Supporting information for 'Tuning the Biodegradability of Chitosan Membranes: Characterization and Conceptual Design'

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Number of pages: 11

Number of figures: 8

Number of texts: 2

Figure S1

Schematics showing the key steps for fabricating the AgNPs-enabled chitosan membranes.

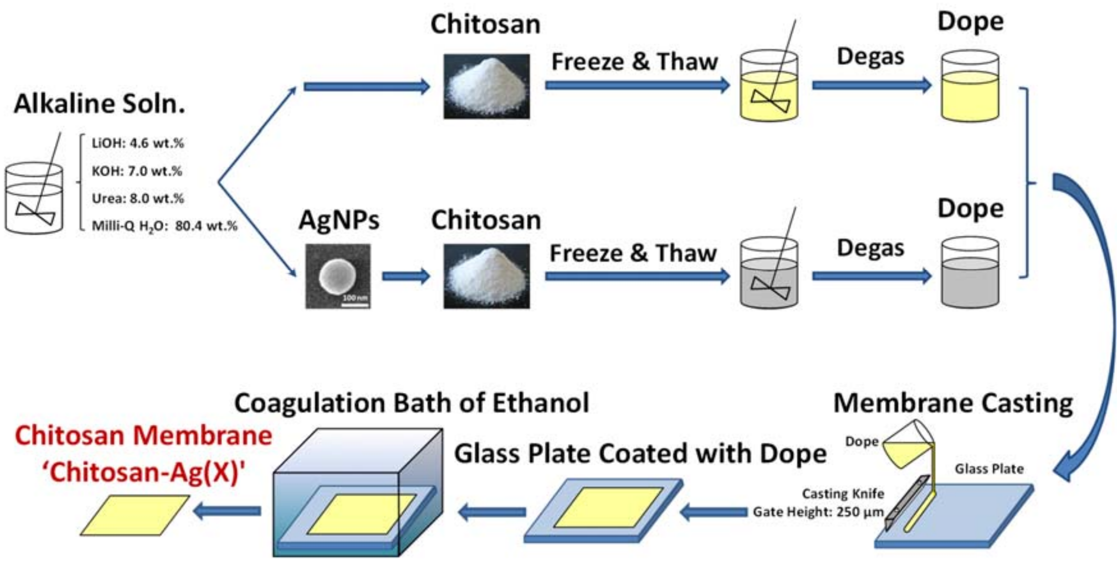


Figure S2

Water flux as a function of time with a varied crossflow rate. The feed solution (1 μm PS beads ~0.05 g/L) was circulated on the feed side with a TMP = ~1 bar.

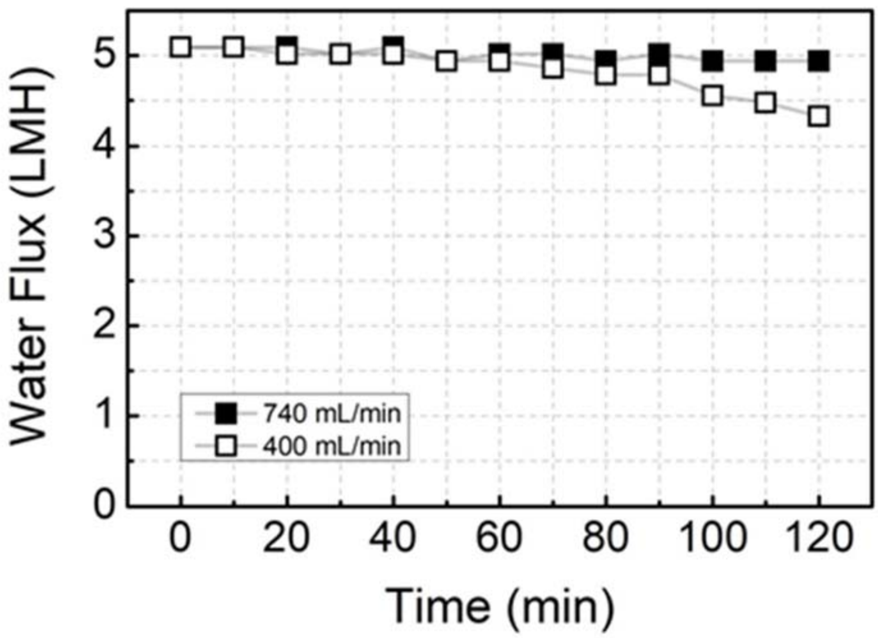


Figure S3

Calibration curve of the UV-vis spectroscope for determining the concentration of 1 μm PS beads. The wavelength was fixed at 206 nm that yielded the highest absorbance.

