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AC Electric Field Deposition Behavior of TiO_2 Ceramic Nanoparticles

Vahid Majazi Dalfard

Young Researchers Club, Kerman Branch, Islamic Azad University, Kerman, Iran
*E-mail: vmd_60@yahoo.co.nz

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In this research, the AC electric field deposition behavior of TiO2 ceramic nanoparticles at different applied frequencies was investigated. For this purpose, dilute suspensions of ceramic nanoparticles in acetone media were prepared. The deposition process was conducted on two parallel planar electrodes for a dwell time of 10 minutes. It has been shown by scanning electron microscopy (SEM) that by increasing the frequency from 1 to 10000 Hz, the deposition mechanism of TiO2 particles on the surface of gold electrodes changes. The results obtained from the SEM images also show the capability of this technique for controlling the deposition pattern and manipulating ceramic nanoparticles as it was reported for biological nanoparticles previously.

Keywords: Nanoparticles, Deposition, AC Electric Field, TiO2

1. INTRODUCTION

Titanium has replaced all similar materials due to high refractive index as standard white pigment. So that titanium pigment forms about 60% of general pigments production. Ability of this material causes to increase annual production of this material in the world as ultraviolet light absorber and photocatalytic properties and hydrophilic property and it is predicted that this trend will continue in the future. In addition, broad applications of titanium thin layers in dielectrics[1], sensors[2], and in air and water purification[3] caused to consider titanium thin layers production methods such as sol-gel, sputtering, and chemical deposit of steam in recent years. [4]

AC Electrokinetics means expression of suspending particles motion in a fluid when it is exposed to AC applied electric fields. The electric field applies the forces on particles and fluid and AC Electrokinetics studies each one of them.[5] Displacement and control methods for motion of nanoparticles with AC Electrokinetics have been turned into one of the interesting subjects of the

researchers. These methods have been broadly applied in different sciences in recent years due to technical simple and cheap provision for displacement, separation, study of properties and identification of nanostructures. One of the most important Electrokinetic phenomena is electrophoresis which is basis of electrophoresis deposition method. In the past 100 years, this technique has been used for deposition and formation of thick layers from different materials. Techniques based on electrophoresis are applied for separation of large organic molecules. [6, 7] The second Electrokinetic force is known as dielectrophoresis. Dielectrophoresis of particles transmission motion is due to effects of polarization in non-uniform electric fields. This phenomenon which was explored in 1951 was developed in recent years due to broad applications in study of internal properties of nanostructures and provision of a method for separation of nanoparticles and formation of nano-dimension electromechanical systems. [8]

High intensity of elexctric field can cause fluid flow. Electric field - induced fluid flow in low frequencies (f<100kHz) which was explored in 1998 has been observed in many electrokinetic tests. Ramos et al showed that such fluid flow can't be related to electrothermal mechanisms but it is originated from electroosmosis phenomenon. Fluid flow is created due to electroosmosis of the forced applied on the double layers by a tangent electric field. [9]

Most researches on AC Electrokinetic relate to biological nanoparticles and carbon nanotubes. Application of AC Electrokinetic methods have been considered for suspensions containing ceramic nanostructures and few reports are available in this field. In the present research, ceramic nanoparticles deposition mechanisms have been studied under different frequency conditions and methods based on AC Electrokinetic methods to deposit Tio2 nanoparticles with different deposition models have been shown by the suggested mechanisms.

2. MATERIAL AND METHOD

Two parallel electrodes were applied on a nonconductive base for deposition. Electrodes were made on a borosilicate glass with use of trading gold paste (Degussa, GZ117) . Gold layer was dried and then stabilized at temperature of 610°C for one hour. A narrow groove of 100 microns was created on gold layer with etching with alumina pen. Disconnection was studied and deposited flow between two electrodes was measured at 400 C. deposited flow between two electrodes was obtained to be less than 0.2 μA.

Tio2 nanopowder (Merck) was applied in pure acetone medium (Merck #12) with very low densities (1gr/lit) for deposition. The related suspensions were obtained after 15 minutes under ultrasonic ray for stabilizing particles in acetone medium. Electric conduction of suspension was measured with conductometer probe (InoLab) and its value was obtained to be 1.0μS/cm. results of Tio2 powder XRD(Siemens , D500) conforming to production standard indicate anatase structure(figure 1).

