Rhodamine B degradation efficiency of differently annealed titanium dioxide nanotubes

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ABSTRACT

Titanium dioxide is employed as photocatalytic substrate in heterogeneous catalysis, specially in the development of Advanced Oxidation Processes (AOP) which exploit the synergetic use of UV irradiation and oxidizing compounds to increase the degradation efficiency of hazardous chemical compounds [1]. Its main uses range from the mineralization of organic substances in air and in wastewaters, for environmental clean-up and deodorizing, to the removal of metal ions from wastewaters, from photovoltaic cells to the creation of antifouling, antibacterial, self-cleaning and antifogging surfaces [2]. When titanium undergoes anodic oxidation in fluoride-containing electrolytes, nanotubular amorphous oxides are obtained [3]: these oxides can acquire photoactivity through annealing treatments, which modify the amorphous structure of the oxide by inducing the formation of anatase crystals [4] and may lead to oxide doping depending on the annealing atmosphere. This paper presents an investigation over the photoefficiency of nanotubular TiO_2 films in the degradation of organic pollutants: rhodamine B was chosen as model reactant [5]. The effects of thermal treatments in several atmospheres on the oxides photoactivity are investigated.

First, specimens were characterized by means of Scanning electron microscopy (to investigate the attained morphology: fig. 1), X-ray diffraction (to achieve information on the oxide crystal structure) and Glow-discharge optical emission spectroscopy (to analyze the oxide elemental composition). The degradation of the organic compound was proved to follow a pseudo-first order kinetics, and a 90% mineralization of the rhodamine B solution was achieved after 23 hour irradiation of a 6 cm^2 nominal area specimen with UV-Vis light. While at a first glance no marked influence of nanotubes length was detected on the photocatalytic efficiency of the TiO_2 layer, an interesting influence was noticed when the adsorption extent of rhodamine B was taken into account: in fact, the active sites saturation was reached at growing concentrations with increasing nanotubes length, which was proved by a sudden change in the degradation kinetics with initial organic compound concentration. Finally, the effect of the annealing atmosphere was investigated by using air, pure nitrogen, and mixtures of: 20% oxygen 80% argon, 20% argon 80% nitrogen, and 50% oxygen 50% nitrogen; the presence of nitrogen was intended to dope the oxide and therefore to shift its activity towards visible light [6]. Only negligible effects were found on the UV-Vis photoactivity of the specimens (fig. 2); conversely, in all cases a detrimental effect was noticed on the photocatalytic activity of the specimens irradiated with pure visible light, specially when annealing was performed in atmosphere totally devoid of oxygen. A beneficial effect was exerted by the presence of nitrogen on the oxide activity under visible light radiation.

Submission track: Advanced materials - Nanostructured coatings, surfaces and films

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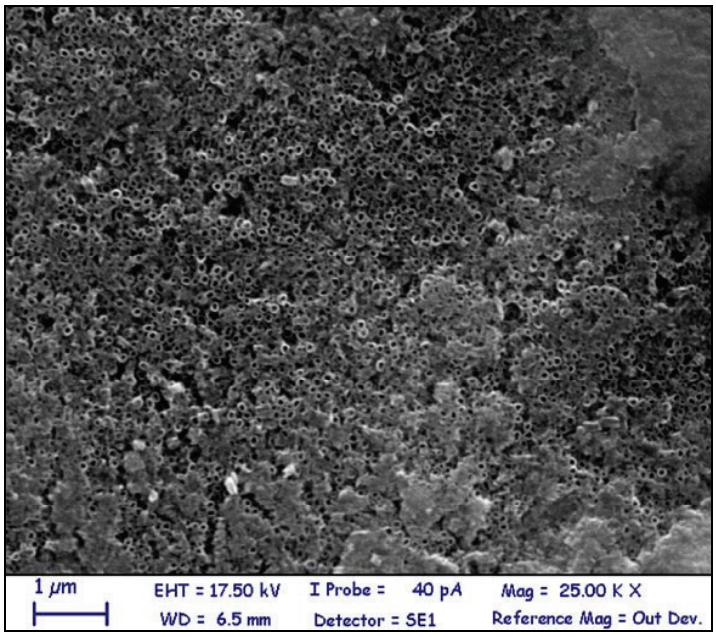

Figure 1 – SEM investigation of the surface morphology of titanium anodized in the chosen fluoride-based solutions: formation of amorphous TiO_2 nanotubes.

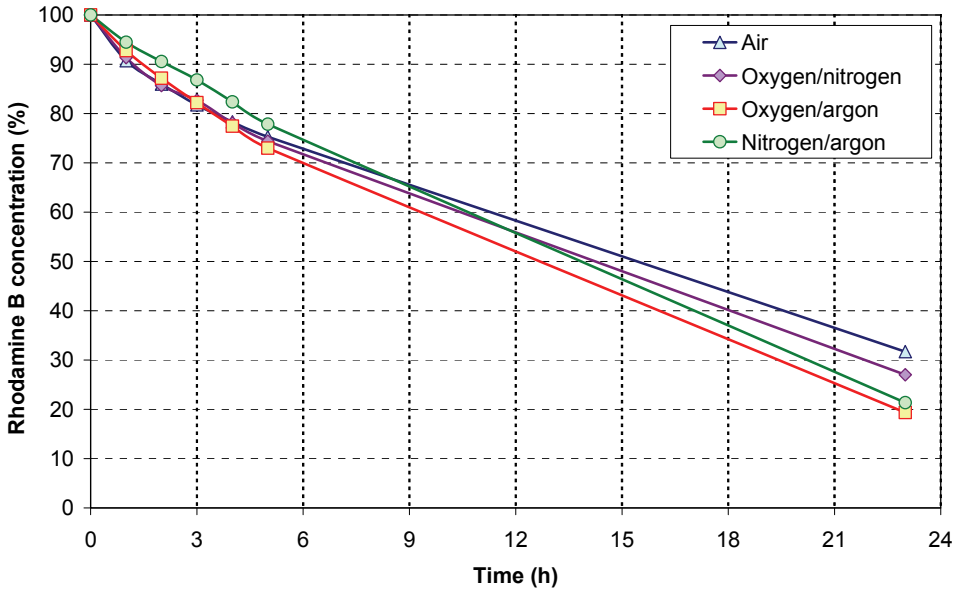

Figure 2 – Photocatalytic degradation in time of rhodamine B in presence of differently annealed substrates irradiated with UV-Vis light source. Resulting degradation extents and kinetics are comparable for all annealing treatments.