Stand Up Texture In Thick Film TiO2

Atta Gueye, Banasari Roy, Paul Fuierer

New Mexico Institute of Mining & Technology, Socorro, NM 87801

Introduction

Texturing provides a method for improving the electronic, optical and/or structural properties of functional ceramics with anisotropic structures. The current methods for producing textured ceramics use high temperatures and pressures for bulk materials, or LPE, CVD or PVD to achieve epitaxial thick or thin films. The processes we are exploring could yield novel textures in large area ceramic thick films, with potentially low production costs which could benefit ceramic manufacturers and many related industries. Our main goal in this work is to produce a thick film ceramic layer containing TiO2 acicular particles which are oriented with their long axes normal to the plane of the film. Processes which apply strong shear force to slurry formulations, such as screen printing and spraying have been attempted.

Background motivation: the Gratzel Cell

Grätzel cells convert sunlight energy into electric current. They depend on a non-galvanic chemical action in which the active chemicals are constantly regenerated. The cells behave in a way analogous to photosynthesis in which chlorophyll molecules reflect green light but absorb light the red and blue parts of the spectrum.

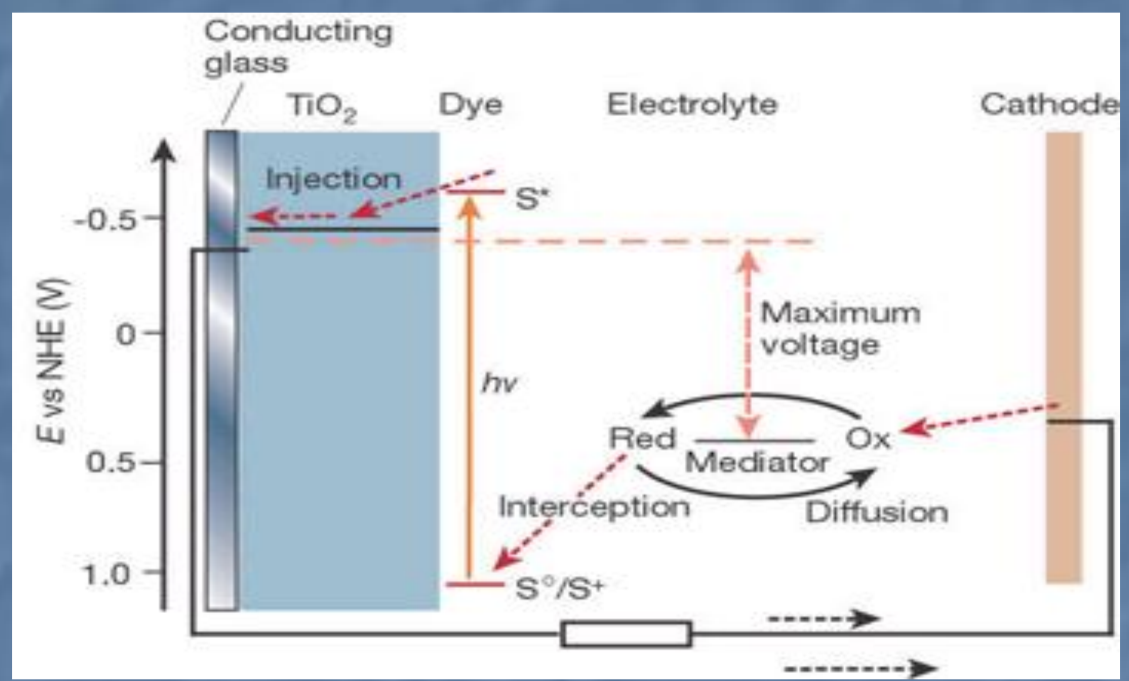


Fig 1 : Operation of Dye-Sensitized solar cell

Prior work done on Low Temperature Synthesis of Nanocrystalline Anatase Films for use in Dye – Sensitized Solar Cells (M. Jensen:) uncovered that high surface area nanocrystalline-anatase layer at very low temperature (75°C) are compatible with flexible polymer substrates.