Deposition was done with an alternate current generator signal with a signal amplifier in order increase outlet voltage. Inlet voltage was measured by a voltmeter. In order to ensure correct connections in circuit and perform deposition process, ammeter was placed serially in the circuit.

More explanation about ACEPD cell was given in other articles. Deposition with voltage of 40 volts was done for 10 minutes in different frequencies between 0.01 and 10000 Hz. In order to study mechanism of the deposited samples behavior in different frequencies, SEM images were studied. [10]

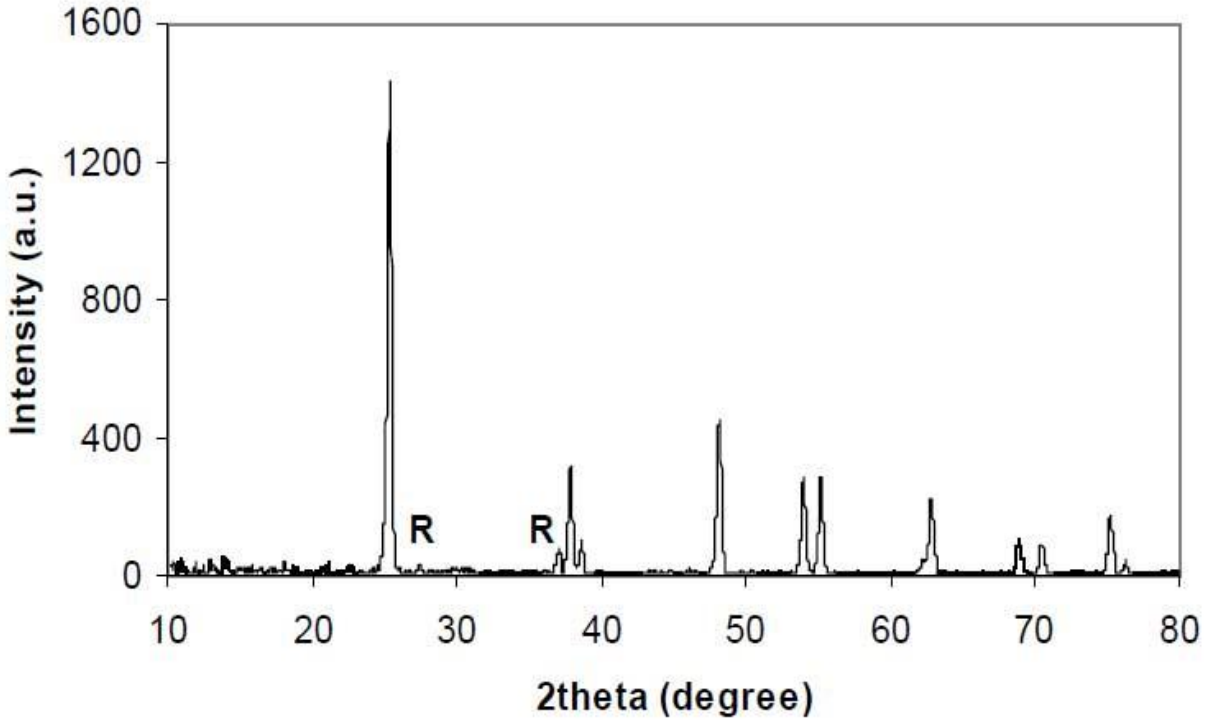

Figure 1. XRD model of Tio2 nano size powders used for deposition

3. RESULTS AND DISCUSSION

When nanoparticles are placed between two flat parallel electrodes under AC electric field, Particles move due to different forces.[11] Due to electrophoresis phenomenon, particles move in direction of field while particles can move under other forces in different directions by applying AC particles field. In addition to electrophoresis, two phenomena effective on motion of particles in frequencies lower than 100 KHz are Dielectrophoresis and motion due to fluid flow. Phenomenon of dielectrophoresis occurs due to nanoparticle polarization in the field and causes motion of articles in direction perpendicular to direction of the field. This phenomenon causes motion of particles to close edges of two electrodes and filling of their distances. [12]

