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Measurement of the Zeta Potential of Planar Surfaces With a Rotating Disk

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The technique of the rotating disk was used to measure the zeta potential of planar surface of different materials, like minerals, polymeric materials, and films of paints and particles. This technique is simple and reliable from the experimental point of view. The results are discussed concerning the principles of the technique, the rheological characteristics and the applications of these materials.

Keywords: *zeta potential, rotating disk, planar surfaces, film of particles*

1. Introduction

Every surface of a material has a tendency to adsorb electric charges. The electrical state of a surface depends on the spatial distribution of free charges in its neighborhood. This distribution is usually idealized as an electrochemical double-layer. The views of the electrical double-layers are based on a physical model in which one layer of the double-layer is envisaged as a surface charge attached to the solid surface, while the other layer is distributed more or less diffusively in the liquid in contact with the solid. This layer contains an excess of counterions, opposite in sign to the fixed charge, and usually with a deficit of co-ions of the same sign as the fixed charge. Counter and co-ions in the immediate contact with the surface are said to be located in the Stern layer, and form with the fixed charge a molecular capacitor. Ions farther away from the surface form the diffuse layer or Gouy layer. The electrokinetic potential, or zeta potential, is the potential drop across the mobile part of the double-layer, which is responsible for electrokinetic phenomena[1]. The radial electrical current produced by the ions in the mobile part of the double-layer in the vicinity of a rotating disk immersed in a fluid with electrical charges is proportional to

$$\varsigma = \left[z \cdot \frac{\partial \varphi}{\partial z} \right]_0^\infty - \left[\varphi \right]_0^\infty \quad (1)$$

where ζ is the zeta potential, φ is the electric potential, and z is the distance along the axis of a rotating disk[2]. The surface of the disk is made of the material being measured. Equation 1 is the electric potential drop across the double-layer due to the dipoles formed by the mobile charges near the surface because of the separation between positive and negative charges as a consequence of the preferred adsorption of charges at the surface of the material. If negative charges are adsorbed, the zeta potential is negative and vice-versa.

The zeta potential is of great scientific and technological importance in many fields, like nanotechnology, biology, food, ceramic, and ore processing. It has a strong correlation with the development of biochemical and physicochemical processes at the surface of materials. The technique of the rotating disk is a new procedure to measure the zeta potential of planar surfaces. It is simple and reliable from the experimental point of view.

This paper presents the results of the measurement of the zeta potential with a rotating disk as a function of pH of planar surface of some materials of general use in our society. A discussion based on the results of these measurements is also presented.

2. Materials and Methods

The zeta potential was measured with the ZetaSpin of the Zeta-Metrix, Inc., developed by P. Sides and collaborators[2].

2.1. Sample preparation

2.1.1. Paints

A film of commercial acrylic paint without pigments (Suvinil® Acrilic Premium, base C) was applied on the surface of a 2.54 cm diameter disk of polycarbonate. The application was made by dropping the paint with a glass stick on the surface of the disk. The disk was screwed in the rotor of the zeta meter and rotated at 1000 rpm during 15 minutes to obtain a dry and uniform film of paint. Another film of paint with the addition of 2.6 grams of black tourmaline powder per liter of paint (from the dravite-schorlite series, 12000 Mesh) was also prepared in the same way. After drying, the disks were immersed in de-ionized water up to the position of measurement. The rotation of the disk followed a sinusoidal pattern from zero to 4000 rpm. The electric conductivity and the streaming potential were measured for calculation of the zeta potential. The pH was controlled by titration with solutions of 0.05 M of HCl or KOH.

2.2. Plastic materials

A disk of 2.54 cm diameter of PET (polyethylene terephthalate) was cut from a bottle of mineral water. A disk of 2.54 cm diameter of HDPE (high density polyethylene) was cut from of a food bag. A disk of 2.54 cm diameter of PVC (polyvinyl chloride) was cut from a butter package. A disk of 2.54 cm diameter of PP (polypropylene) was cut from a package of flavored sugar candies. All these samples were

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post-consumption. The disks were fixed to the polycarbonate rotating disk face with a double sided adhesive tape. The surfaces of the disks were cleaned with water and detergent, washed with de-ionized water, dried with hot air, cleaned with ethylic alcohol, and dried with hot air before immersion in de-ionized water for measurement. The zeta potential was measure according to the above procedure.

2.3. Minerals and glass

A disk of 2.54 cm diameter of black tourmaline (dravite-schorlite series) was cut, polished up to 1 µm diamond paste, and fixed to the polycarbonate rotating disk with a double sided adhesive tape. The tourmaline surface was washed in ultrasonic bath with de-ionized water before immersion in de-ionized water for measurement. A disk of 2.54 cm diameter of mica was fixed in the same way to the rotating disk. The surface of the mica was prepared by removing a sheet with an adhesive tape. A disk of the same size of agalmatholite with inclusions of black tourmaline was cut, polished, cleaned as above, and fixed in the rotor as the rotating disk. All measurements were performed in de-ionized water and the pH was controlled by tritation with 0.05 M solutions of KOH or HCl.

