

In-situ investigations of the curing process in ultra low-k materials

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Porous spin-on glasses belong to ultra low-k (ULK) dielectrics and are promising candidates for integration in the semiconductor device fabrication technology. Their microstructure consists usually of interconnected pore networks distributed across the film rather than separated voids. The pore size and distribution are controllable to a large extent, however, the pore formation process itself is still not well understood. A dielectric damage during integration and material degradation of films with large porosity are still problematic issues. The first results on in-situ investigations of the pore formation during a curing process – a porogen removal by vacuum annealing will be presented. The main motivation is to obtain the insight into early stages of the pore formation and up to its full development. The in-situ annealing and Doppler Broadening – Positron Annihilation Spectroscopy (DB-PAS) measurements have been done on our Apparatus for In-situ Defect Analysis (AIDA) system [1], which is the end-station of the slow positrons beamline at HZDR. The comparison between preliminary ex-situ studies by means of DB-PAS [see Fig. 1], Positron Annihilation Lifetime Spectroscopy (PALS), and Fourier Transform Infrared Spectroscopy (FTIS) will be given.

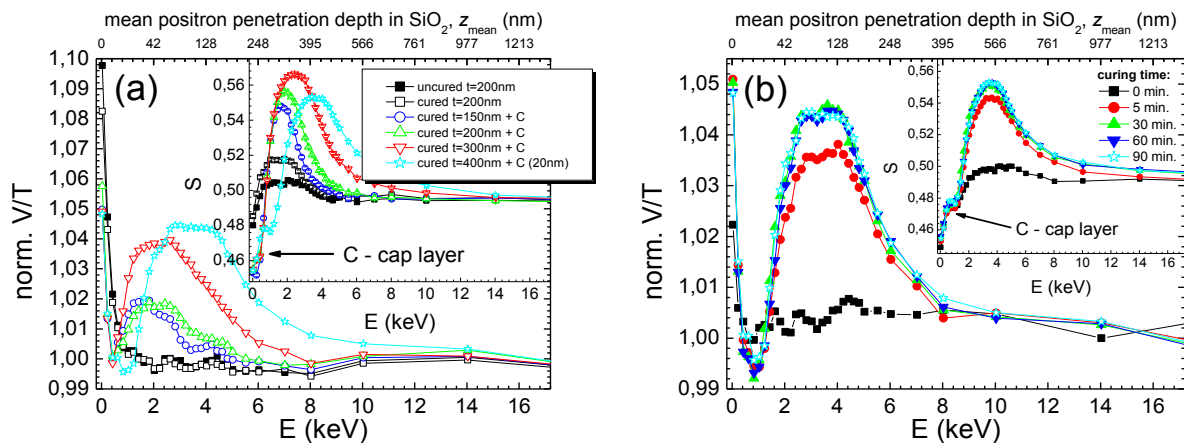


Fig. 1. ortho-Positronium (o-Ps) emission [norm. to bulk V/T parameter] as a function of positron implantation energy, E and mean positron penetration depth, z_{mean} for samples with different (a) thicknesses, t and (b) curing times for $t=400\text{nm}$ [450°C , 1h]. Cured samples with the ULK film thickness variation were capped with a carbon layer (10nm thick for $t<400\text{nm}$, and 20nm for $t=400\text{nm}$). In (b) all the samples were capped with 20nm C. S-parameter as a function of E (insets).

In Fig. 1(a) it is shown that o-Ps emission increases with t , thus can be a probe of films porosity as long as they are capped. The curing time of 5-30min. is sufficient to fully develop the pore network [Fig. 1(b)]. Porosity development and distribution will be discussed for annealing temperatures in the $100\text{-}400^\circ\text{C}$ range and varied annealing time.

[1] M.O. Liedke et al., *Journal of Applied Physics* **117**, 163908 (2015).