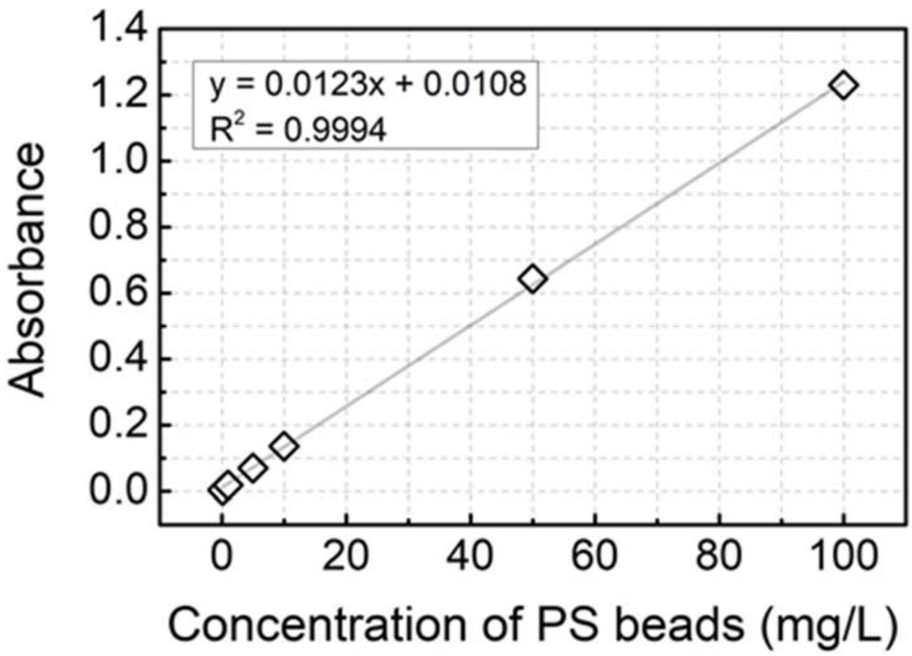


Figure S4

Schematics showing the sampling approaches to determining the silver-leaching rate: (a) batch immersion and (b) immersion with periodic replacement of the extraction solution.

