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Advances in Applied Science Research, 2011, 2 (2): 140-145

ISSN: 0976-8610
CODEN (USA): AASRFC

Investigation of time dependences of random force in various colloidal suspension exhibiting Brownian movements in the Markoffian approximation

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ABSTRACT

The present work describes the nature of Brownian movement exhibited by colloidal suspensions. In the experiment we have used 5mW He-Ne laser light at 6328Å and also Ar^+ laser light (green) to illuminate a sample cell containing the liquid with colloidal suspensions of medicinal plants Alpine allughas, Murraya Koenigii(Linn), leucas cephalotes .The intensity fluctuations of the Brownian movements are measured with the help of silicon photodiodes placed at particular positions and connected to a sensitive digital multimeter. The readings are recorded with the help of a video camera [Model DCR-TRV 460 E Sony].The records of the fluctuations are taken for about two minutes and are transferred to a computer by USB cable. The fluctuating patterns per second are worked out with the help of a computer and they indicate the nature of particular colloidal suspensions. The intensity fluctuating patterns per second also exhibit the time dependence of the random force $F_v(t)$ which are characteristics of Brownian motion.

Keywords: Brownian movement.

INTRODUCTION

Many optical patterns in nature are irregular and fragmented while they exhibited a high degree with different level of complexity. Therefore, Mandelbrot (1977)[1] terms this family of irregular shapes as fractals. If a colloidal suspension is viewed with a special microscope, the dispersed colloidal particles appear to move in a zigzag and random motion through the dispersing medium. The special microscope consists of a regular microscope focused on the colloid suspension with a strong light source at right angles to the colloid and it is viewed against a black background. What are actually seen are reflections from the colloidal particles. The erratic and random motion of the dispersed colloidal particles in the dispersing medium is due to bombardment of the dispersed colloidal particles in the medium, creating a zigzag, random motion. Since this refection of light is due to the colloidal particle's size, no such motion is seen in a common solution: though, the solute and solvent particles are in continuous random motion. This motion effects the colloids in motion due to bombardment and this is the reason why the colloidal particles don't settle out on standing .The dispersed colloidal particles remain suspended indefinitely. This effect is named after the English botanists Robert Brown (1773-1858) who first observed it with cytoplasm granules in pollen grains. Such motion is also observed in living organism such as in algae and bacteria.

It was Raman[2] who introduced a technique to observe Brownian movement in colloidal suspension without a microscope. Einstein[3] first worked out in the problem of damped harmonic oscillator for Brownian motion and the so called Einstein relation of Brownian motion is probably applicable to Markoffian systems[4].Langevin also suggested similar treatment of Brownian movement and showed how the damping and diffusion terms in Brownian movement are related. As is well known, the individual particles in colloidal suspensions and emulsions execute Brownian Movements which are most lively when the particles are very small and are suspended in an non- viscid fluid. For this purpose it is necessary to select a substance in which the particles are of fare size so that the coronal disc is of sufficient intensity and also exhibits visible structure. The advent of laser as and intense source of monochromatic radiation has helped us to observe this phenomenon of Brownian movement or speckle patterns without a microscope.

In the present work we shall set out the results of the studies carried out on the fluctuating patterns exhibited by a number of colloidal suspensions of medicinal plant leaves when illuminated with the help of a 2mW He-Ne laser radiation (6328Å).These colloidal particles are analogous to nano particles.

MATERIALS AND METHODS

Experimental

We have used a 2mW He-Ne Laser (6328Å) to illuminate a sample cell of dimensions 1cm x1cm x 6cm containing the particular colloidal solution in a suitable solvent. The beam is allowed to be incident at a point which is at middle of the cell. The image is projected at a distance of 2 meters from the cell. By suitably adjusting the position of the cell one can observe fluctuation patterns within an area of .045 sq. mtrs of the projected image. There are few salient features of this fluctuation. We may classify those under three categories (a) Oscillatory pattern, (b) Fluctuation pattern where the oscillation increases as one proceed from the central line, (c) Minimum fluctuating pattern or nearly stationary patterns.