A water suspension of black tourmaline powder (12000 Mesh) was poured in the face of the disk with a double sided adhesive tape. After drying at 120 °C during 30 minutes a uniform film of particles was produced on the surface of the tape. The disk was immersed in de-ionized and rotated at 4000 rpm during 1 minute to assure the adhesion of the film. The uniformity of the film after this procedure was observed with a magnifying glass. The zeta potential of the film was measured according to the above procedure.

A disk of 2.54 cm diameter of borosilicate glass was cut from a laboratory plate, fixed to the rotating disk with a double sided tape, and cleaned as above. The zeta potential was measured according to the same procedure.

3. Results and Discussion

3.1. Paints

Figure 1 shows the results obtained for the zeta potential of films of paints. One observes that the isoelectric point is altered by the addition of tourmaline powder in the paint. The lower isoelectric point of the paint with tourmaline in relation to both the paint without tourmaline and the film of tourmaline particles suggests a strong interaction of the tourmaline particles with the paint. Houchin also observed that tourmaline particles can adsorb a large amount of ions on their surfaces[3]. This fact may be related with the observation that the addition of tourmaline powder in acrylic paints can hinder the growth of bryophytes on the surfaces of external walls. The lower pH of the isoelectric point presumably reduces the ability of microorganisms to adhere to the surface of the wall that is necessary for the development of the bryophytes. The bryophytes can destroy the sheet of paint in a few months in regions of high humidity. Tourmaline

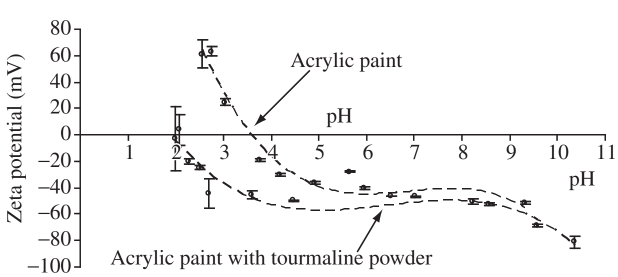

Figure 1. Zeta potential of films of acrylic commercial paints.

is being considered as a non-toxic additive for paints to hinder the growth of bryophytes. Notice that the variation of the zeta potential with pH below 5 of this film of paint with tourmaline is very similar to the one of borosilicate glass shown in Figure 4. Bryophytes do not growth on borosilicate glass surfaces.

3.2. Plastic materials

Figure 2 shows the results obtained for PP, PET, HDPE, and PVC. These materials are of general use as food and beverage packages. One observes that the behavior of the zeta potential as a function of the pH is very similar for these materials. On the other hand, this similarity makes it difficult to separate them by flotation when it is necessary to control the surface of polymeric particles for recycling. This problem could be addressed with the control of the zeta potential.

3.3. Minerals and glass

Figure 3 shows the results obtained for tourmaline. One observes that the film of particles has values of the zeta potential about half the values of the tourmaline disk. This is probably due to the higher roughness of surface of the film, which produces a longer path for the mobile charges in their outward movement to the edge of the disk. The roughness of the surface of the rotating disk was not considered in the calculation of the zeta potential. The isoelectric point is at pH = 4. Houchin[3] observed dissolution of tourmaline for pH lower than 4. It seems that the layer of negative ions that adheres to the surface of tourmaline has a role in protecting it from acid attack (pH between 4 and 7). In the case of particles, these results show that for pH = 8 or higher it is possible to obtain a stable aqueous suspension of tourmaline particles. This fact could be verified for the powder used to produce the film. The relative low zeta potential as compared to glass or mica could be explained by compensation of the permanent electric field near a particle of tourmaline because of its pyroelectricity. Jiang et al.[4] established the adsorption characteristics of heavy metal

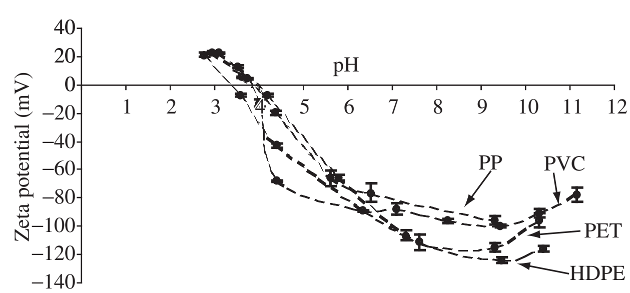

Figure 2. Zeta potential of planar surfaces of plastic materials.