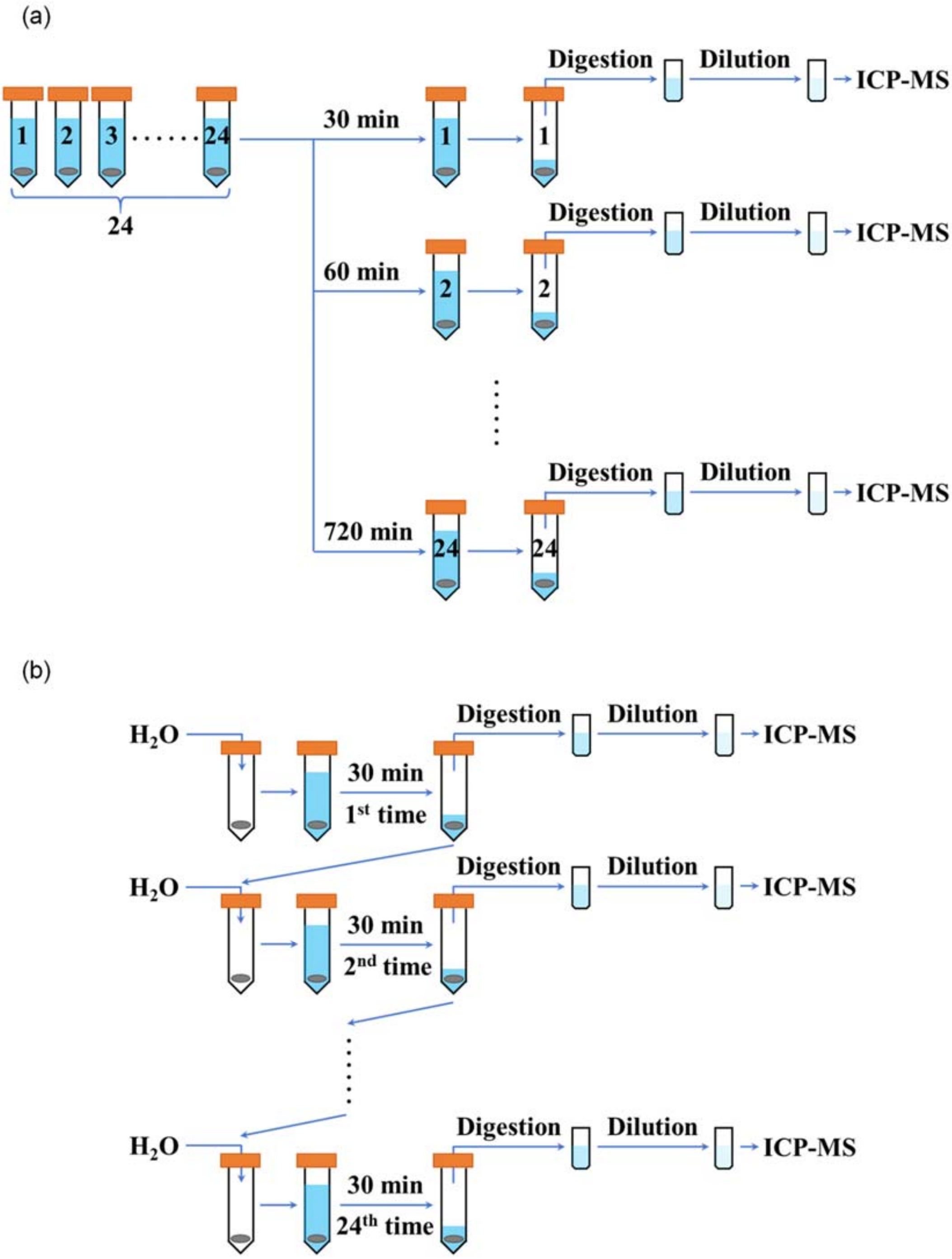


Figure S5

Cross-sectional views of the chitosan membrane created by (a) SEM and (b) OCT. The chitosan membrane was immersed in DI water for the OCT-based measurement. The red curved denotes the membrane surface identified by the intensity-based segmentation.