After establishing field around two flat parallel electrodes, a tangent field on inducted double layer opposite to surfaces of two electrodes is created. As a result, this tangent field experiences charged particles and ions in double layer of a force from the edge to surfaces of the electrodes. This mechanism which is called AC electroosmosis leads to movement of fluid perpendicular to edge of two electrodes and to surfaces of the electrodes. [8]

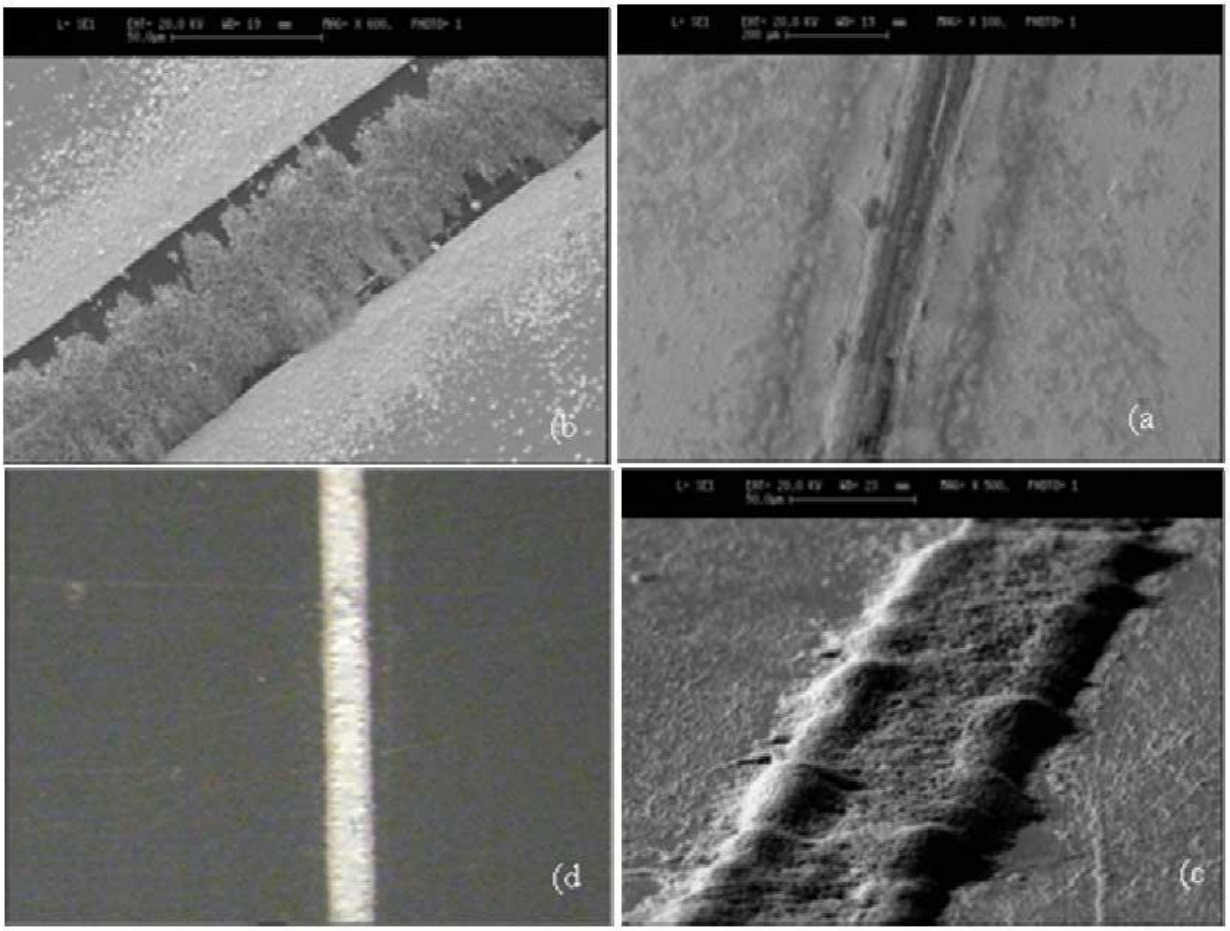

Figure 2. SEM image and stereo optical microscopy of deposited TiO_2 particles wit voltage of 40 volts for 40 minutes in frequency (a (10kHz(d,c 1kHz(b1kHz)

