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Flame Synthesis of C-Doped TiO_2 Nanopowders for Dye Sensitized Solar Cells

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Anatase TiO_2 is still of interest as a candidate material for dye-sensitized solar cells (DSSCs), since it was first developed in 1991 [1]. This is due to the low cost of processing, relative to that of single and amorphous Si-based materials. Given its wide bandgap (3.2 eV), it displays excellent photoelectric activity with UV light absorption. Nevertheless, to further improve efficiency, much effort is being directed to shift its absorbance edge toward the visible wavelength region by modifying the bandgap. Various processing methods have been considered, including doping with nitrogen and carbon [2]. The role of these elements is not fully understood, and further work is needed to understand mechanisms that control efficiency. In this paper, we describe the flame synthesis of C-doped TiO_2 nanopowders utilizing a flat-flame burner of novel design, which is capable of continuous operation at reduced pressures (<20 torr).

The synthesis of C-doped TiO_2 nanopowders is carried out in the flat-flame burner, using titanium-isopropoxide (TTIP) as the precursor material. After thermal decomposition and vapor condensation, the resulting nanopowders are collected on a chilled substrate. Methane gas is used as a source of carbon doping. Carrier gas flow rate was adjusted to control the amount of dopant in the TiO_2 nanoparticles. *In-situ* laser diagnostics techniques are used to determine chemistry of gas-phase species and to detect any phase transformation that occurs during deposition. The synthesized C-doped TiO_2 is used to make the photoanode of DSSCs. Photocatalytic activity of the fabricated DSSCs using standard Pt-FTO as counter electrode, ruthenium dye, and iodide/tri-iodide-based electrolyte is measured. Structural and phase characterizations are determined using analytical electron microscopy techniques. EELS is used for chemical analysis, and elemental distribution.

Fig. 1-a shows a bright-field TEM image of as-synthesized C-doped TiO_2 nanopowder. The micrograph shows an average particle size of 8 nm, and narrow particle size distribution ±0.9 nm. Indexed rings of SAED, **Fig. 1-b** confirms the presence of anatase phase and diffuse rings is indicative of nano-sized particles. The carbon concentration in a typical TiO_2 sample, measured by EELS and EDS, **Fig. 2**, is ~7 at.%. Photocatalytic activity measurements show an increase in visible light absorption, which results in ~17% increase in the photocurrent density, and ~23% overall increase in the efficiency with respect to photoanodes made from commercially available anatase, Degussa P-25 TiO_2. This improvement is due to the increase in the number of absorption sites [2]. Work is underway to determine the locations of the carbon atoms in the TiO_2 structure, and their role in photocatalytic activity.

References:

[1] O'Regan B and Gra¨tzel M, 1991 Nature 353 737

[2] Y. J. Chen*et al.,* J. Vac. Sci. Technol. A 27, 862 (2009).

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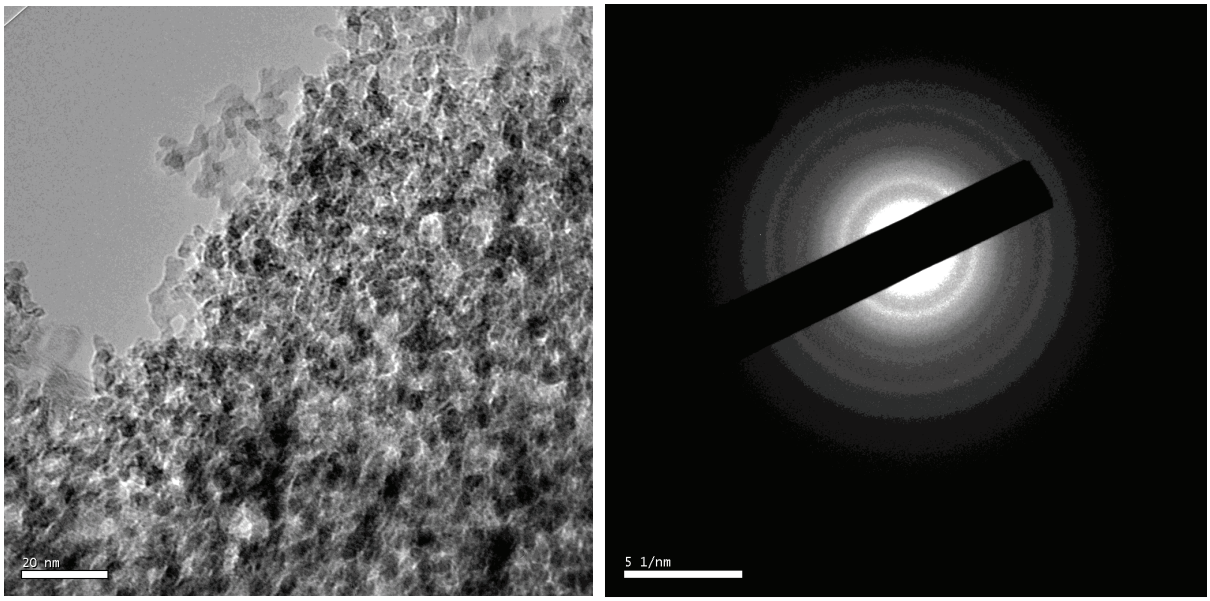

Figure 1, (a) Bright field TEM image of C-TiO2, and (b)corresponding diffraction pattern.

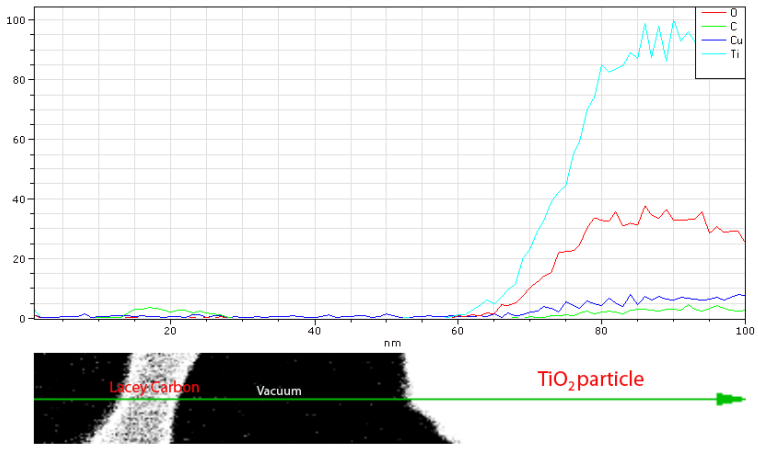

Figure 2, STEM image with EDS line profiles of oxygen, carbon, copper and titanium. Copper signal is generated due to copper TEM grid mesh supporting particles.

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