These three patterns characterized the Brownian movement. To study the three categories we have used a photodiode connected to a digital multimeter. A Video camera [Model DCR-TRV 460E SONY] is used to record the fluctuation in the form of current. The photographs of the fluctuations have been taken for about 2 minutes and the record is transferred to a computer by USB cable. It may be noted that the photo diode has been placed at different points of the projected image to measure intensity at different regions. The intensity fluctuation per second has been worked out with the help of the computer. Fig 1 shows the experiment arrangement of block diagram, Fig 2 (a,b) shows the fluctuating patterns from the different colloidal suspensions, Fig 3 (a,b,c,d) the fluctuation of intensity recorded in this way.

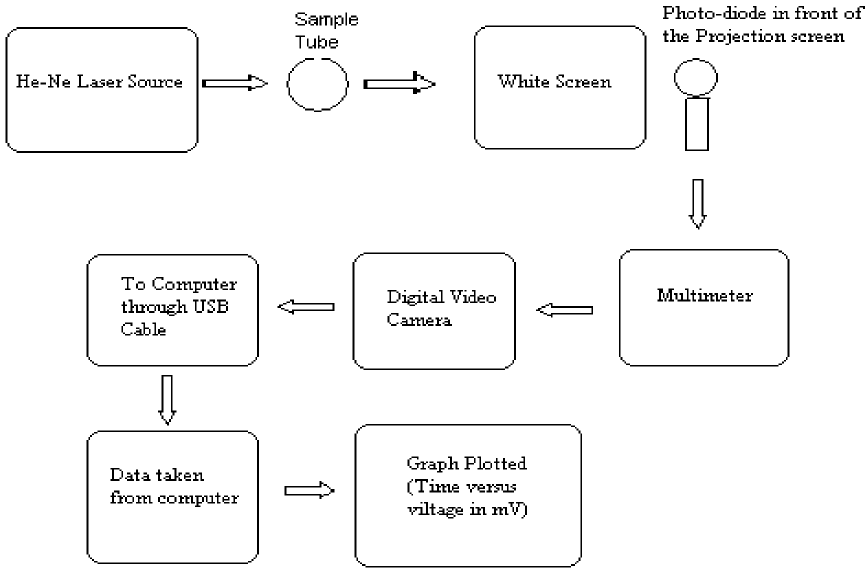
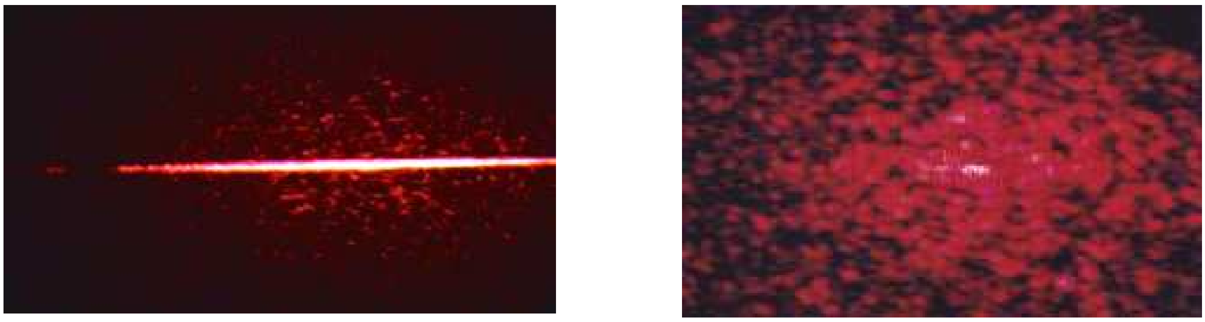
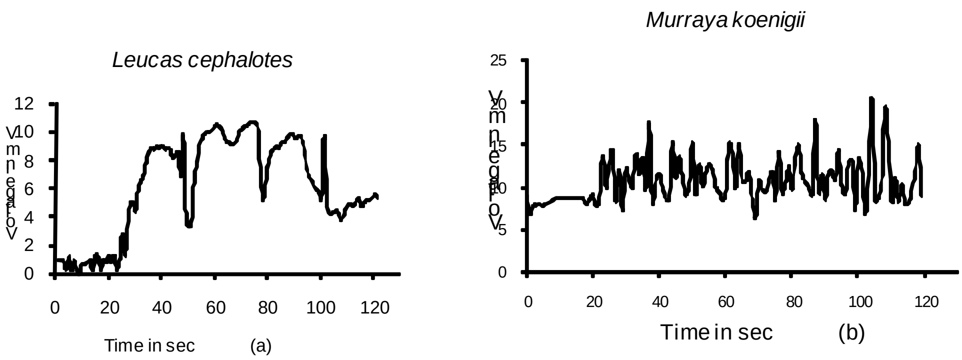


