

In-situ Monitoring of Real-Time Loop-Mediated Isothermal Amplification with QCM: Detecting *Listeria monocytogenes*

Sirirat Wachiralurpan ^{1,*}, Isaratat Phung-On ¹, Narong Chanlek ² Supatra Areekit ^{3,4}, Kosum Chansiri ^{4,5} and Peter A. Lieberzeit ^{6,*}

¹ Maintenance Technology Center, Institute for Scientific and Technological Research and Services, King Mongkut's University of Technology Thonburi, 126 Prachautit Rd., Bangkok 10140, Thailand; sirirat.wac@gmail.com, isaratat.phu@kmutt.ac.th

² Synchrotron Light Research Institute (Public Organization), 111 University Avenue, Muang District, Nakhon Ratchasima 30000, Thailand; narong@slri.or.th

³ Innovative Learning Center, Srinakharinwirot University, Sukhumvit 23, Bangkok 10110, Thailand; supatraa@g.swu.ac.th

⁴ Center of Excellence in Biosensors, Panyanantaphikkhu Chonprathan Medical Center, Srinakharinwirot University, 222 Moo1 Tiwanon Rd., Pakkred district, Nonthaburi 11120, Thailand; supatraa@g.swu.ac.th, prof.kosum@gmail.com

⁵ Department of Biochemistry, Faculty of Medicine, Srinakharinwirot University, Sukhumvit 23, Bangkok 10110, Thailand; prof.kosum@gmail.com

⁶ Department of Physical Chemistry, Faculty for Chemistry, University of Vienna, Waehringer Strasse 42, Vienna 1090, Austria; peter.lieberzeit@univie.ac.at

* Correspondence: sirirat.wac@gmail.com (S.W.); peter.lieberzeit@univie.ac.at (P.A.L.)

1. Estimation of mass and molecule numbers on the working surface.

The irreversible signal (ΔF , Hz), is given in Eq. (1) according to the Sauerbrey's equation [47].

$$\Delta F = - \frac{2F_0^2}{A\sqrt{\rho_q\mu_q}} \Delta m \quad (1)$$

For the mass change (Δm , g), is given in Eq. (2)

$$\Delta m = - \frac{\Delta F \cdot A}{S_Q} \quad (2)$$

where ΔF is the measured irreversible frequency shift, Δm the mass change (g), A the electrode area 0.2 cm^2 , ρ_q the density of quartz ($2.648 \text{ g}\cdot\text{cm}^{-3}$) and μ_q the shear modulus of quartz for AT-cut crystal ($2.947 \times 10^{11} \text{ g}\cdot\text{cm}^{-1}\cdot\text{s}^{-2}$) so that S_Q or $\rho_q\mu_q$ is $2.26 \times 10^8 \text{ cm}^2\cdot\text{g}^{-1}\cdot\text{s}^{-1}$, 10 MHz AT-cut Quartz was used in the study. The molecule numbers on working surface is obtained from the mass change (Δm) in Eq. (2) and Eq. (3), as follows

$$\begin{aligned} \text{Number of mols} &= \frac{\text{gram (mass)}}{\text{Molecular weight (Mw)}} = \frac{\text{number of molecules}}{6.022 \times 10^{23} \text{ (Avogadro's number)}} \\ \text{Number of molecules} &= \frac{\Delta m}{Mw} \times (6.022 \times 10^{23}) \end{aligned} \quad (3)$$

Example; Figure 1 shows the ΔF of -342 Hz ,

$$\begin{aligned} \Delta m &= - \frac{\Delta f \cdot A}{S_Q} \\ \therefore \Delta m &= - \frac{-342 \times 0.2}{(2.26 \times 10^8)} = 0.303 \times 10^{-6} \text{ gram} = 0.303 \mu\text{g} \end{aligned}$$

Therefore, the estimation of mass on working surface is $0.3 \mu\text{g}$

$$\begin{aligned} \text{Number of molecules} &= \frac{\Delta m}{Mw} \times (6.022 \times 10^{23}) \\ \therefore \text{molecule} &= \frac{0.3 \times 10^{-6}}{9982.52} (6.022 \times 10^{23}) = 1.81 \times 10^{13} \text{ molecules} \end{aligned}$$

Therefore, the number of molecules of ssDNA probe on surface contain approximately 1.8×10^{13} molecules.