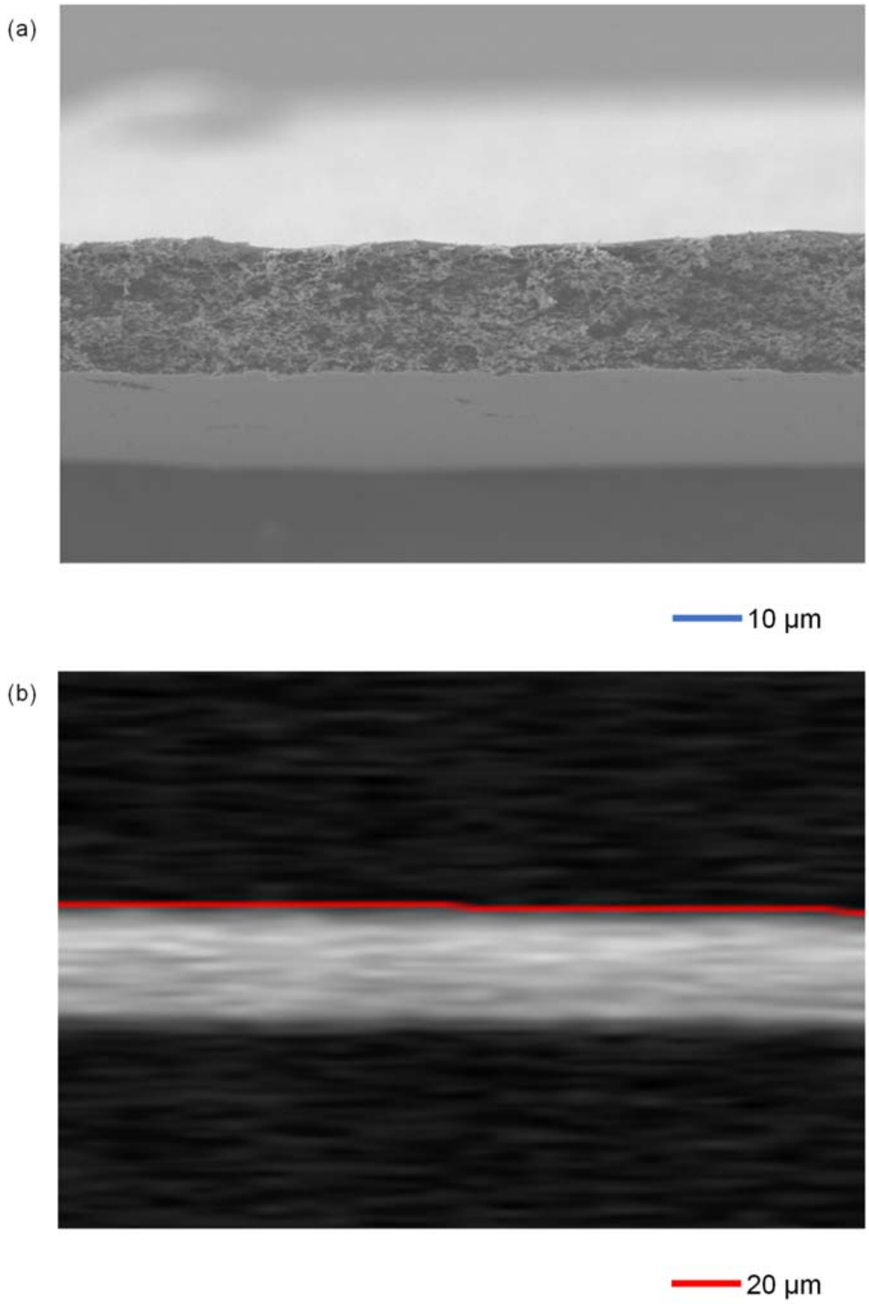


Figure S6

Comparison of the representative stress-strain curves of the AgNPs-enabled chitosan membranes before and after the biodegradation. The enzymatic digestion was implemented by immersing the AgNPs-enabled chitosan membranes with a size of 20 mm × 50 mm in a solution of ~20 mg/L lysozyme for ~120 h.

