# Characteristic Times of Microsturcture Formation in Electrorheological Fluids, Determined by Viscosity and Speckle Activity Measurements


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**Abstract:**

Viscosity measurements of a suspension of cornstarch in silicone oil, at several concentrations and subject to different electrical field strengths, were conducted. An increase in the apparent viscosity, in correlation with the field strength, which is characteristic of the so-called electrorheological fluids (ERF), was observed. For a given field intensity, the value of the viscosity increases rapidly in the first seconds after the application of the electric field, and then it increases slowly until it finally approaches a saturation value. This behaviour of the apparent viscosity has been related to the microstructure formation due to interactions between dipoles induced by the electric field. Characteristic times, related to structure formation after application of an electric field, are investigated by means of diffuse light transmission and speckle-pattern activity measurements. Two characteristic times were found that should be related to the state of aggregation of the suspended particles: orientation of the non-isotropic particles and later chain formation. These results agree reasonably with that obtained from electrorheological measurements. Microscopic observations of structure formation are also reported.

**Zusammenfassung:**

Viskositätsmessungen einer Suspension aus Stärkemehl in Silikonöl mit mehreren Konzentrationen wurden bei unterschiedlichen elektrischen Feldstärken durchgeführt. Ein Ansteigen der scheinbaren Viskosität mit der elektrischen Feldstärke, das charakterisch für sogenannte elektrorheologische Fluide (ERF) ist, wurde beobachtet. Der Wert der Viskosität steigt bei gegebener Feldstärke in den ersten Sekunden nach dem Einschalten des elektrischen Feldes schnell an, und dann steigt er langsam an, bis er einen Sättigungswert erreicht. Dieses Verhalten der scheinbaren Viskosität wurde in Beziehung gesetzt zur Bildung der Mikrostruktur durch die vom elektrischen Feld induzierten Wechselwirkungen zwischen den Dipolen. Charakteristische Zeiten in Bezug auf die Strukturbildung nach dem Einschalten des elektrischen Feldes wurden untersucht mittels diffuser Lichttransmission und Fleckenmusteraktivitätsmessungen. Zwei charakteristische Zeiten wurden gefunden, die bezogen werden auf den Zustand der Aggregation der suspendierten Partikel: Orientierung nicht-isotroper Partikel und spätere Kettenbildung. Diese Resultate stimmen gut mit Ergebnissen elektrorheologischer Messungen überein. Über mikroskopische Untersuchungen der Strukturbildung wird ebenfalls berichtet.

**Résumé:**

Nous avons effectué des mesures de viscosité obtenues avec des suspensions d'amidon de maïs dans une huile de silicone, à différentes concentrations, et soumises à différentes forces de champ électrique. Nous avons constaté une corrélation entre l'augmentation de la viscosité apparente et la force du champ, ce qui est caractéristique des fluides soit-disant électro-rhéologiques. Pour une intensité de champ donnée, la valeur de la viscosité augmente rapidement, dans les premières secondes qui suivent l'application du champ électrique, puis elle augmente lentement jusqu'à ce qu'une valeur de saturation soit finalement atteinte. Ce comportement de la viscosité apparente a été expliqué par la formation d'une structure microscopique due aux interactions entre les dipôles induits par le champ électrique. Les temps caractéristiques associés à la formation de la structure après l'application d'un champ électrique, ont été obtenus au moyen de la transmission de la lumière diffusée ainsi qu'avec des mesures d'activité de figures de taches. Deux temps caractéristiques ont ainsi été découverts et qui









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behaviour of this curves are different to those obtained in the preceding experiments because the speckle activity reflects the movements of the particles dispersing the light. In the first's stages since the application of the field, the sample contains many particles moving at high speed and a few unstable chains, which cause the fast growing of the activity. As long as the particles aggregate in more stable chains, their speed diminished causing the activity to decrease. Next, as the chains aggregate in columns, its movements diminished progressively until a stationary state is reached. Nevertheless, even at the stationary state, the speckle activity does not cease completely. While the field is applied, small cluster of particles and chains are seen oscillating in various places into the sample. Hence, the speckle activity measurements are correlated with different stages of structure formations.

These results are consistent with those obtained in the transmittance measurements. Comparing Fig. 6 and Fig. 9, it is observed that higher variation of the transmittance and speckle activity, respectively, happens within the first 10 seconds for the same concentration and range of electric field intensities. From ocular inspection of the process, it is observed that within the first 10 seconds the structures are completely developed (Fig. 4D).

## 5 CONCLUSIONS

Electrorheological and optical measurements in presence of an electric field of relatively high intensity were carried out to investigate the dynamics and the extent of formation of microstructures induced by the electric field. This behavior would be closely related to the increment of the fluid apparent viscosity. It can be observed the concordance of results between the two methods used. The first responses to the field are given in the first 2 to 3 seconds, during which the orientation of induced dipoles in the particles by the electric field would take place. Within the first 10 seconds, the alignment of the particles forming chains reaches the electrodes and coalesces into columns. Beyond this time, the structures are completely developed. This indicates that while an initial rapid response to the electric field is obtained, the attainment of a final complete microstructure involves a longer time. It can also be observed that the transmittance from the studied samples depends on the field intensity and on the concentration of the dispersed phase. From the flow mode measurements, the quasi-reversibility of the phenomenon is verified. This means that when the electric field is removed, the viscosity decreases rapidly, but does not return completely to its initial condition.

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