Dielectric Measurements Applied to Label-Free Protein Quantitation with Dual-Frequency Liquid Crystal

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Abstract

This study established a dual-frequency-liquid-crystal (DFLC)-based biosensor and utilized its frequency-dependent dielectric characteristics to detect and quantitate a standard model protein, bovine serum albumin (BSA). Detectable range of BSA concentrations from 10^{-2} g/ml to 10^{-7} g/ml using DFLC as the sensing element was confirmed by dielectric spectroscopy in conjunction with textural observations under a polarizing optical microscope.

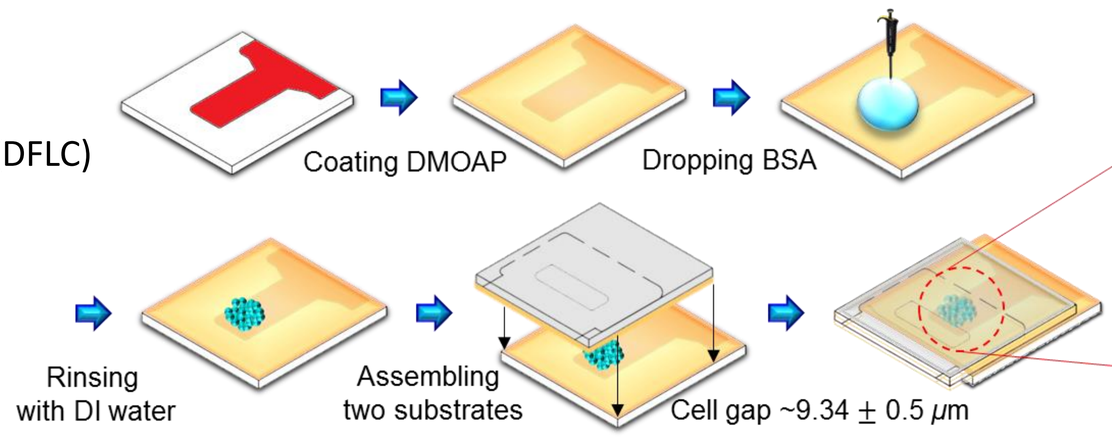
Experiment

Materials

◈ **Liquid crystal**
- Dual-frequency liquid crystal (DFLC)

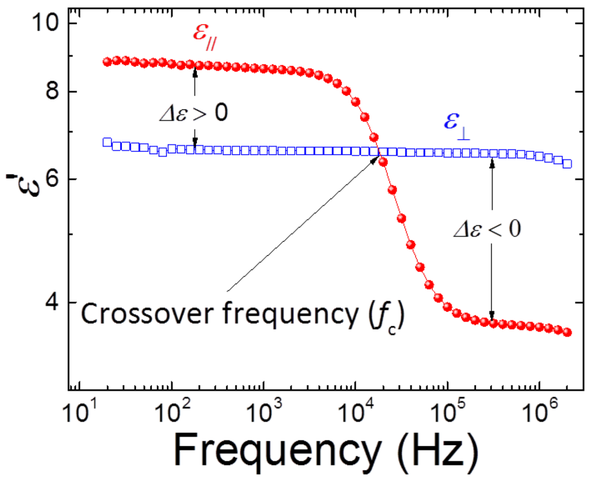
◈ **Detection target**
- Bovine serum albumin (BSA)

◈ **Alignment layer**
- DMOAP



Results

1 Unique dielectric properties of DFLC



◆ $f < f_c$:

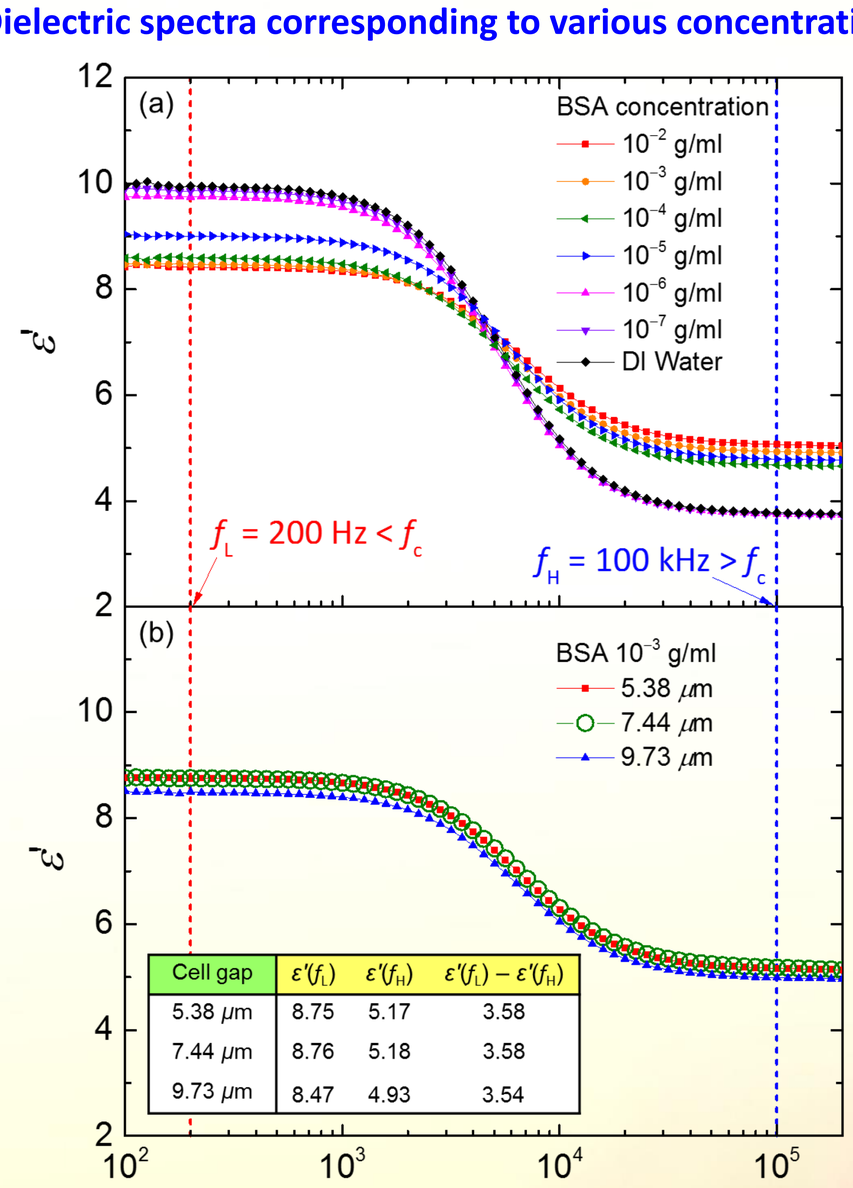
$\Delta\varepsilon > 0$, positive compounds

◆ $f > f_c$:

$\Delta\varepsilon < 0$, negative compounds

▣ **The frequency at which $\Delta\varepsilon = 0$ is defined as crossover frequency (f_c).**

2 (a) Dielectric spectra corresponding to various concentrations of BSA



Cell gap	$\varepsilon'(f_L)$	$\varepsilon'(f_H)$	$\varepsilon'(f_L) - \varepsilon'(f_H)$
5.38 μm	8.75	5.17	3.58
7.44 μm	8.76	5.18	3.58
9.73 μm	8.47	4.93	3.54

(b) The permittivity difference of 10^{-3} g/ml BSA with various cell gaps

▣ **The deviation of the permittivity difference is only 1.1%.**

3 DFLC-based protein quantitative methods

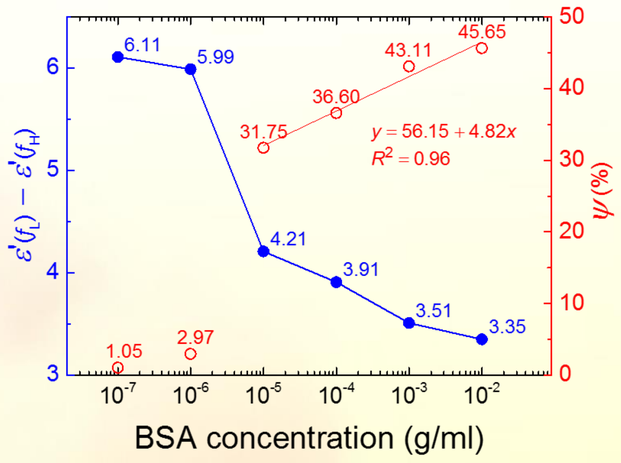
f_L : 200 Hz
f_H : 100 kHz
$\delta\varepsilon$: $\varepsilon'(f_L) - \varepsilon'(f_H)$

$$\psi = \frac{\delta\varepsilon_{max} - \delta\varepsilon}{\delta\varepsilon_{max}}$$

ψ : the extent of disruption of LC alignment

0 % (Homeotropic) → (planar) 100 %

BSA (g/ml)	$\varepsilon'(f_L)$	$\varepsilon'(f_H)$	$\delta\varepsilon$	ψ (%)	d (μm)
0	9.95	3.78	**6.17**	0	8.82
10^{-7}	9.86	3.75	6.11	1.05	9.58
10^{-6}	9.75	3.76	5.99	2.97	9.40
10^{-5}	9.00	4.79	4.21	31.75	9.86
10^{-4}	8.59	4.68	3.91	36.60	9.42
10^{-3}	8.50	4.99	3.51	43.11	9.10
10^{-2}	8.42	5.07	3.35	45.65	8.97



▣ **A detection limit of 10^{-7} g/ml for BSA.**

Conclusion

- According to the dielectric properties of the DFLC, the value of $\varepsilon'(f_L) - \varepsilon'(f_H)$ can eliminate unexpected errors caused by cell gap variations. (Fig. 2(b))
- The detectable range of the DFLC-based protein assay can be as wide as 10^{-2}–10^{-7} g/ml in terms of a parameter ψ which was specifically defined to represent the effect of BSA concentration on $\varepsilon'(f_L)$ and $\varepsilon'(f_H)$. (Fig. 3)
- This proof-of-concept research provides first insights into the dielectric spectroscopy of DFLCs in protein quantitation.

Acknowledgment

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