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Article

Chemical Vapor Deposition of Longitudinal Homogeneous Parylene Thin-Films inside Narrow Tubes

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Abstract: The effect of quasi-exponentially decreasing film thicknesses of thin poly-*para*-xylylene (PPX-N) coatings inside narrow tubes or micro scaled gaps is well known and has been discussed by many authors since the late 1970s. However, for technical applications it is often necessary to provide a longitudinal homogeneous film thickness to ensure the constant properties that are required. In a previous work, it was shown, in principle and for the first time, that a temperature gradient along the tube will effectively counteract the longitudinal decreasing film thickness of the PPX-N coating of the interior wall of a capillary. Therefore, this effect is discussed in theory and the provided model is verified by experiments. Our prediction of a required sticking coefficient curve yields experimentally measured homogeneous film thicknesses and shows a good agreement with the given prognosis. Further, it is shown in theory that there is a maximum achievable homogeneous film thickness in the tube in comparison to a blank surface, which can be understood as a coating efficiency for this type of deposition.

Keywords: parylene; chemical vapor deposition; deposition model; constant film thickness; sticking coefficient; temperature gradient

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1. Introduction

Chemical vapor deposition (CVD) is well known for forming high conformal coatings with uniform thickness on rugged surfaces with deep valleys or high mountains, on nearly all types of materials. Especially for modern applications as in medical [1–5] or in electronic devices [6–8], where constant film properties across the whole substrate are demanded, this type of processing has nowadays found widespread usage.

In contrast to other deposition techniques, e.g., sputtering or evaporation techniques, which involve atoms as film-building species, reactive molecules or radicals in CVD form a polymeric film by a chemical reaction. According to Arrhenius and the law of mass action, chemical reactions always depend strongly on temperature [9,10], and their manufacture is challenge with respect to process parameters and their stability [11–13].

For the coating of medical implants, one of the most promising polymers is poly-*para*-xylylene (PPX-N), or other related derivatives [14,15], providing the ability to form high-precision thin-films on substrates. These thin-films have excellent properties such as transparency, high temperature resistance, mechanical flexibility, bio-compatibility, and chemical resistance and can even act as diffusion barriers [8,16,17]. Hereby, various methods are known to influence the film quality, properties and growth rate during PPX-N CVD. For example, diluting the monomer vapor with a non-reactive residual gas, such as argon, reduces the film growth rate but yields a higher optical transparency [18], and is therefore a state of the art technique in industry and research.

Thin films of PPX-N are typically formed within the so-called Gorham process [19], where a precursor is evaporated under reduced pressure (temperatures between 120 °C and 150 °C, total pressure in the order of 10 Pa). The dimeric species is thermally cracked