Designing the surface of biomaterials – real-time evaluation using QCM-D

A. Oom
Q-Sense AB, Hängpilsgatan 7, 426 77 Västra Frölunda, Sweden
e-mail: anna.oom@q-sense.com

Introduction

Protein adsorption is of utmost importance when designing new biomaterials, since the introduction of a foreign material into the body will cause a layer of biomolecules on the surface, mainly proteins. The subsequent cellular attachment is therefore in turn mediated by interactions with this protein layer. However, current biomaterials research is limited by the availability of tools for real-time evaluation of such events. Quartz Crystal Microbalance with Dissipation Monitoring (QCM-D) is a versatile instrument that enables real-time studies of processes taking place at a surface. QCM-D simultaneously measures the mass and viscoelastic properties of molecular layers forming on the sensor surface. This provides unique information on the structure of the layer and therefore events such as binding and conformational rearrangements of molecules can easily be tracked. Here we present a number of studies where QCM-D reveals novel insights into how surface modifications affect protein adsorption and cell attachment.

Materials & methods

Protein charge dependence. QCM-D was used to study protein adsorption and correlate the net charge of the protein with the charge density of the surface [1]. Protein adsorption was investigated on PAA (adsorption promoting) and PEO (adsorption resistant) polymer surfaces, using BSA, lysozyme, lactoferrin and fibronectin at pH 4 – 8.5.

Surface morphology. The impact of surface morphology on protein adsorption was investigated in two studies using QCM-D. BSA was adsorbed onto smooth and rough platinum sensor surfaces [2] and fibronectin was adsorbed onto smooth and rough tantalum sensor surfaces [3].

Cell attachment. QCM-D was combined with fluorescence microscopy to monitor cell attachment and spreading onto surfaces preadsorbed with fibronectin, calf serum or albumin [4].

Results & discussion

Protein charge dependence. Each protein exhibited unique adsorption properties, in most cases adsorbed and rearranged in multiple phases, which could be studied in real-time. Fibronectin at pH 4 adsorbed in two phases on PAA and was the only protein to form fibrils in its second phase, most probably due to its unfolded conformation that revealed self-associating domains.

Surface morphology. BSA molecules on the rough surface placed themselves in a more densely packed protein layer and showed a two step adsorption behavior, where the second step involved proteins adsorbing in a more open structure, which was not seen on the smooth surface. The nanoscale roughness induced an increased stiffening of the saturated fibronectin layers. This suggests that the roughness promoted proteins to adsorb in a more spread out rigid conformation which was further supported by differences in antibody adsorption. *Cell attachment.* Depending on the surface coating, the optical image revealed different cell behavior, which was consistent with the QCM-D signal. Interestingly, QCM-D was able to sense events associated with changes in cell-surface contacts and cytoskeleton rearrangements, which were not detectable with microscopy.

Conclusions

QCM-D is a powerful tool for the analysis of protein and cell interactions with surfaces. The real-time analysis enables direct monitoring of the ongoing events in situ. Furthermore, the unique information on viscoelastic properties of adlayers provides valuable insight into protein conformation characteristics and cell behavior phenomena at surfaces, not easily detectable by other methods. Taken together the QCM-D technique is an interesting tool for evaluation of biomolecular structures.

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References

[1] Belegrinou S, Mannelli I, Lisboa P, Bretagnol F, Valsesia A, Ceccone G, Colpo P, Rossi F (2008) Langmuir, 24, 7251-7261.
[2] Dolatshahi-Pirouz A, Rechendorff K, Hovgaard MB, Chevallier J, Besenbacher F (2008) Colloids and Surfaces B: Biointerfaces, 66, 53-59.
[3] Hovgaard MB, Rechendorff K, Chevallier J, Foss M, Besenbacher F (2008) J. Phys. Chem. B., 112, 8241-8249.

[4] Lord MS, Modin C, Foss M, Duch M, Simmons A, Pedersen FS, Milthorpe BK, Besenbacher F (2006) Biomaterials, 27, 4529-4537.