Infrared gas phase studies in high-current dielectric barrier discharges containing organo-silicon precursors

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The gas phase of dielectric barrier discharges in roll-to-roll configuration for synthesising SiO_2-like barrier layers from HMDSO or TEOS were studied by infrared absorption spectroscopy. Main products were identified along with their dependence on the (average) power density in pulsed plasmas. Links to earlier model assumptions on the film formation and precursor consumption are provided.

1. Introduction

Silica-like layers formed during large-area plasma-enhanced (PE) roll-to-roll processing of polymeric substrates in diffusive dielectric barrier discharges (DBDs) have been shown to yield high-quality barrier layers [1]. This has been obtained through chemical vapour deposition (CVD) at atmospheric pressure (AP) using organo-silicon precursors and air-like gas mixtures. Provided an electronic stabilisation circuit is applied, high currents in a diffusive discharge mode can be achieved. Complementary gas-phase studies using infrared (IR) absorption spectroscopy were carried out to (i) identify main (dissociation) products in discharges, (ii) study their dependence on the (average) power density in pulsed DBDs, and (iii) to establish links to earlier model assumptions consumption [2].

2. Experimental

The AP PE-CVD setup used was an industrial roll-to-roll configuration (0.5 mm gap). The measurements using a Fourier-Transform IR (FT-IR) spectrometer were therefore carried out *ex-situ*. A small fraction of the effluent of the discharge was sampled under flowing conditions into a multi-pass cell (7 m absorption path) at reduced pressure (~ 50 mbar) to increase the selectivity for different absorption features. The discharge was operated at 185 kHz in a pulsed mode with duty cycles between 10 - 75 %, i.e. plasma-on periods of 0.16 to 1.20 ms. In this way, the precursor dissociation could be studied, even through sampling at the end of the active plasma zone, as at low power densities precursor fragments might be still present.

3. Results

At high (average) power densities the gas phase composition in TEOS or HMDSO containing plasmas is comparable to situations where no precursor is present (fig. 1, [3]) which agrees well with earlier model assumptions about the precursor dissociation along the active plasma zone [2]. Main (stable) species are NO, NO_2, N_2O and HONO as well as carbon containing species such as CO, CO_2 (fig. 1).

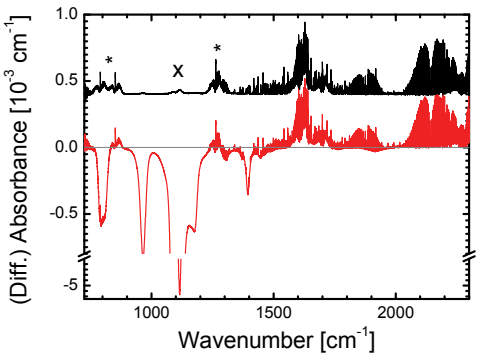

Fig. 1: *FT-IR spectrum recorded in N_2/O_2/Ar+TEOS (15/1.8/1.0 slm+ 5 g/hr). The lower trace shows a spectrum (plasma on-off) with an almost complete precursor dissociation (50 % duty cycle). The upper trace (stacked for clarity) highlights the formation of intermediate species: HONO (*), HCOOH (+), precursor traces (x).*

Distinct differences in the product distribution between the two precursors can be seen, particularly at low power densities. Similar to etching conditions (i.e. no precursors present [3]), HCOOH transpires to be a good marker molecule to distinguish different discharge and film formation regimes. Quantitative aspects of selected gas phase species will be discussed along with the analysis of the injected energy.

References

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