

ANALYZING CLEANING AND DEGRADATION PROCESSES

Quartz Crystal Microbalance with Dissipation is a new, real-time scientific method for evaluation of cleaning efficiency and analysis of degradation processes. QCM-D analyses are easy to conduct and provide an excellent model system for cleaning of hard surfaces. Measurable parameters include removal of stains with nano-gram sensitivity, real-time removal-rates and changes in stain properties and behavior during exposure to the surfactant, enzyme or detergent under investigation. Here QCM-D is used to study efficiency of different cleaning products and how concentration and temperature affects the cleaning behavior of a single surfactant.

The heart of the QCM-D analysis method is a sensor coated with material of interest, such as a specific stain. Sensors are available in a wide variety of materials such as stainless steel, metals, plastics and glass. Furthermore, sensors can be coated with almost any material as long as it can be applied as a thin homogenous film. The analysis provides simultaneous, real-time information on mass, thickness and structure of the film on the sensor enabling simple quantification of film removal rates.

Stains can be removed from a surface by several mechanisms affecting cleaning efficiency. The efficiency can be defined by e.g. the surfactants ability to form aggregates effective in dissolving a stain and holding it in solution. This occurs at the critical micelle concentration (CMC). Efficiency might also be dictated by the surfactants capability to partition into the stain enabling absorption of water. The latter typically results in swelling and decreased film viscosity, both of which can be characterized with QCM-D.

APPROACH

Two studies were conducted; the first investigated the concentration and temperature effects on efficiency of stain removal by a single surfactant.

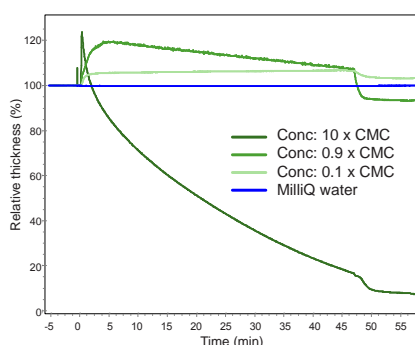


FIGURE 1. Changes in thickness of lipid film upon addition of TritonX-100 in three different concentrations and subsequent rinse with water (47 min) at 40 C. 100% refers to the initial thickness of the triolein film.

TritonX-100 was used as model non-ionic surfactant since it is common in many formulations. The second study was focused on cleaning efficiency and real-time removal-rates of three commercially available, ready-to-use kitchen cleaning sprays. The three products were used according to manufacturer’s instructions. Triolein lipid was used as a model stain. Measurements were performed on the Q-Sense E4 system enabling simultaneous evaluation of four solutions. All experiments were at least duplicates done in flow, starting in milliQ water, followed by sample solutions and subsequent milliQ water rinse. Data was evaluated in QTools enabling simultaneous evaluation of four solutions. All experiments were at least duplicates done in flow, starting in milliQ water, followed by sample solutions and subsequent milliQ water rinse. Data was evaluated in QTools enabling simultaneous evaluation of four solutions. All experiments were at least duplicates done in flow, starting in milliQ water, followed by sample solutions and subsequent milliQ water rinse. Data was evaluated in QTools enabling simultaneous evaluation of four solutions.

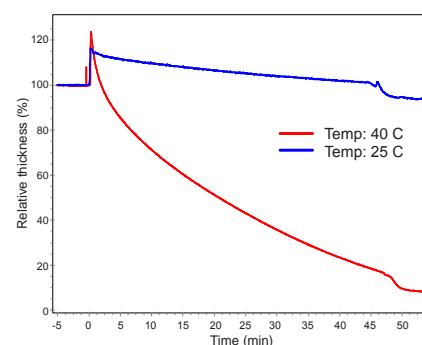


FIGURE 2. Changes in thickness of lipid film upon addition of TritonX-100 at concentration well above CMC, and subsequent rinse with water (47 min) at 25 C and 40 C. 100% refers to the initial thickness of the triolein film.

RESULT AND DISCUSSION

Triolein was successfully spin-coated into a thin, stable film of approximately 40 nm. The lipid stain was unaffected by water, seen as stable controls (milliQ water), fig 1, 3.

Results from the first study show that lipid stain behavior and efficiency of lipid removal are influenced by TritonX-100 concentration (fig 1) and temperature (fig 2).