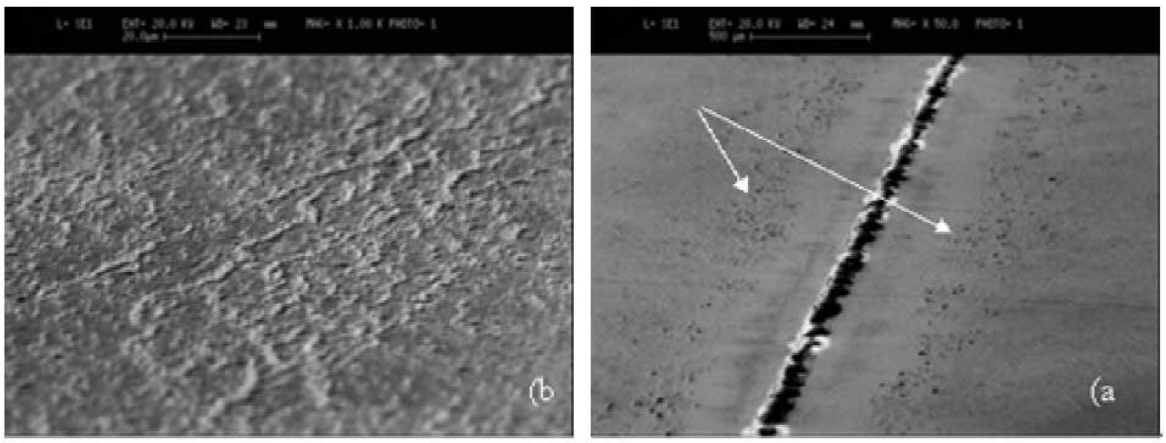

Figure 3. SEM images of deposited TiO_2 particles wit voltage of 40 V for 10 minutes in frequency of 100Hz

Electron microscopic images and stereo optical microscope images of deposited TiO_2 particles in different frequencies are shown in figures 2 and 3. As seen in figure 2, when deposition frequency

increases from 1 to 10000 Hz, form and manner of particles disposition are different. With increase in frequency, fewer particles are deposited on two electrodes due to electrophoresis force and nanoparticles have been deposited only in distance and edge of the electrodes in high frequency. Figure 3 shows electron microscopic images of titanium nanoparticles deposition in frequency 100 Hz. As shown above, continuous deposit of nanoparticles is not formed on electrodes like frequency 1Hz. In addition to address layer in gap of two electrodes and around edge of the electrode, a band of deposited particles is seen far from edge of the electrode.

Wavelike deposition of these particles due to motion of fluid is shown in figure 3(b). For more study of nanoparticles disposition, weights of the deposited particles were compared with each other . as shown in Figure 4, when frequency increases, this value decreases so that it is not measurable in frequency of 10 kHz. Electric current intensity in terms of time and impedance in zero time is given in Figure 5 for different frequencies. With elapse of time in different frequencies, intensity of electric current falls. This is due to formation of double layer and insulated layer resulting from deposition of nanoparticles on electrodes. As given in cell primary impedance curve in terms of frequency, impendence rate decreases when frequency increases. This is due to decreased effect of double layer formation when frequency increases which is given in other reports. Current intensity curve in terms of time in frequency 10 kHz shows that when time increases, current intensity increases. [13, 14] This is due to filling of gap between two electrodes with nanopowders and helping more polarization between two electrodes in high frequency.