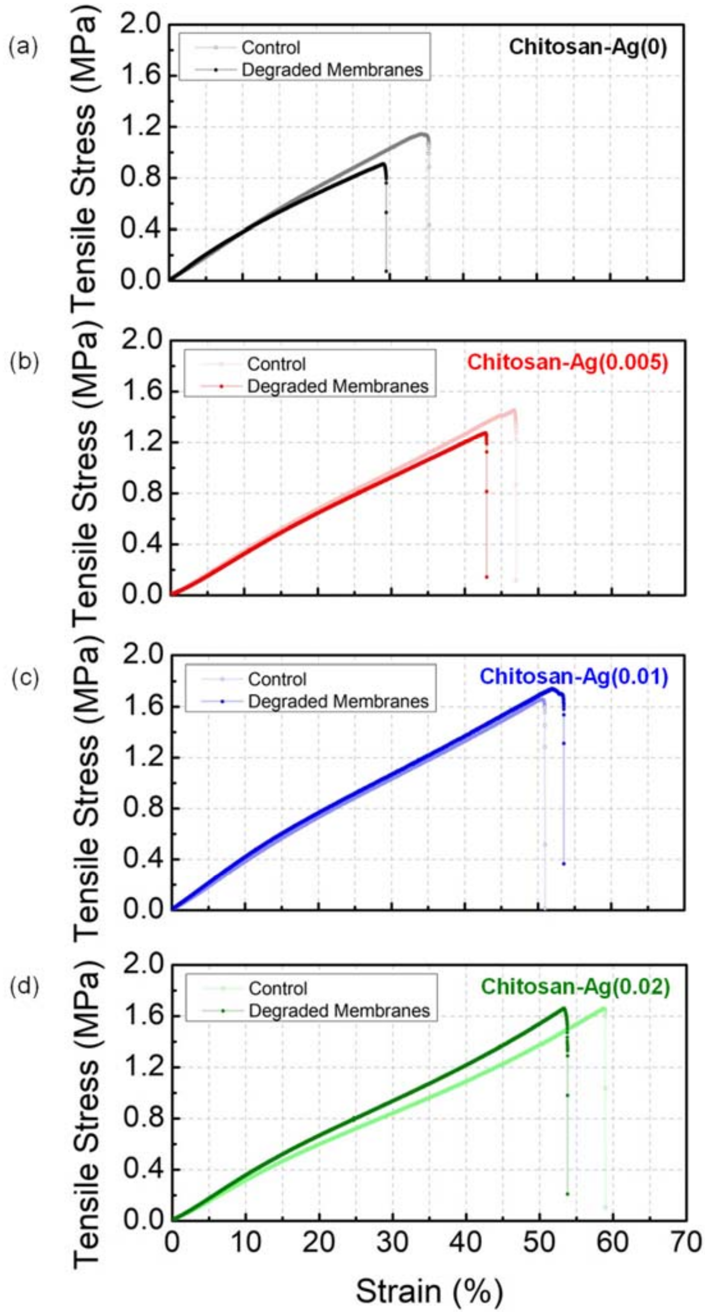
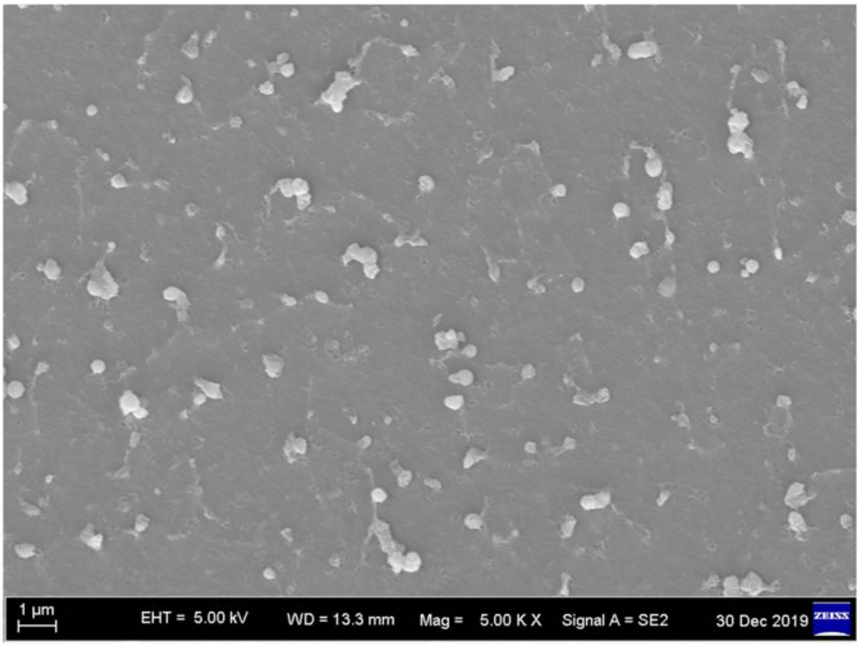


Figure S7

SEM images showing the top views on the dense side of (a) the chitosan membrane without doping the AgNPs and (b) the chitosan-Ag(0.02) membrane.

(a)



(b)