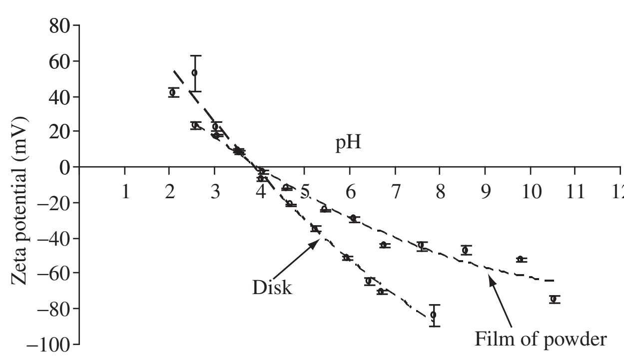

Figure 3. Zeta potential of a disk and a film of particles of black tourmaline.

ions on the surface of tourmaline particles. The adsorption increases strongly with the pH. The results of the zeta potential measurements suggest that the positive heavy metal ions are attracted by the layer of the negative ions that adhere to the surface of tourmaline for pH higher than 4. Tourmaline is also considered as an adsorbing agent for the removal of heavy metal ions from aqueous solutions (Cu^{2+}, Pb^{2+}, Zn^{2+}, and Cd^{2+}).

Figure 4 shows the results for mica, glass, and agalmatholite. The mica disk has the more negative zeta potential. The results published by Scales[5] for mica in a solution of 0.1 mM KCl is also shown. The difference between our results and the ones of Scale arises from the different background solutions. Our measurements were performed in de-ionized water. This difference is expected because the zeta potential is inversely proportional to the square root of the ionic strength. Leja[6] also reported similar results for zirconia. The isoelectric point of glass is at pH = 2.1, compared to 3.4 to 4 for the plastic materials usually employed for package of foods. The agalmatholite with inclusions of tourmaline in being considered to produce a mineral additive for paints with antibryophyte properties.

4. Conclusions

The technique of the rotating disk for measurement of the zeta potential of planar surfaces can give important insights in the application of different materials. The addition of black tourmaline powder can alter the isoelectric point in de-ionized water of a film of acrylic paint from pH = 3.5 to pH = 2.0. This fact suggests a strong interaction of the dispersed tourmaline particles with the paint. The zeta potential in de-ionized water of plastic materials of general use (PET, HDPE, PP, and PVC) is very similar in the range pH = 3 to pH = 10. The zeta potential as a function of pH of a film of particles of black tourmaline in de-ionized water was used to obtain a stable aqueous suspension of tourmaline particles. A comparison of the results of the measurement of the zeta potential between a polished disk and a film of tourmaline particles suggests that the roughness of the surface of the rotating disk should the taken into account in the calculation of the zeta potential.

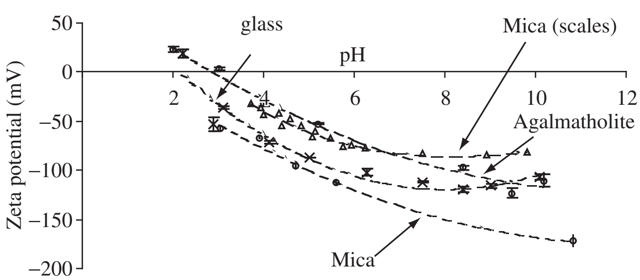

Figure 4. Zeta potential of disks of mica, glass and agalmatholite.

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References

1. Everett DH, Koopal LK. Manual of Symbols and Terminology for Physicochemical Quantities and Units. Appendix II. Definitions, Terminology and Symbols in Colloid and Surface Chemistry. Part I. Washington DC, USA. Available from: <http://old.iupac.org/reports/2001/cooloid_2001/manual_of_s_and_t>. Acessed on 2008. April. 8.
2. Sides PJ, Newman J, Hoggard JD, Prieve DC. Calculation of the Streaming Potential near a Rotating Disk. *Langmuir* 2006; 22(23):9765-9769.
3. Houchin M R. Surface studies on aqueous suspensions of tourmaline (dravite). *Colloids and Surfaces* 1986; 19(1):67-82.
4. Jiang K, Sun T, Sun L, Li H. Adsorption characteristics of copper, lead, zinc and cadmium ions by tourmaline. *Journal of Environmental Sciences* 2006; 18(6):1221-1225.
5. Scales PJ, Grieser F, Healy TW. Electrokinetics of the Muscovite Mica-Aqueous Solution Interface. *Langmuir* 1990; 6(3):582-589.
6. Leja J. Surface Chemistry of Froth Flotation. New York: Plenum Press; 1982. p. 205-339.