Fig 1 The block diagram of the experimental arrangement



(a) (b)

Fig 2 (a,b) shows the fluctuating patterns from the different colloidal suspensions



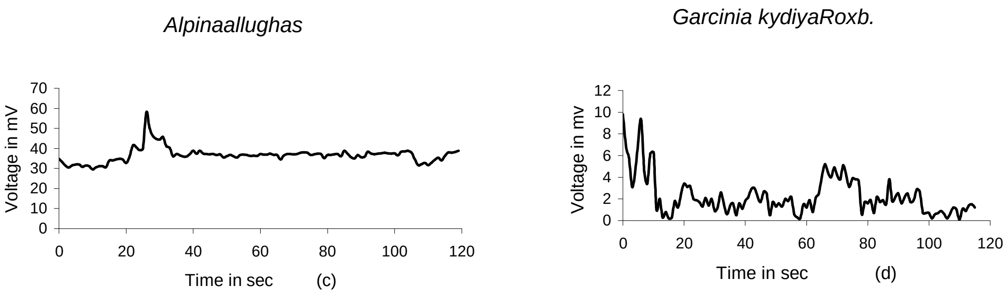


Fig 3: Fluctuation intensity of the Brownian pattern for
(a) *Leucas cephalotes (b) Murraya koenigii(Linn.) (c) Alpinaallughas (d) Garcinia kydiyaRoxb.*

As regards the size of the colloidal particle used in the present experiments it is worthwhile to indicate here that the particles are of different sizes and shapes. Therefore whatever is observed on the projected screen is the manifestation of a large number of colloidal particles of different sizes. It is possible to estimate the relative sizes of these particles with the help of a simple technique based on geometry. Assume that a colloidal particle is located at one side of the test tube and at a distance of 0 .1cm from the surface of the tube of diameter 0 .7 cm and the He-Ne laser source as a point source incident on the surface of the test tube. We find that the linear size of the image projected on a screen at a distance of 500 cm from the tube is 0.1cm. If the size of the actual colloidal particle is x then using simple trigonometry relation, we find that x = 2000Å .The size of the colloidal particle estimated in this way is slightly higher than the usual size found in literature which is in between 10 Å to 1000 Å. The colloidal particles can consist of one huge molecule, such as starch molecule, or aggregates of many molecules. Using the same procedure one can obtain information about the size of the colloidal particles in the range 100Å - 3000Å. As for example assuming the actual size of the projected image as .01cm we observe that the size of the colloidal particle is about 200Å.We must indicate here that the observation are in the present work may throw sufficient light on the nature and behavior of nano systems, involved in the present case.

RESULTS AND DISCUSSION

The primary aim of the experiment is to examine the Brownian pattern observed for different colloidal solution containing medicinal plants species. Visual observations do indicate the differences in the fluctuating pattern. It is worthwhile to note that the oscillatory pattern occurs at the projected image and these occur at the beginning of the experiments. We have seen that when the colloidal solution is made it is immediately transferred to the sample cell and when the beam is incident on the sample cell there is a fast movement of the speckle pattern and after 10 sec the movement slows down and it starts exhibiting fast movement again. There is some short of relaxation oscillations and it continues for sometime. The time interval between two oscillation increases in subsequent cases. This indicates some short of damping being introduced. Survey of available literature indicates that such type of relaxation oscillation in usual Brownian movement has not been reported yet. But it is to be noted that this is a characteristic features of the colloidal solution. The relaxation oscillation is strikingly demonstrated when the sample solution is *Saccharum officinale* while this is not the case with other solutions. As for example in the case of *Averrhoa-carambola-linn* solution relaxation oscillation are not so prominent. Colloids bridge the gap between solutions and suspensions. In colloids the particles are dispersed without appreciable bonding to solvent molecules, and they do not settle out on standing. In discussing solutions, we speak of solutes and solvents, but in discussing colloids, we use the terms "dispersed particles" (dispersed phase). The dispersed phase consists of the colloidal particles, comparable to the solute in a solution. The dispersing phase is the substance in which the colloidal particles are distributed, comparable to the solvent in a solution. As may be inferred from Fig.2 (a,b), the fluctuating pattern shows considerable different from colloid to colloid. We have measured the intensity of the fluctuation with the help of a photodiode and as may be seen from Fig.3 (a, b, c, d) the intensity patterns recorded at every second shows the time dependence of the random force F_V(t) which is characteristic of Brownian motion. It is worthwhile to describe the nature of the fluctuating force on a particle which obeys the Newton's second law of motion (for each Cartesian component).Langevin treatment[4] of Brownian motion is based on this fluctuating force. A suspended particle obeys the equation