The Problem with this discovery is that long percolation path between weakly linked nano-anatase creates high internal resistance, and low current output.

The proposed solution is to develop a heterogeneous TiO2 composite layer containing erect rutile needles as electrical conduits using shear stress and "chemically sinter" the nano-scopic Anatase to the microscopic rutile on a layer of Titania coated glass Micro-spheres.

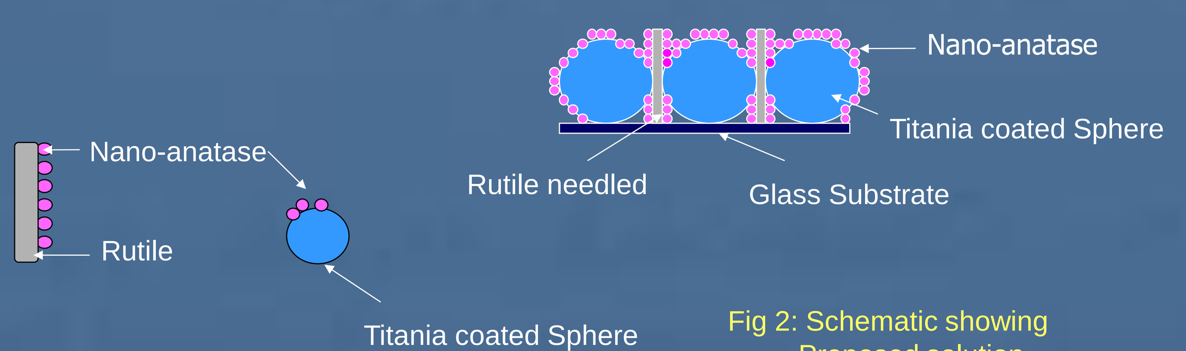


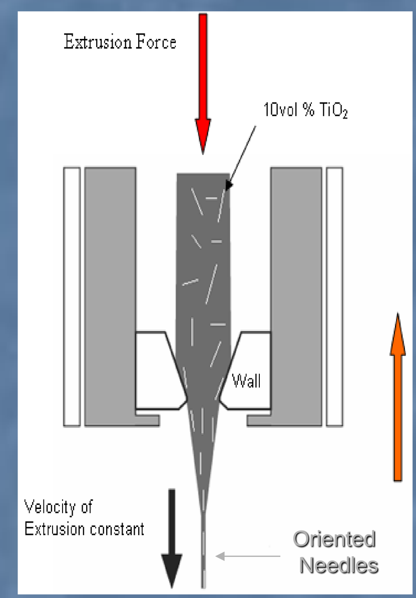
Fig 2: Schematic showing Proposed solution

Proof of Concept

Polymer Extrusion

Polycarbonate (10cc) was dissolved in 150ml of Tetra-hydro-fluoride. Then FTL300 (Rutile) was added to the mix. The resulting slurry was then emerged in a Homogenizer for about 5 mn @ 1200 MPA; an equal amount of methanol was also added. The slurry was left to dry out , the resulting powder was put in a capillary rheometer with the expectation that the shear forces near the internal walls of the instrument would orient the whiskers.

