Development of antibacterial functionalized textiles by 3D printing

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ABSTRACT

Water is vital for life and the essential key to important industrial processes. Due to the increasing consumption and contamination, the access, treatment and safety of water is becoming challenging and costly. Therefore, new technologies have to be developed to ensure sustainable protection and safe access to water for both human consumption and industrial use. The DAF3D project aims to develop an innovative and sustainable 3-D-printed filter based on antibacterial functionalized textiles with zinc oxide (ZnO) for water disinfection. The expected application is centred on production and reusability of process water from diverse industrial sectors and grey waters within households. These new antibacterial textiles are capable of generating in situ highly reactive oxidizing species (ROS), which can degrade a wide range of organic substances, including microorganisms.

Zinc oxide could be synthesized by different chemical method such as sol/gel, precipitation, hydrothermal… methods. In our lab, a synthesis route was selected and optimised. It consists in dissolving zinc acetate in ethanol and adding KOH, dropwise, to the zinc acetate solution. This synthesis allows the formation of crystallite around 5nm with interesting intrinsic defects for our application: oxygen vacancies (Vo). XRD pattern, on Figure 1 (a), shows the ZnO in its wurtzite phase.

Indeed, oxygen vacancies are of particular importance for catalysis in the dark: the electron trapped in this potential trough will be able to react with the oxygen dissolved in the water and form the superoxide anion, a radical that will be involved in the destruction of bacteria.

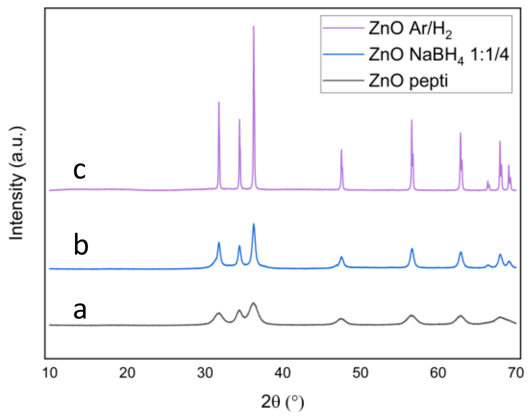

Figure 1 XRD patterns for the three ZnO from bottom tot he top: ZnO, ZnO/$NaBH_4$ and ZnO/H_2

To increase the concentration of Vo, various methods are being developed: directly treated the ZnO powder with Ar/H_2 flux at 800 °C or mixing sodium borohydride with previously synthesized zinc oxide at 500°C under (Figures 1 b and c). Different molar ratios ZnO/$NaBH_4$ were tried in order to achieve maximum degradation of a dye, nitro blue tetrazolium (NBT), by reaching the complete degradation after 24h, contrary to 30% in 24 h for the ZnO/H_2 and 30% in 48h for the initial catalyst.

SEM images of the three different catalysts are shown in Figure 2. After treatment with NaBH4, the surface of the catalyst is rougher (Figure 2 b) and particles are bigger after the treatment under H_2 due to the thermal treatment at 800 °C (Figure 2 c).

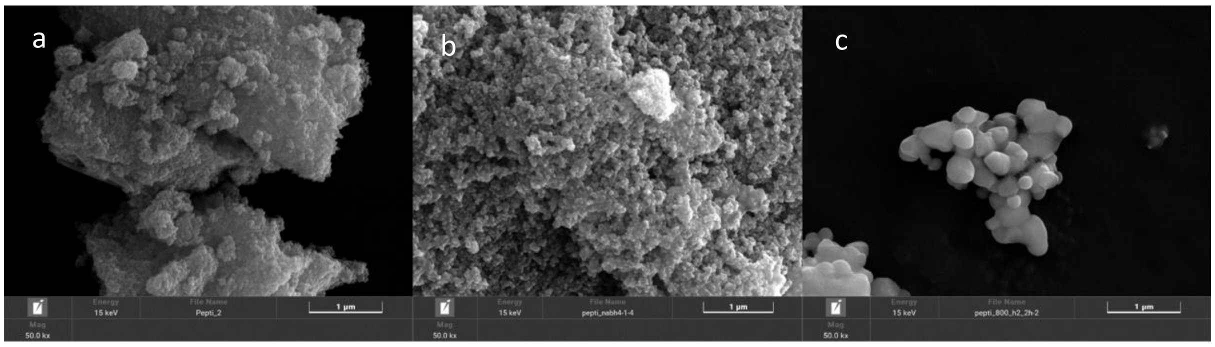

Figure 2 SEM images fort he three powders: (a) ZnO, (b) ZnO/$NaBH_4$ and (c) ZnO/H_2

In order to understand the differences between the NBT degradation results, characterizations of the material formed are performed by several methods such as photoluminescence (Figure 3) where a shift toward shorter wavelengths (500 nm) is observed and correspond to the Vo formation. Finally, electron paramagnetic resonance with DMPO experiments were done in order to detect the presence of superoxide radicals (Figure 4).

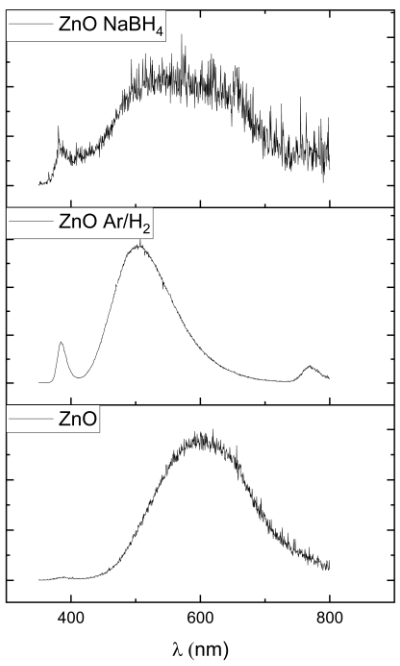

Figure 3 PL spectra

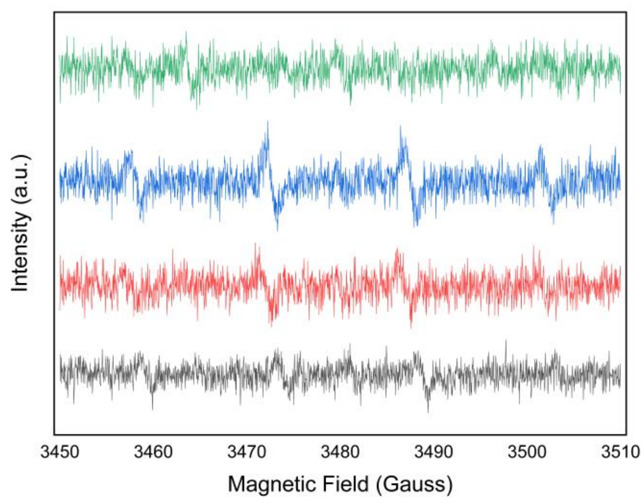

Figure 4 EPR spectra with spin trap (DMPO) to detect superoxide radicals. In black ZnO, red ZnO/H_2, blue ZnO/$NaBH_4$ and green $NaBH_4$ only

To conclude, increasing the amount of Vo leads to a better activity of the catalyst in the dark. It is especially observed for the sample treated with $NaBH_4$ due to a better contact between the hydrogen source and the ZnO and the lower temperature of the treatment (500 °C)