Oral presentation

Pressure-induced structural modifications of imogolite metal-oxide nanotubes

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Imogolite metal-oxide nanotubes, with diameters similar to those of single or double-walled carbon nanotubes, are emerging as promising nanostructures in several nanoscience fields, such as nanofluidics [1] and photocatalysis [2]. Compared with carbon nanotubes, they offer the advantage of being synthesized with a well-controlled morphology and monodispersity in diameter and chirality. They can also be functionalized so that their hydrophilic internal cavity is rendered hydrophobic, by replacing the internal hydroxyl groups with methyl groups. Methylated nanotubes also exhibit a different chirality to hydroxylated ones, changing from zig- zag to armchair. We present here a study on alumino- silicate and germanate imogolite nanotubes and their methylated analogues, of chemical form $(OH)_x(CH3)_{1-x}Si(Ge)Al_2O_6H_3$, (x=0 or 1).

Applying high pressures to nanomaterials enables to study some of their physical properties or to form new nanostructures. Investigation of structural modifications of imogolite metal-oxide nanotubes under hydrostatic pressure (Pmax = 8 GPa) was carried out by X-ray scattering at synchrotron SOLEIL. Radial deformations are studied as a function of nanotube composition, morphology (single- or double-walled nanotubes), organization (isolated or bundled nanotubes) or functionalization. Axial Young's moduli and radial collapse pressures of nanotubes are determined for the first time. The (pseudo) axial Young's modulus is found to be much smaller in methylated nanotubes [3], which underpins the role of nanotube chirality in mechanical properties. Lamellar structures occur after the collapse of single-walled nanotubes. Furthermore, an original phenomenon of structural relaxation with pressure is observed in single-walled aluminogermanate nanotubes [4] (see Fig.1). Finally, the role of the transmitting medium in the pressure cell on the value of the collapse pressure is highlighted.

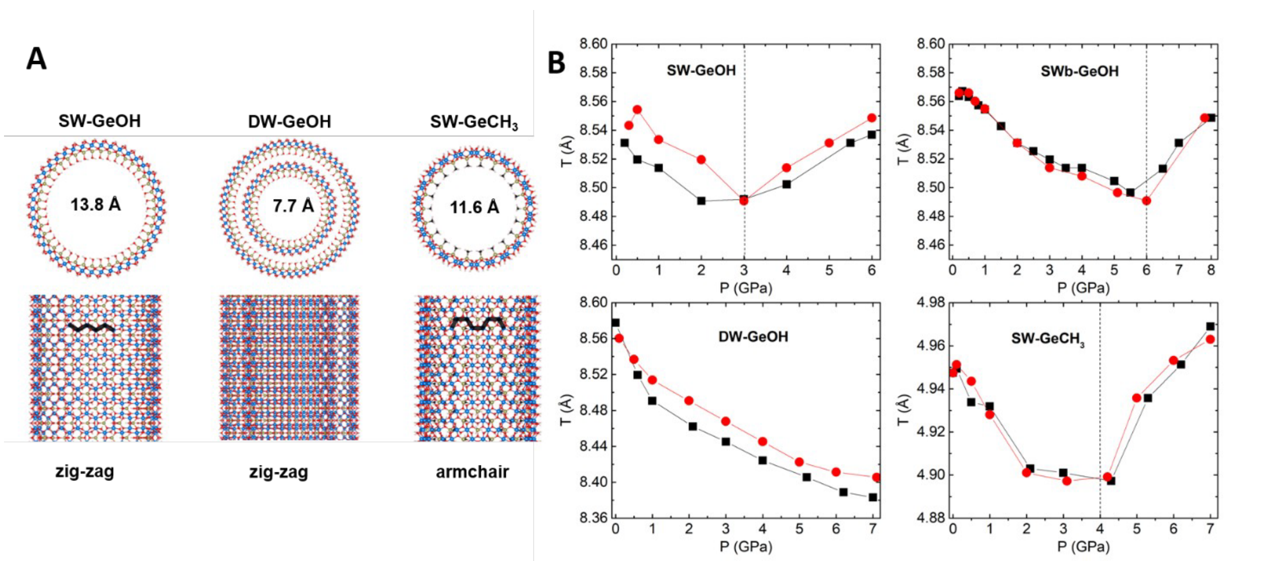

Figure 1. **A:** View of the structures of single-walled (SW-GeOH), double-walled (DW-GeOH) and methylated (SW-$GeCH_3$) aluminogermanate imogolite nanotubes. Respective diameters of the inner cavity and the chiralities are indicated. **B**: Dependence of the nanotube axial period *T* upon pressure for the aluminogermanate nanotubes (SWb: single-walled bundled nanotubes), with the transmitting medium, Si oil (black squares) or ethanol/methanol mixture (red circles). Vertical dashed lines are guides for the eye to determine the axial compression to relaxation transition pressure.

[1] Monet *et al*., *Nanoscale Advances* (2020), **2**, 1869–1877.

[2] Jimenéz-Calvo *et al*., *Small Methods* (2023), 2301369.

[3] Rouzière, S.,Victor Balédent, V., Bodin, J., Elkaim, E., Paineau, E., Launois, P. *Appl. Clay Sci. accepted.*

[4] Rouzière, S. *et al*., *Inorg. Chem.* (2023), **62**, 957 – 966.