Figure 3: Polymer extrusion process



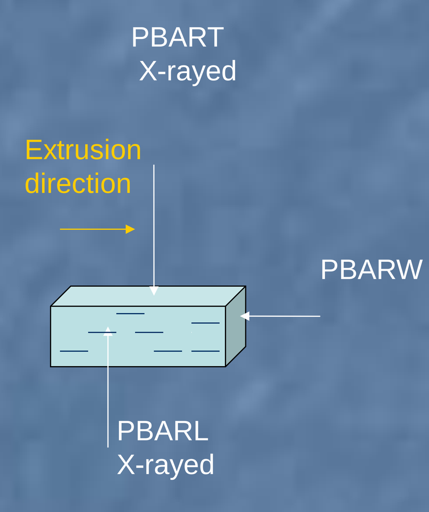
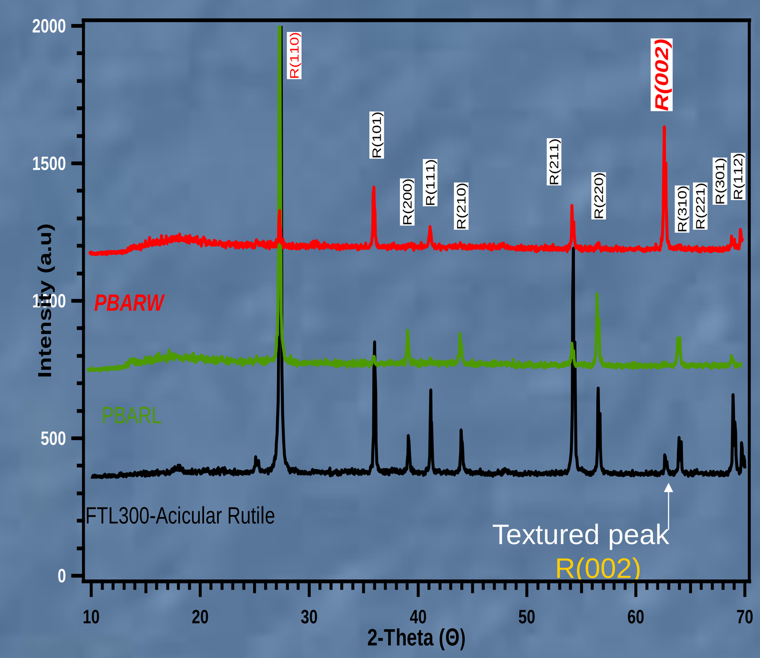


Figure 4: Extruded Block

Figure 5: X-ray Pattern of Extruded Block



When our X-ray data was compared to the publish pattern ,we noticed a decrease in the (h,k,0) as well as an increase of the (0,0,l) peaks . It could therefore be concluded that we have signs of texturing .

Texturing /Orientation Methods 1

In this process, the slurry is applied to the substrate by placing the screen over the substrate . A slurry with a paint-like consistency is placed onto the top of the screen and forced through the fine mesh openings using a squeegee that is drawn across the screen. Applying pressure forces the ink through the pores of the screen .Shear forces orient the needles as they are deposited on the substrate. The resulting thick film is then exposed to UV light.

