

Non-aqueous zeta potential measurements of carbon black powders



PARTICLE SIZE



ZETA POTENTIAL

Introduction

Carbon black nanopowders are widely used in many industrial fields, including ink, paint, and coating applications; asphalt sealants and decorative concrete colorants; textiles and conductive/resistive applications. There are several applications in which the carbon black has to be dispersed in non-aqueous media. There has been much effort spent, mostly based on empirical formulation, in finding the best medium to disperse carbon black particles to minimize the presence of aggregates. For different dispersion media, besides the molecular structural differences, one parameter that relates the charge transfer capability, and therefore the surface charge of dispersed particles, is the dielectric constant. A systematic way to find the best medium for the dispersion of carbon black particles is to measure its zeta potential, as well as its particle size in media of various relative permittivities.

Non-Aqueous Zeta Potential Measurement Considerations

The measurement of the zeta potential of non-aqueous suspensions is challenging. The electrophoretic mobility of particles is directly proportional to the relative permittivity of the dispersion medium and hence for non-aqueous dispersants, the mobilities and hence frequency shifts will be very small. Phase analysis light scattering (PALS) has extremely high sensitivity ($10^{-12} \text{ m}^2/\text{V.s}$) suitable for the detection of very small particle velocities, and has been shown to be very suitable for measuring electrophoretic motion in non-aqueous suspensions [1,2]. An appropriate measurement cell is also required to make successful non-aqueous measurements. The Zetasizer Nano has a universal dip cell accessory capable of generating high field strengths at low voltages with excellent solvent compatibility.

Experimental

For this study, a carbon black standard test powder (JIS Z 8901) was obtained from the Association of Powder Process, Industry and Engineering, Japan with a specified size distribution of 0.03 – 0.2 micron. It was dried overnight in an oven prior to use and dispersed in the following organic solvents: toluene, decane, chloroform, trichloroethane, tetrahydrofuran, butan-2-one and propan-2-ol. Powders were dispersed in solvents at 0.1% w/v concentration by bath ultra-sonication for 3 minutes, then left overnight prior to being measured. The solvents used were pure and obtained from Wako and Nacalai Tesque Japan and had relative permittivities ranging from 4.8 to 19.2 respectively.

When the dispersions achieved were sufficiently stable, measurements were performed on a Malvern Zetasizer Nano ZS in conjunction with a universal dip cell accessory [3]. At least three repeat zeta potential measurements were made on each sample. In addition, particle size measurements were made using the dynamic light scattering (DLS) capability of the Zetasizer Nano ZS in order to confirm the colloidal state of the particles, and in both instances measurements were made at 25°C.

Results and Discussion

For non-aqueous solvents, the mechanisms by which surface charge is generated, the structure of the electrical double layer and the meaning of the hydrodynamic plane of shear are not well understood and have not been widely studied [4]. Possible charging mechanisms in non-aqueous media include the presence of trace water in the solvent, [5,6] acid–base interactions between a charging agent and the particles, [7,8], acid–base or Lewis acid–base interactions between the solvent and the particles [8,9] and the presence of impurities in the solvent.

Figure 1 summarizes the zeta potential and particle size measurement results obtained from the carbon black powder dispersed in media with different relative permittivities. Measurement results could not be obtained in the pure solvents with the lowest relative permittivities (toluene = 2.4 and decane = 2.0) since the dispersions were unstable and the carbon particles aggregated and sedimented overnight in these non-polar solvents. For the other solvents, data are displayed using relative permittivities as the ordinate, where the measured electrophoretic mobilities were converted into zeta potentials using Hückel's approximation. The sizes reported are the intensity-weighted mean diameter as defined in ISO13321 [10]. Two media with the same relative permittivities were used; trichloroethane and tetrahydrofuran and these produced oppositely charged zeta potentials. The halogenated solvents used in this study (chloroform and trichloroethane) resulted in positive zeta potential values which suggests that the carbon particle charge arises through a Lewis acid–base interaction between the particle surface and the solvent.

