	Experiment title: Porosity study of ultra low-k dielectrics deposited by PECVD by GISAXS	**Experiment number**: 02-01-673
Beamline:	**Date of experiment**: from: **02 July 05** to: 05 July 05	**Date of report**: 30 September 05
Shifts: BM02	**Local contact(s)**: J-P Simon	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

Jean-Paul SIMON*

Lab. Thermodynamique et Physicochimie Métallurgiques, UMR5614, INPG-CNRS-UJF, Grenoble

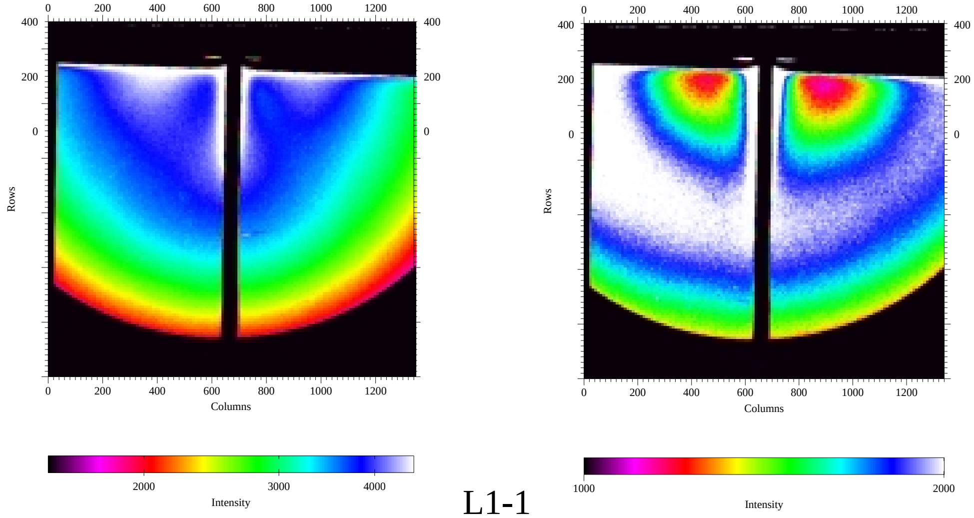
Laurent FAVENNEC*, Vincent JOUSSEAUME*, Guy ROLLAND*

CEA, LETI, Grenoble

Report: this experiment is part of the thesis of L. Favennec which is focused on the elaboration of thin layers of ultralow-k dielectrics by Plasma-Enhanced-CVD. One of the actual problems to improved functionality and speed in integrated circuits is the crosstalk between wires through the dielectric barrier. The high frequency capacitance is compared to vacuum with a ratio k (>1). In actual devices, k larger than 3 using bulk $Si_xO_yC_z$ materials. k of the order of 2 is now obtained with nanometric pores in volume fraction larger than 30%. This layer is obtained by the deposition of the mixture of a matrix and a porogen which is further sacrified (evaporated). PECVD elaboration does not need high temperatures and, well mastered in the microelectronics environment, is preferred by industrials [1]. The samples are issued of the same chemistry with or without oxygen, before and after evaporation of the porogen by a thermal or UV treatment (table).

GISAXS, SAXS in reflection, has been measured with the small angle camera of BM02 (all its elements being under vacuum): the advantages are an increase of the signal using a grazing incidence (~x200) and no need of thinning of the Si wafer support. A beam height about 0.1mm (FWHM) insured that the printfoot of the beam did not expend beyond the sample (70mm long) and allows to compare intensities and not only sizes. This was verified as in previous experiment (fig. 1 of experimental report 02-01-643). A compact GISAXS geometry (sample to detector distance of 300mm at 8keV) covers the 0.7-7nm^{-1} q range. This geometry has the other advantage to increase the signal/noise ratio of these weak scattering samples (typical counting time 10 frames of 100s).

Typical 2d images are given below:



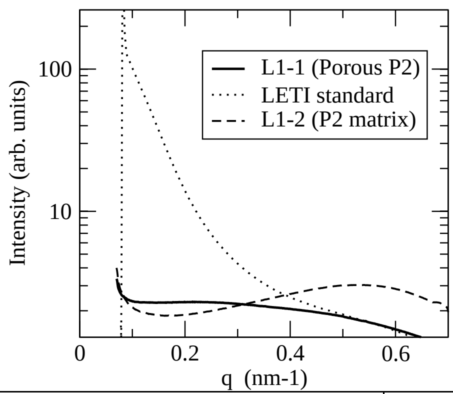
L1-1 L2-2

Note the anisotropy of L1-1 scattering with scattering maxima parallel to the layer and perpendicular to the layer. All other samples give isotropic scattering patterns similar to L2-2 image. In both cases, the stronger intensity along the shadow comes from the Yoneda peak

n of the Si waffer.

ge +-15 degree to +-

analysis in the table:



	Pore size (nm)	Interdistance (nm)	Iint (arb. units)
L1-1 (porous Pelikan2)	(0.6)	2.86	0.177
L1-2 (Pelikan2 matrix)	(<0.5)	1.18	0.275
L1-3 (L1-2 without O_2)	(0.5)	1.4	0.2123
L1-4 (L1-1 without O_2)	(0.5)	1.4	0.268
L2-1 (hybride pelikan2)	(0.5)	1.4	0.1755
L2-2 (L2-1 without O_2)	(0.5)	1.4	0.165
L2-3 (~L1-1, with UV)	(0.5)	1.4	0.268
Standard LETI k=2.2)	4 (and 0.5)	-	0.30

Values of “pore size” in parenthesis indicate that the size of the defects is very small, close to the atomic distance: we prefer to speak of heterogeneity of density or “ free” volume. They are already present in the matrix and the integrated intensities Iint are of the same order of magnitude, even higher before thermal treatment than after. But the volume fraction of pores can be related to the SAS-Iint only after the substraction of the intensity coming from short range electronic density fluctuation (Iint as defined by Porod). It sis necessary to compare these results with those given by other techniques: such an analysis is under progress.