Supplementary Material

S1-General solution for spreading of a film driven by an arbitrarily chosen disjoining pressure

If we define the disjoining pressure, Π, as a following form:

$$\prod = \prod_{el}(h) = \frac{B}{h^n} \qquad (S1-1)$$

B, is a constant and subscript *el* means the electrostatic component of disjoining pressure. The case considered here is referred to the final stage of the spreading of a corona discharge-exposed film, when the substrate is completely wetted by the particulated precursor. The dynamics of film profile can be described as:

$$\frac{\partial h}{\partial t} = -\frac{1}{3r\mu}\frac{\partial}{\partial r}\left(rh^3 \prod'(h)\frac{\partial h}{\partial r}\right) \qquad (S1-2)$$

The conservation equation becomes:

$$\frac{\partial h}{\partial t} = -\frac{nB}{3r\mu}\frac{\partial}{\partial r}\left(rh^{2-n}\frac{\partial h}{\partial r}\right) \qquad (S1-3)$$

Considering the non-dimensional parameters:

$$t^* = \frac{3\mu r^{*2}}{nBh^{*2-n}} \quad , \quad h^* = \frac{V}{2\pi r^{*2}}$$

$$\frac{\partial \bar{h}}{\partial \bar{t}} = \frac{1}{\bar{r}}\frac{\partial}{\partial \bar{r}}\left(\bar{r}\bar{h}^{2-n}\frac{\partial \bar{h}}{\partial \bar{r}}\right) \qquad (S1-4)$$

In order to find the similarity solution for spreading dynamics due to the repulsive disjoining pressure arising from double layer confinements, let us consider the following parameter:

$$\Omega = \bar{r}f(\bar{t})$$

where $f(\bar{t})$ is an unknown function. Since the volume of the film is constant during the evolution, then:

$$\int_0^{\bar{R}(\bar{t})\bar{f}(\bar{t})} \left(\Omega\frac{\bar{h}}{\left(\bar{f}(\bar{t})\right)^2}\right) d\Omega = 1 \qquad (S1-5)$$

The tested dielectric liquid (silicone oil) is not volatile and the volume of the film is preserved in all moments during the expansion process, thus the above equation should not be a function of time. Therefore,

$\bar{R}(\bar{t})\bar{f}(\bar{t}) = cte$ and $\bar{h} = g(\Omega)\left(\bar{f}(\bar{t})\right)^2$

Considering $\bar{h} = g(\Omega)\left(\bar{f}(\bar{t})\right)^2$ as a similarity solution for governing equation and using $\bar{r} = \frac{\Omega}{f(\bar{t})}$, the governing equation becomes:

$$\bar{f}\frac{d\bar{f}}{d\bar{t}}\left\{\left(\Omega\frac{dg}{d\Omega}\right)+2g\right\}=-\left(\bar{f}\right)^{8-2n}\frac{1}{\Omega}\frac{d}{d\Omega}\left(\Omega g^{2-n}\frac{dg}{d\Omega}\right) \qquad (S1-6)$$

Since the above equation should not be a function of time:

$\bar{f}\frac{d\bar{f}}{d\bar{t}}=-\left(\bar{f}\right)^{8-2n}$ or $\frac{d\bar{f}}{d\bar{t}}=-\left(\bar{f}\right)^{7-2n}$

Therefore:

$\bar{f}(\bar{t})\sim c^{*}t^{1/(-6+2n)}$

Since $\bar{R}(\bar{t})\bar{f}(\bar{t}) = cte$

$$\bar{R}(\bar{t})=C^{*}\bar{t}^{\,1/(6-2n)} \qquad (S1-7)$$

substituting the $\bar{f}(\bar{t})\sim c^{*}t^{1/(-6+2n)}$, eq.(6) becomes in the following form:

$$\left\{\left(\Omega\frac{dg}{d\Omega}\right)+2g\right\}=-\frac{1}{\Omega}\frac{d}{d\Omega}\left(\Omega g^{2-n}\frac{dg}{d\Omega}\right) \qquad (S1-8)$$

$$\Omega\left\{\left(\Omega\frac{dg}{d\Omega}\right)+2g\right\}=-\frac{d}{d\Omega}\left(\Omega g^{2-n}\frac{dg}{d\Omega}\right)$$

$$\frac{d}{d\Omega}\left\{\left(\Omega^{2}g\right)\right\}=-\frac{d}{d\Omega}\left(\Omega g^{2-n}\frac{dg}{d\Omega}\right)$$

Therefore, the profile of the film can be obtained by the following differential equation:

$$\Omega=-g^{1-n}\frac{dg}{d\Omega}$$

For relatively thick films (thicker than the double layer thickness), the conduction mechanism mainly remains in ohmic regime. In this case, electric pressure is constant (since the current density is constant) and $V_f \propto h$, therefore, n in eq. (1) must equal to zero. Substituting $n=0$:

$$\bar{R}(\bar{t})=C^{*}\bar{t}^{-1/6} \qquad (S1-9)$$

This is the spreading dynamics of the main film we obtained previously both experimentally and theoretically through the Stephan's analogy [2].

Considering the disjoining pressure, the precursor film spreading can be obtained by substituting *n=2* in eq.(7) as:

$$\bar{R}(\bar{t})=C^{*}\bar{t}^{\,1/2} \qquad \text{(S1-10)}$$