CHEMICAL DEGRADATION OF POLYETHYLENE IN CONTACT WITH CHLORINE, DIFFUSION LIMITED OXIDATION ASPECTS

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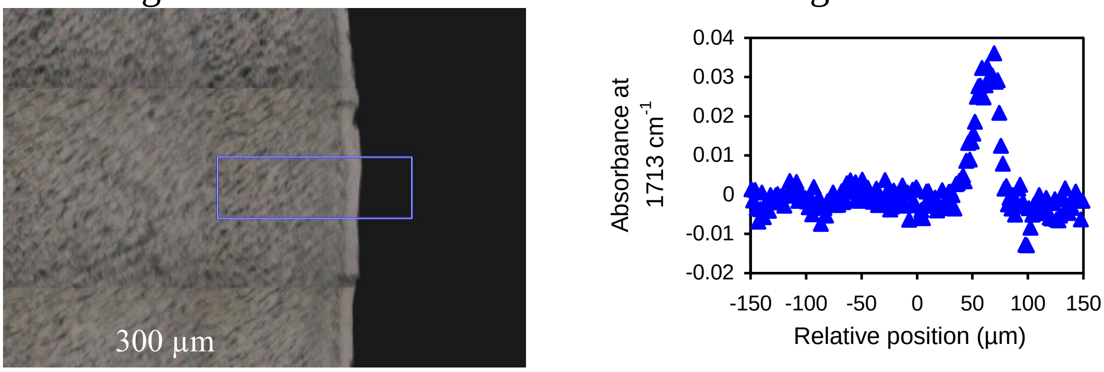
High density polyethylene (HDPE) is a semi-crystalline polymer widely used for drinking water supply. A good microbiological quality of the distributed water is ensured by adding disinfectants such as chlorine dioxide ClO_2 or chlorine Cl_2. However, these disinfectants have the potential to initiate oxidation processes. Indeed, under specific operational conditions (chlorine concentration, pressure and temperature), long-term contact with water containing chlorine is known to lead to degradation effects such as pipe inner surface embrittlement.

In order to accelerate the ageing, two approaches have previously been used. The first approach consists of increasing the temperature of the water containing the chlorine [1]. The second approach consists in increasing the chlorine concentration up while keeping the immersion temperature close to room temperature [2]. For thick samples, a gradient of degradation from the surface in contact with chlorine solution should be observed due to the diffusion of species like chlorine and oxygen.

Carbonyl profiles as a function of time of exposure for several chlorine concentrations are assessed using different tools as ATR-FTIR imaging. An example of carbonyl cartography by ATR-FTIR imaging is shown in Figure 1. The thick sample has been exposed during 333 days in contact of 70 ppm chlorine solution at 40°C. Thanks to optical microscopy, a brittle layer with cracks of 50 µm thick appears clearly. In a same time, FTIR mapping by following carbonyl absorbance at 1713 cm^{-1} put in evidence an oxidized layer having a thickness close to 50 µm. As a result, brittle layer thickness which can initiate pipe failure can be assessed precisely by FTIR mapping during exposure. Figure 2 shows oxidized layer thickness changes as a function of time exposure for three exposure conditions: oxidized layer increases linearly with time and the corresponding slope is proportional to chore concentration. These results will be discussed according to a diffusion limited oxidation modeling.



(a) (b)

Figure 1: a) section of a thick sample exposed during 333 days in contact with a 70 ppm chlorine solution at 40°C, observed by optical microscopy (the blue rectangle corresponds to the analyzed zone by FTIR mapping) b) Carbonyl absorbance through the section in the blue rectangle.

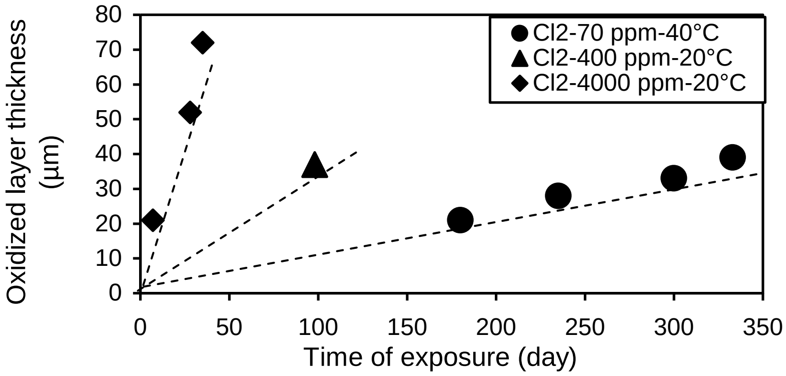


Figure 2: Oxidized layer thickness as a function of exposure time for three exposure conditions.

References

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2. Devilliers C, Fayolle B, Laiarinandrasana L., Oberti S., Gaudichet-Maurin E. Polymer Degradation and Stability 96:1361-1368, 2011.