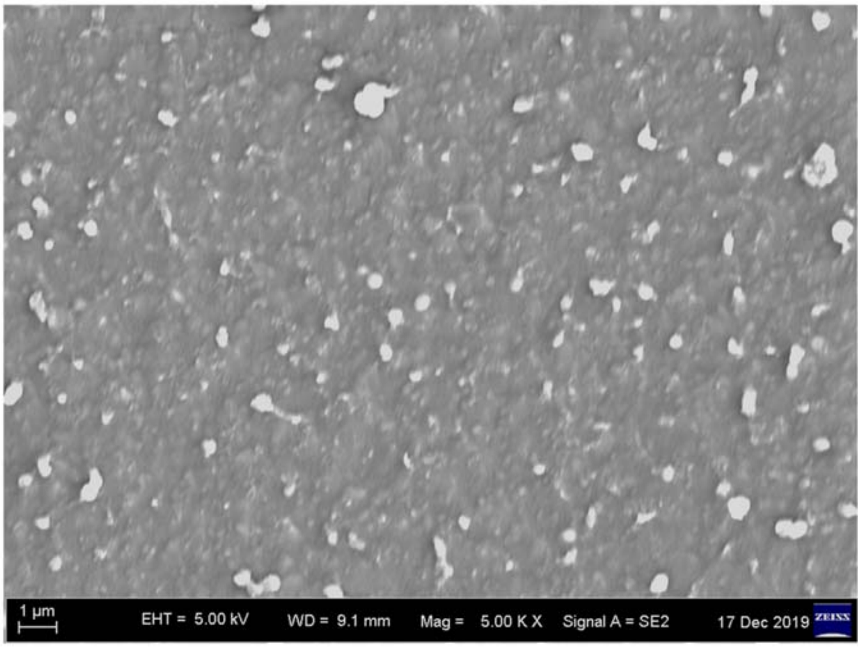
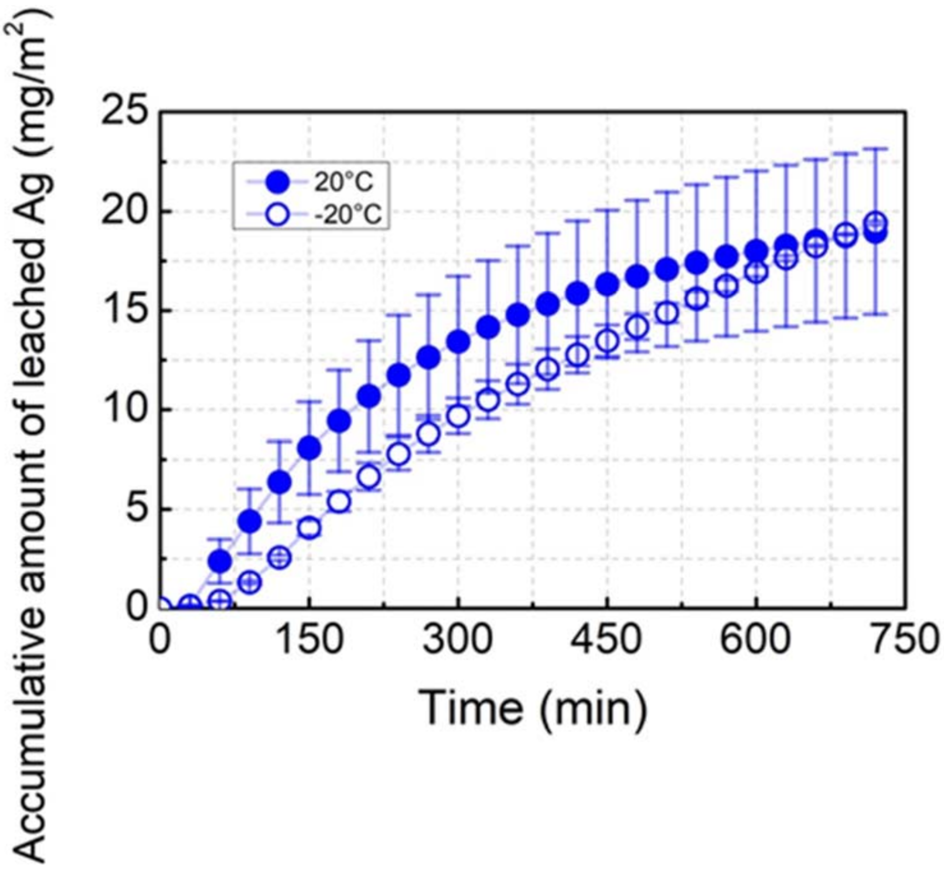


Figure S8

Accumulative amount of leached silver in terms of the integration of the rate-time curve. The silver-leaching rate was measured via an approach based on the periodic replacement of the extraction solution (Milli-Q water). The chitosan-Ag(0.01) membrane with a total area of ~9.0 cm^2 was immersed in the extraction solution of 10 mL with a replacement interval of ~30 min.



Theory S1

Equations correlating the water flux with the weight loss resulting from the biodegradation.