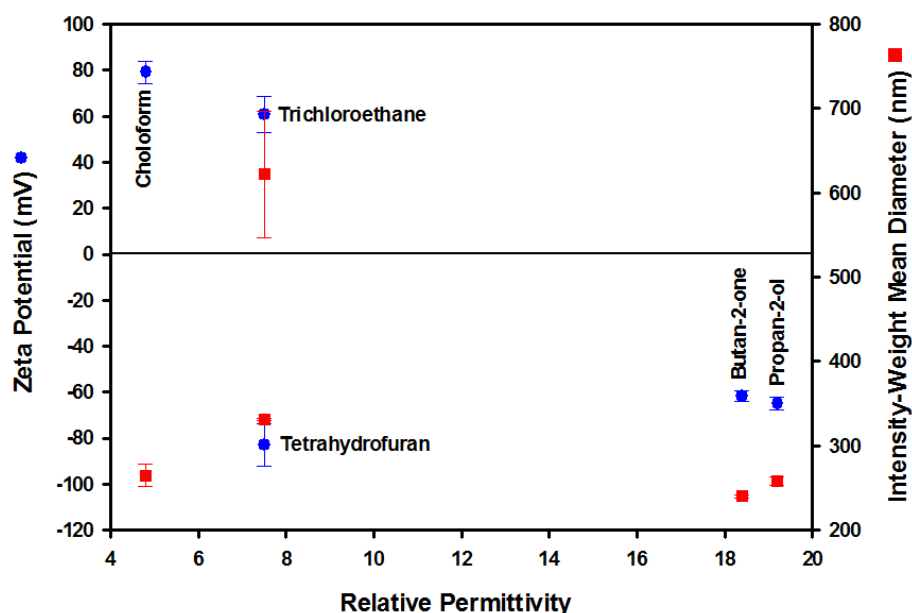


Figure 1. The variation of the zeta potential and intensity-weighted mean diameter of carbon black nanopowder dispersed in a variety of non-aqueous solvents with different relative permittivities

The data in figure 1 indicates that, in this case, optimizing the dispersion in non-aqueous media is related to the relative permittivity and the Lewis acid base character of the solvent. The size and zeta potential information contained in figure 1 allows optimum dispersants for the carbon black powder to be selected. Stable suspensions with small particle sizes were achieved in chloroform, tetrahydrofuran, butan-2-one and propan-2-ol where the intensity-weighted mean diameters were between 240 and 330nm respectively. These low size values were associated with significant zeta potential means (both negative and positive in sign) suggesting that simple electrostatic stabilisation mechanisms can exist in non-aqueous solvents.

Conclusions

The results summarized in this application note show that successful zeta potential measurements can be made of carbon black powders dispersed in non-aqueous solvents. Zeta potential in combination with size measurements can be used to study and predict their dispersion stability.

References

- [1] J.F. Miller, K. Schätzel, B. Vincent (1991) *J. Colloid Interface Science* 143, 532.
- [2] J.F. Miller, O. Velev, S.C.C. Wu and H.J. Phloehn (1995) *J. Colloid Interface Science* 174, 490.
- [3] <http://www.malvern.com/zetasizer>

- [4] R. Xu. et al (2007) *Carbon* 45 (14) 2806.
- [5] J. Goodwin, F. McDonald, P.A. Reynolds (1988) *Colloids and Surfaces* 33, 1.
- [6] A. Kitabara, M. Amano, S. Kawasaki, K. Kon-No (1977) *Colloid and Polymer Science* 255, 1118.
- [7] F.M. Fowkes, H. Jinnai, A. Mostafa, F.W. Anderson, R.J. Moore (1982) *A.C.S. Symp. Ser.* 200, 307.
- [8] Ph.C. Van Der Hoeven and J. Lyklema (1992) *Advances in Colloid and Interface Science* 42, 205.
- [9] A.V. Delgado, F. Gonzalez-Caballero, R.J. Hunter, L.K. Koopal, J. Lyklema (2005) *Pure Appl Chem* 77, 1753.
- [10] International Standard ISO13321 (1996) Methods for Determination of Particle Size Distribution Part 8: Photon Correlation Spectroscopy, International Organisation for Standardisation (ISO).



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