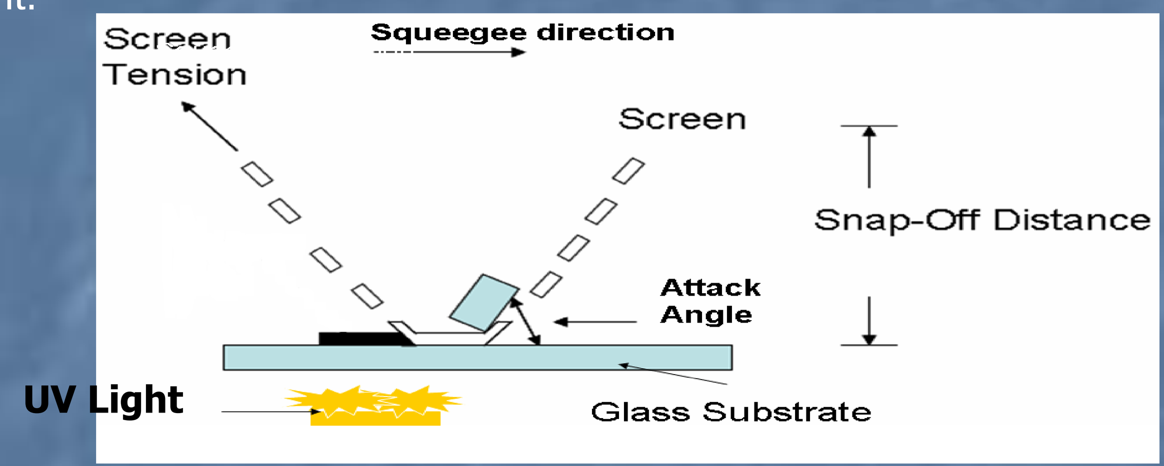


Fig 6 .Screen printing apparatus & squeegee

Fig 7. Parameters in the Screen printing process using a squeegee

Screen printing Results

Fig 8. Resulting Films

Fig 9. SEM Images of Screen Printed of Film

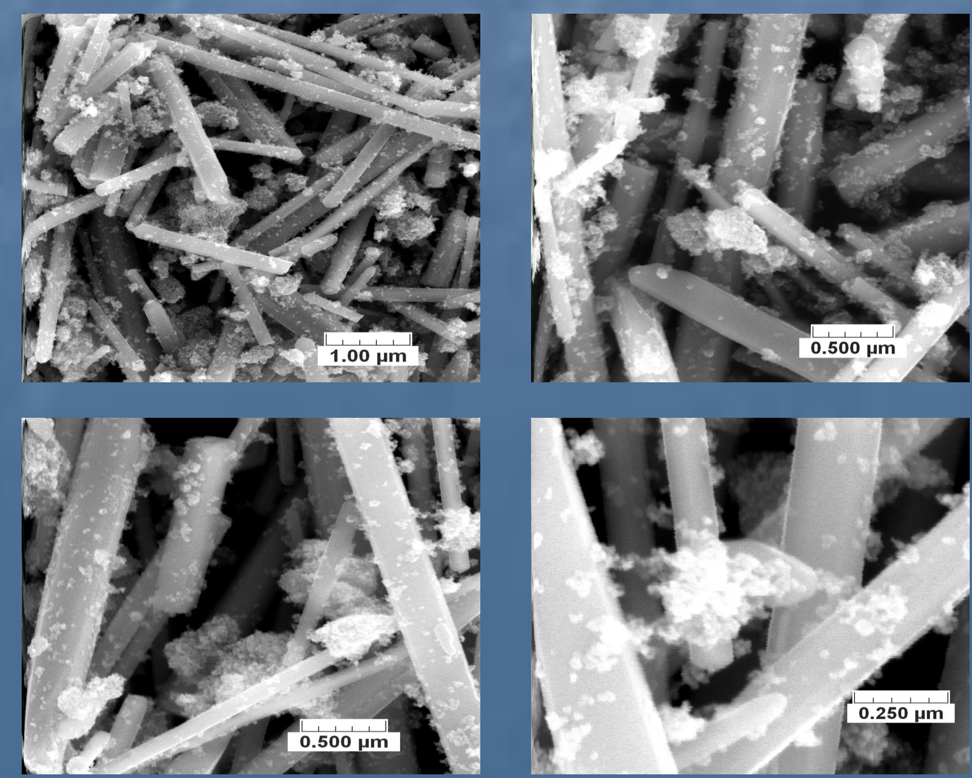
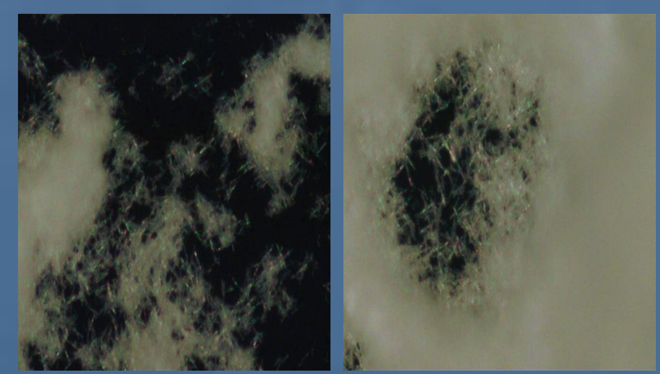


Fig 10.Optical Microscope Images



No sign of Alignment of the needles as can be noticed the SEM Images on the right

Texturing /Orientation Methods 2

Spraying /Air Brushing

A stream of fast moving (compressed) air through the gun creates a local reduction in air pressure (suction) that allows the Titania slurry to flow. The high velocity of the air atomizes the slurry into very tiny droplets as it blows past a very fine needle which help orient and or deposit The Tio2 particles on to the Glass micros-sphere substrate.