It is assumed that the membrane is composed of straight-through cylindrical pores and the water flow rate (viscosity is μ_w) within a single pore Q_p (driven by the hydraulic pressure drop Δp) can be described by the Hagen-Poiseuille equation:

$$Q_p = \frac{\pi r_p^{\ 4}}{8\mu_w \delta_m} \Delta p \,,$$

where r_p is the radius of the pores and δ_m is the membrane thickness. If the number of pores within the area of S_m is n_p, the water flux J_w can be evaluated as:

$$J_w = \frac{n_p Q_p}{S_m} = \frac{n_p \pi r_p^{\ 4}}{8\mu_w \delta_m S_m} \Delta p = \frac{n_p \pi r_p^{\ 2} \delta_m}{\delta_m S_m} \frac{r_p^{\ 2}}{8\mu_w \delta_m} \Delta p = \frac{\varepsilon_p r_p^{\ 2}}{8\mu_w \delta_m} \Delta p \,,$$

where ε_p is the porosity. On the other hand, the density of the polymer ρ_s can be expressed by:

$$\rho_s = \frac{m_s}{S_m \delta_m \left(1 - \varepsilon_p\right)} \,,$$

where m_s is the weight of the membrane (i.e., the polymer).

The enzymatic digestion of the membrane will result in the decrease in the membrane thickness or the dilation of the membrane pores. When assuming that the dilation of the membrane pores can be ignored, ε_p should be constant during the enzymatic digestion. Therefore, the decrease in the membrane thickness can be related with the weight loss by

$$\Delta \delta_m \equiv \delta_m - \delta_m' = \frac{\Delta m_s}{\rho_s S_m \left(1 - \varepsilon_p\right)} \,.$$

The water flux of the degraded membrane J_w' then can be related with the weight loss by:

$$J'_w = \frac{\varepsilon_p r_p^{\ 2}}{8\mu_w \delta'_m}\Delta p = \frac{\varepsilon_p r_p^{\ 2}}{8\mu_w \delta_m \left[1 - \frac{\Delta m_s}{\rho_s S_m \delta_m \left(1-\varepsilon_p\right)}\right]}\Delta p = \frac{J_w}{1-\frac{\Delta m_s}{m_s}} .$$

Therefore, the curve of J'_w versus time should be convex when there is a linear relationship between the weight loss and time.

When assuming that the enzymatic digestion is dominated by the dilation of the membrane pores, the variation in the porosity can be related with the weight loss by:

$$\Delta\varepsilon_p \equiv \varepsilon'_p - \varepsilon_p = \frac{\Delta m_s}{\rho_s S_m \delta_m} .$$

The variation in the pore radius can be related with the porosity by:

$$r_p^{\ \prime 2} = r_p^{\ 2} \frac{\varepsilon_p^{\ \prime}}{\varepsilon_p} .$$

Therefore, The water flux of the degraded membrane J'_w then can be related with the weight loss by:

$$J'_w = \frac{\varepsilon'_p r'^2_p}{8\mu_w \delta_m}\Delta p = \frac{r_p^{\ 2}\left(\Delta m_s + \varepsilon_p \rho_s S_m \delta_m\right)^2}{8\varepsilon_p \mu_w \rho_s^{\ 2} S_m^{\ 2} \delta_m^{\ 3}}\Delta p = J_w\left(1 + \frac{1-\varepsilon_p}{\varepsilon_p}\frac{\Delta m_s}{m_s}\right)$$

Therefore, the curve of J'_w versus time should be linear when there is a linear relationship between the weight loss and time.

Theory S2

Equations correlating the dilation of membrane pores with the weight loss resulting from the biodegradation.

It is assumed that the membrane is composed of straight-through cylindrical pores. The weight of the membrane then can be calculated as:

$$m_s = \rho_s S_m \delta_m \left(1 - \varepsilon_p\right),$$

where ρ_s is the density of the polymer; S_m and δ_m are the area and thickness of the membrane, respectively. If the enzymatic digestion is dominated by the dilation of the membrane pores, the weight of the degraded membrane is given by:

$$m_s' = \rho_s S_m \delta_m \left(1 - \varepsilon_p'\right).$$

Combining these two equations yields:

$$\frac{1-\varepsilon_p'}{1-\varepsilon_p} = \frac{m_s'}{m_s}.$$

On the other hand, it is easy to show that the porosity and the pore radius can be correlated by:

$$\frac{\varepsilon_p'}{\varepsilon_p} = \frac{r_p'^2}{r_p^2}.$$

Therefore, the variation in the pore radius can be related with the weight loss by:

$$\frac{r_p'}{r_p} = \sqrt{1-\left(1-\frac{1}{\varepsilon_p}\right)\frac{\Delta m_s}{m_s}}.$$