$$\mathbf{m}\dot{V} = \mathbf{F_{ext}\,(t) + F_{res}(t)} \qquad \textbf{(1)}$$

where m is the mass of the particle ,
v is the component of velocity,
$F_{ext}(t)$ represent the external forces,
$F_{res}(t)$ is the force exerted by the liquid reservoir

The second force damps the movement of the particle, as well as causing it to jitter about in Brownian motion. The damping component must clearly be proportional to some combination of powers of v since it vanishes for zero velocity. Experimentally it has been found that the first power suffices for many problems of interest [5]. Hence we set

$$\mathbf{F_{res}(t) = -m\Gamma\langle v\rangle + F_v(t)} \qquad \textbf{(2)}$$

where $F_v(t)$ is a random, rapidly fluctuating force with zero ensemble average:

$$\mathbf{\langle F_v(t)\rangle = 0} \qquad \textbf{(3)}$$

In (2), we replace the ensemble average < v> by v in as much as the small fluctuations in v can be neglected in comparison to those of the force F_V (t), Substituting (2) in to one and ignoring the external force $F_{ext}(t)$ we find the Langevin equation:

$$\mathbf{m\,\dot{v}\,(t) = -m\Gamma v(t) + F_v(t)} \qquad \textbf{(4)}$$

The mean motion or "drift" of v (t) is given immediately by (4) with (3):

$$\mathbf{m\langle \dot{v}\ (t)\rangle = -m\Gamma\langle v(t)\rangle} \qquad \textbf{(5)}$$

The average $<[F_V(t)]^2>$ does not vanish since negative swings of $F_V(t)$ yield positive squared values. Suppose that the minimum time in which $F_V(t)$ changes appreciably is called the correlation time τ_c .

The average of the product $F_V(t)F_V(t^/)$ vanishes for $|t-t'| > \tau_c$, since then the product is as likely to be negative as positive. Hence < $\mathbf{F_V(t)F_V(t^/)}$ > is peaked about $t=t^/$ and falls off to zero in a time difference $|t-t'| = \tau_c$ If τ_c is much less than all other times of interest ,for example, 1/Γ in (4) , we can write

$$<F_V(t)F_V(t^/)>=2D_{VV}\,\delta(t-t^/) \qquad (6)$$

where D_{vv} is some constant expressing the magnitude of the fluctuating forces.

When (6) is a good approximation, the system is said to be Markoffian. Our discussion is limited primarily to such systems. The average value of F_V(t) is zero for members of a give point in time are as often positive as negative. The average of F_V (t) is non-zero, since all members contribute positively. We should remember that Brownian motion exhibit behavior which is odd in two respects. First, it is very erratic. These features are exhibited in the experimental curves. Its points are just connected enough to be continuous, but it is by no means smooth. In fact, Brownian motion is so erratic that no hard drawn depiction can do it justice. Secondly, Brownian motion is Markoffian. Where it is likely to be future depends only on its most recent location. It does not build up momentum.

CONCLUSION

Brownian movements provide a useful technique for investigation of characteristic properties of colloidal solutions of medicinal plants. Since the fluctuating patterns of Brownian movements are different for different colloidal samples, they may be used for the study of characteristic properties of medicinal plants.

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