Upon addition of surfactant, the film swelled, most probably due to surfactant penetration into the film and absorption of water. In QCM-D, this was observed both as increased film thickness (fig 1) and reduced viscosity².

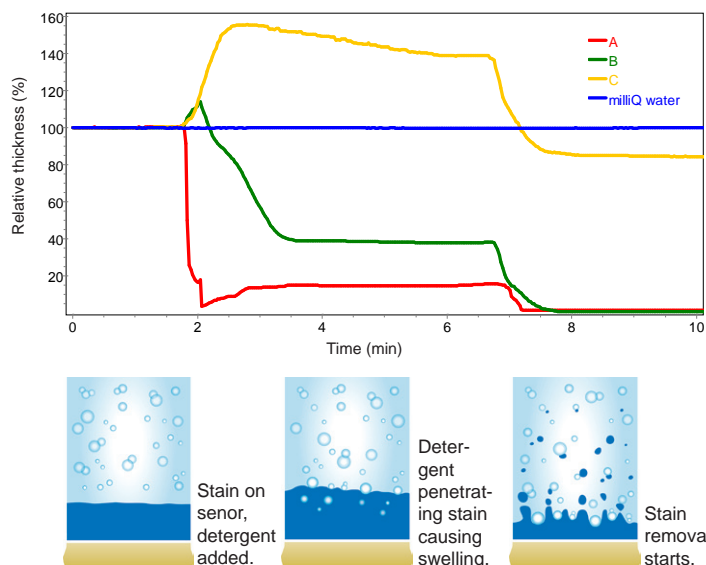


FIGURE 3. Comparison of changes in thickness of lipid films upon injection of three commercial kitchen cleaning sprays (2 min) and subsequent rinsing with water (7 min).

100% refers to the initial thickness of the triolein film.

Data reproducibility was within 5%.

Subsequent behavior was concentration dependent. Figure 1 shows that the highest concentration, well above CMC, removed most of the stain. At the lowest concentration the film swelled resulting in a net thickness increase. This indicates irreversible addition of surfactant and water to the lipid film, which was consistent with a decrease in viscosity². The above trend indicates that TritonX-100 is able to penetrate the triolein stain, with an off-set for stain removal at surfactant concentration close to the CMC and optimal detergency well above the CMC.

Efficiency of stain removal by TritonX-100 was also evaluated as function of temperature (fig 2). Initial film swelling could be observed upon addition of surfactant at both 25C and 40C. However, the efficiency of film removal was drastically higher at 40C compared to 25C for the same surfactant concentration.

In the second study, evaluation of removal efficiency by three ready-to-use kitchen sprays, showed a remarkably different behavior between brands (fig 3).

Lipid stains were immediately affected upon addition of the detergents. Products A and B began immediate removal of lipid, leaving as little as 1-5 nm of the stain after rinsing. Product A was the most efficient cleaner and did not require rinsing for removal as did product B (fig 3). Viscoelastic properties of the films were also investigated, to discriminate between stain removal and contraction, upon rinsing. Viscosity of the films did not increase after rinsing², hence indicating stain removal and not film contraction. Product C caused lipid film swelling, however hardly anything of the stain was removed even upon rinsing. The poor removal was not caused by adsorption of detergent to the surface as such since none of the

detergents left a considerable coating after rinsing in reference measurement². The viscosity changes of the bulk were found to be small enough not to affect the modeling.

CONCLUSION

The optimal surfactant or formulation for cleaning applications is determined by the efficiency of stain removal at specific conditions. The QCM-D real-time monitoring provides information on “how much”, “how fast” and “how” stain removal occur. The flexibility of QCM-D, where parameters such as cleaning agent concentration, temperature, hardness of water, flow, stain type and substrate material can easily be changed and controlled, enables evaluation of cleaning efficiency under customer and product relevant operational conditions.

REFERENCES

- 1) Jeffrey A. Kabin, et al (1998), *Removal of Organic Films From Rotating Disks Using Aqueous Solutions of Non-ionic Surfactants: Effect of Surfactant Molecular Structure*, Journal of Colloid and Interface Science 206, 102–111.
- 2) Measurements by Q-Sense using the Q-Sense E4 system. Data available upon request. Data evaluation performed in QTools.