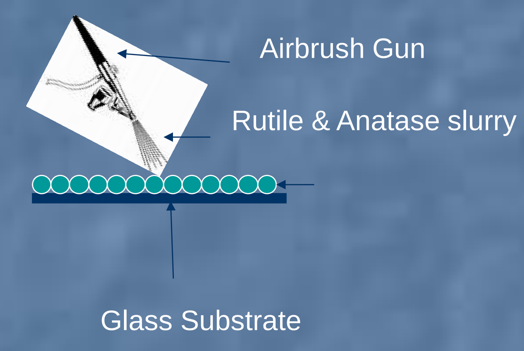


Fig 11. Air brushing process

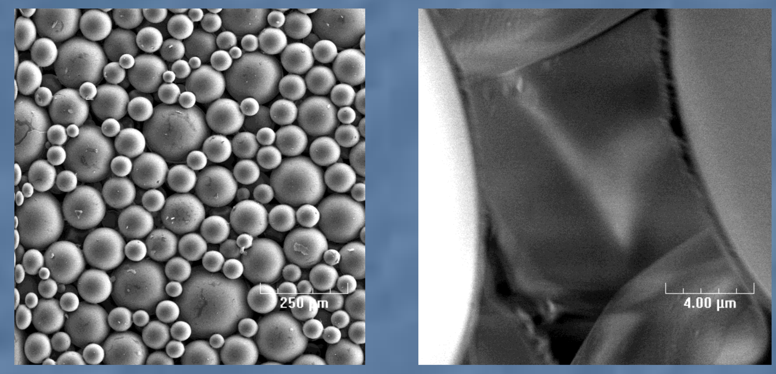
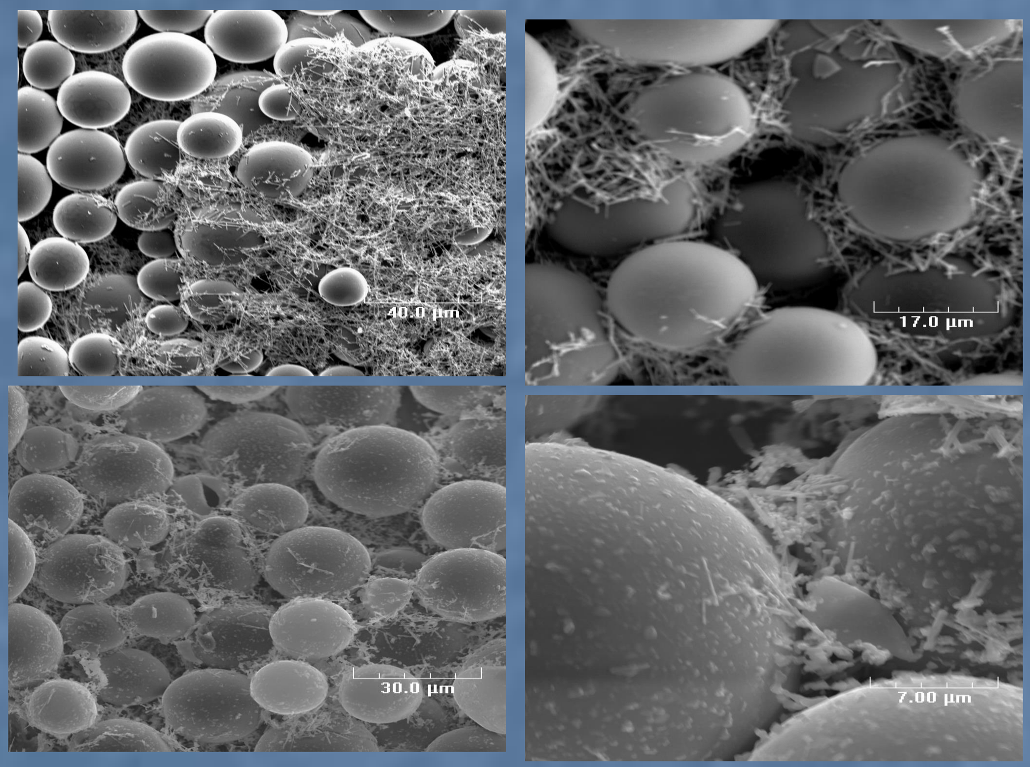


