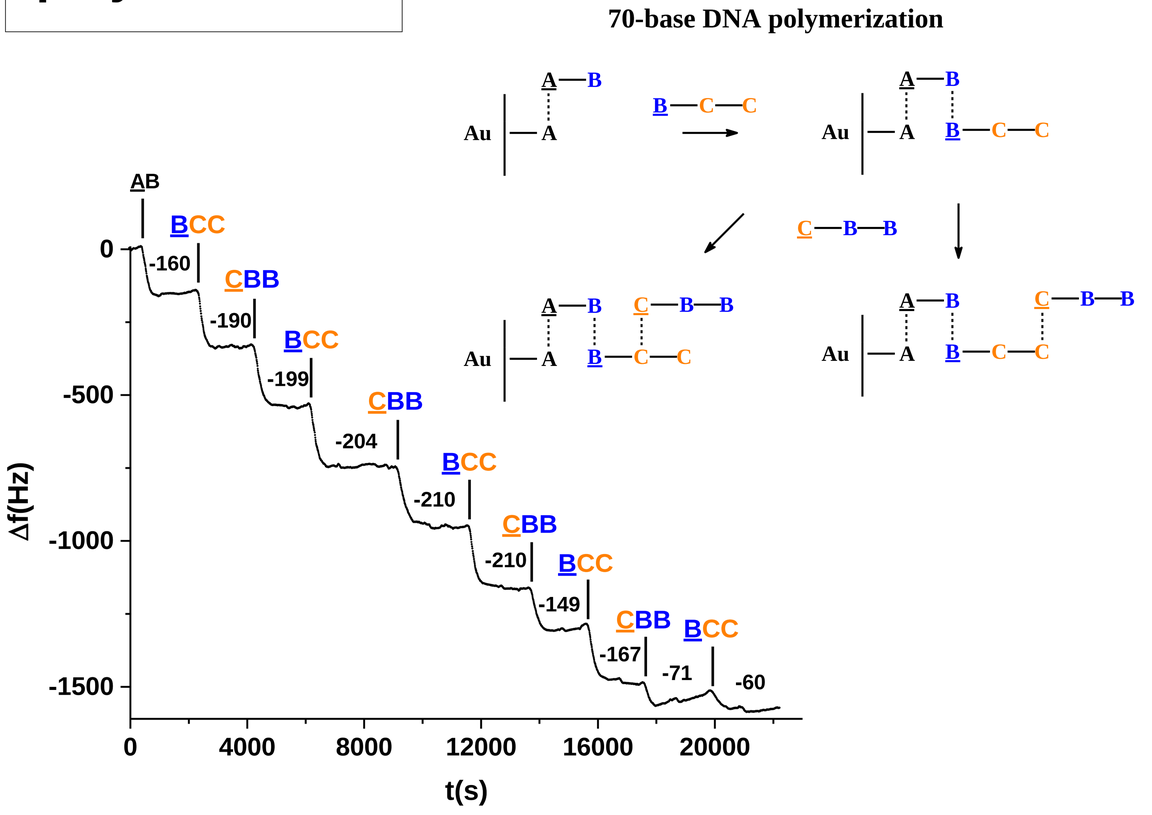
Two 45-base DNA monomers referred to as **A**-**B** and **B**-**A** are used to design a DNA polymer: **A** and **A** 20-base sequences are complementary as are **B** and **B**. The frequency changes are recorded during successive circulation of monomers **A**-**B** and **B**-**A** solutions on the DNA-biosensor surface: successive frequency drops are attributed to successive steps of the supramolecular DNA polymerization reaction. The analysis of this frequency curve allow to calculate thermodynamic and kinetic parameters of the hybridization reaction: we find a 38% hybridization ration of the first DNA layer and a half-time hybridization reaction of 50 s which are consistent with DNA hybridization on solid substrate[2,3]. We observe a progressive decrease of the successive frequency drops indicating a reactivity decrease of the polymerization.

70-base DNA polymerization

70-base DNA monomers

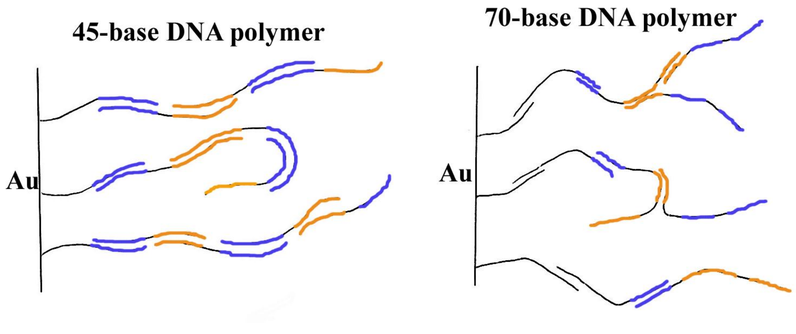


70-base DNA polymerization



Another DNA polymerization reaction is investigated by using two 70-base DNA monomers referred to as **B**-**C**-**C** and **C**-**B**-**B**: **B** and **B** are 20-base complementary sequence as are **C** and **C**. There is a first frequency drop corresponding to A-B DNA hybridization and successive frequency drops attributed to successive steps of the supramolecular DNA polymerization reaction of **B**-**C**-**C** and **C**-**B**-**B** DNAs. In this case, there is regular hybridization of successive DNA layers during the five first steps and progressive decrease during the last four steps. Hybridization half-time is 188s which is three times the 45-base DNA hybridization half-time reaction, indicating that the increase of the length strand induces decrease of DNA surface diffusion rate.

Linear and branched DNA polymers



The product of the 45-base DNA polymerization is a linear DNA strand. We suggest that the reactivity decrease is due to DNA fold that increase with polymer length: the extremity of a folding DNA anchored on the biosensor surface is less accessible to free DNA monomers in solution.

In the case of the 70-base DNA, there is regular polymerization during the first steps. We suggest that the enhancement of reactivity in this case is due to the formation of a branched polymer.

Conclusion

Beyond interest of these step by step synthese of linear and branched DNA polymers, this work demonstrates that the quartz crystal microbalance is a sensitive tool to design supramolecular biostructures on solid substrate by following *in situ* thermodynamic and kinetics of successive reactions.

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