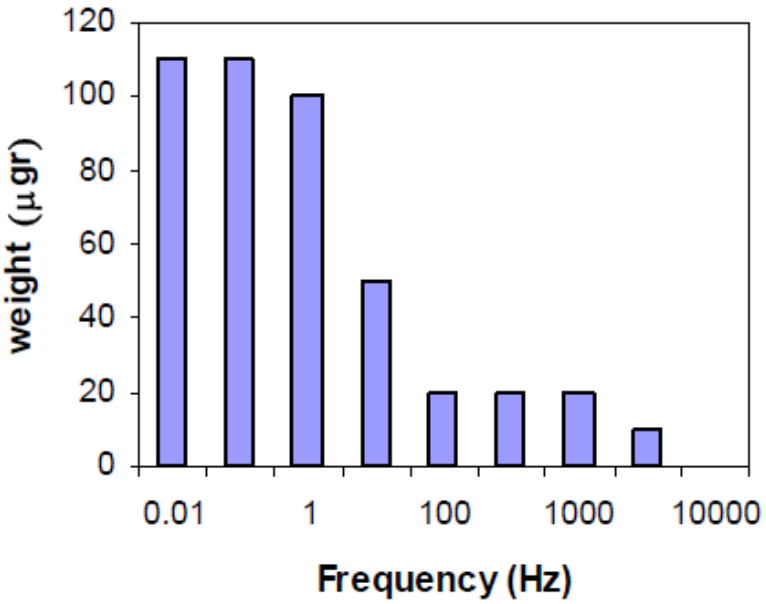

Figure 4. Diagram of deposited particles weight in different frequencies

In this deposition method, reaction of particles to AC field has important role in deposition of the particles. The distance travelled by particles dependent on AC electric field and viscose delay force can be basis of motion and deposition of the particles on the basis of their size, shape, surface

properties and composition. Time of particles motion in each half cycle of field is specification of each particle which is different for particles with different sizes. As result, ability of this method to control, separate and even deposit the particles on the basis of the fluid speed so that we can control it by designing the field with the desired shape and intensity.[15, 16, 17] The results show that when parameters effective on the applied electric field such as frequency are changed, we can apply desirable effects on nanoparticles deposition behavior and centralize nanoparticles in the related places with electric field or deposit them on the surface due to fluid motion.

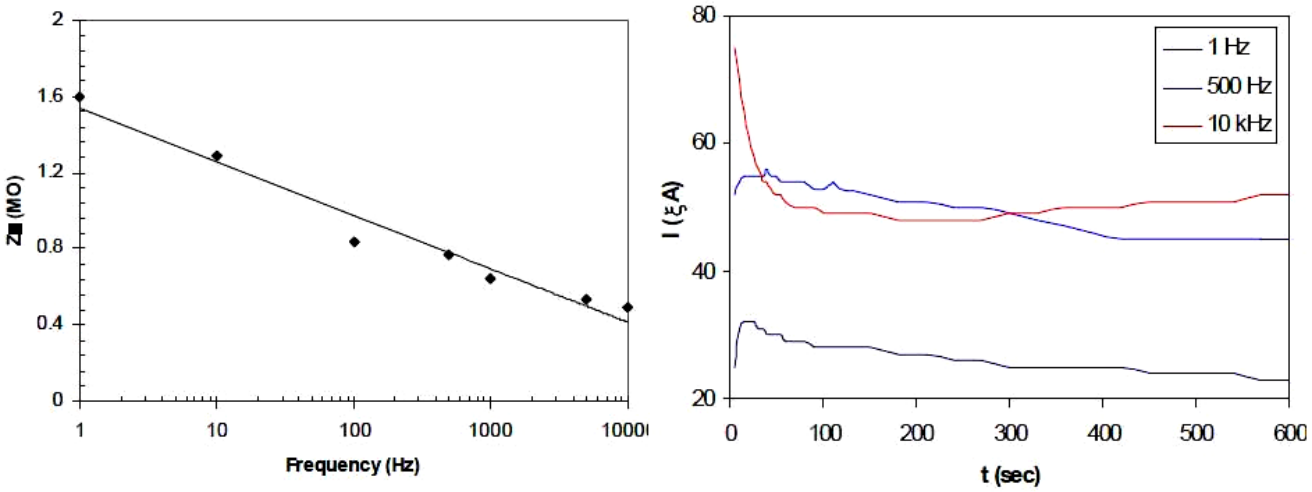

Figure 5. Diagram of electric current in terms of time and impedance in zero time in different frequencies

4. CONCLUSION

Deposition method was applied with AC for covering electrodes with TiO_2 nanoparticles. It was shown that when electric field frequency changes in deposition process, deposition of the nanoparticles will change and deposition behavior depends on frequency. This phenomenon is due to relationship between size and particles displacement in environment and this displacement depend on electric field value and fluid resistant force. Therefore, this method can be applied for deposition of nanoparticles in different forms by changing the applied parameters such as frequency.

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