Fig12. Surface being Airbrushed (sprayed with TiO$_2$)

Spraying /Air Brushing Results

Fig.13 SEM images of Sprayed Film



Texturing/Orientation Method 3

Paint substrate

A glass slide was dipped into a paint formulation with TiO2 pigment sub-micron particles. After drying the slide covered paint was shot with a mix of Rutile needles and Nano-anatase. The idea is to have the paint particle help orient the needles

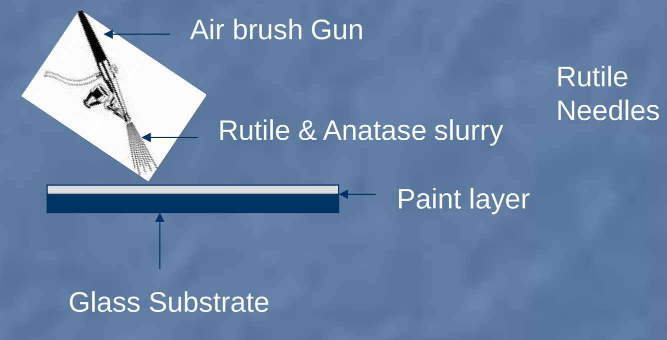
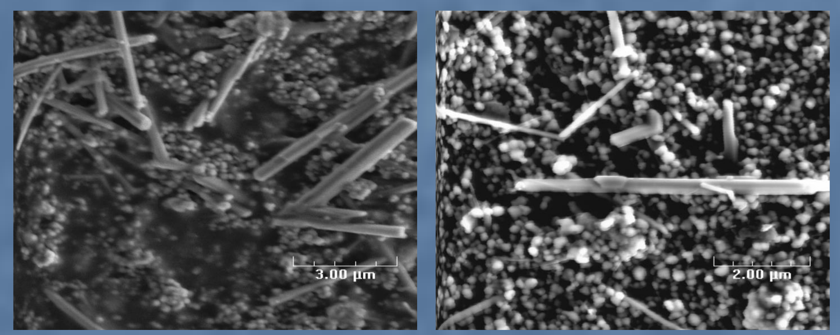


Fig 14. Spray process

Fig 16. SEM images of sprayed film



Evidence of texturing could be noticed in the tilt of the needles as(see SEM Image above)

Conclusion & Future work

Solar Cell

Standing up TiO2 whiskers using shear forces through texturing methods (Screen printing, Airbrushing) has proven to be very challenging. Our future goal will be to build a solar cell out of our novel heterojunction thick films with nano anatase coated glass micro-sphere/acicular rutile .This solar cell will be consequently be characterized electrically and optically

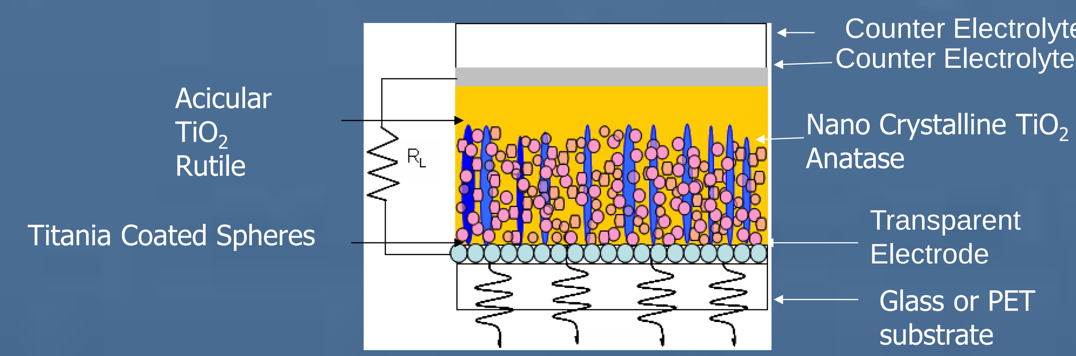


Fig 16.Solar Cell Built from novel Textured Ceramic