Reaction Engineering of CVD Methylammonium Bismuth Iodide Layers for Photovoltaic Applications

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**Supplementary Information**

**Calculation of Reynolds Number**

It is assumed that nitrogen behaves as an ideal gas and that its fluid dynamic behavior is not affected by MAI and BiI3 in the vapor phase.

The Reynolds Number is defined as [1]:

$$Re=\frac{u∙d∙ρ}{η}$$

With u as the fluid velocity, d as the diameter of the pipe, ρ as the fluid density and η as the viscosity. From the ideal gas law, the following relation can be deducted [1]:

$$ρ= \frac{p∙M}{R∙T}$$

Here, p is the pressure, M the molar mass, R the ideal gas constant and T the temperature. The continuity equation is defined as [1]:

$$\dot{m}=ρ∙A∙u$$

Here, $\dot{m}$ is the mass flow and A is the cross-section of the pipe. By combining these equations, the Reynolds number can be described as:

$$Re= \frac{4∙\dot{m}}{μ∙π∙d}$$

With r as the radius of the pipe (2.29 mm). The viscosity is estimated by Sutherland’s formula. It states [2]:

$$μ\left(T\right)= μ\_{0}\frac{T\_{0}+C}{T+C}\left(\frac{T}{T\_{0}}\right)^{\frac{3}{2}}$$

For nitrogen, $μ\_{0}=1.781∙10^{-5}$, $T\_{0}=300,55 K$ and $C=111 K $apply. Moreover, for nitrogen

 $ρ\_{0}=1.292\frac{kg}{m^{3}}$ which is needed to describe the mass flow of 500 sccm in kg per s [2].

With $T=20 °C$ and $T=400 °C$, the Reynolds number is calculated to be $Re\left(20°C\right)=171.54$ and

$Re\left(400°C\right)=95.65$.

Since the flow regime is changing from laminar to turbulent at Reynolds numbers around 2300, it is assumed that the whole process is in a laminar flow regime [1].

**Literature**

1. R. Darby, *Chemical engineering fluid mechanics*, Marcel Dekker, New York, 2nd edn., 2001.
2. F. M. White, *Viscous fluid flow*, McGraw-Hill, Boston, Mass., 3rd edn., 2006.