# GRAPHENE NANOFLAKES BASED POLYMERIC PASTES OR GELS FOR MEGA-ELECTROVISCOUS UTILITIES

## IITM Technology Available for Licensing

### Problem Statement

- An **electrorheological fluid** is a colloidal system prepared from **a base fluid and suspended particles** with appreciable **dielectric properties** such that the colloid **responds to an externally applied electric field by showing drastic changes in its viscous properties.**
- Conventionally, the colloidal particle sizes are generally chosen in micron scale ranges such that thermal fluctuations do not disrupt the chain formation of the particles. **Larger particles are avoided so as to prevent long time sedimentation.**
- Adsorption of water on the surfaces of the dispersed particles is preferable from the viewpoint of higher electrorheological properties. However, **presence of water often leads to disruption of function in oil-based systems.**
- There is a **need for electrorheological gel that addresses problems associated with conventional electrorheological fluids** such as concentration of particles, corrosion, sedimentation and issues related to oils and degradability

### Intellectual Property

- IITM IDF Ref.**1282**
- **IN 352112 Patent Granted**

### TRL (Technology Readiness Level)

**TRL 4 Technology Validated in Lab**

### Technology Category/ Market

**Category-Micro & Nano Technologies**
**Industry Classification:**

- **NIC (2008)- 20299** Manufacture of various other chemical products
- **NAICS (2022)- 325** Chemical Manufacturing

**Applications:** The field tunable viscous properties of these pastes can find applications in electrically activated motion sensors/actuators/controllers, electrically activated damping devices at the micro-nanoscale and miscellaneous similar applications such as damping systems for dynamic micro-machinery components, as normal shock absorbers in automotive/ instrumentations etc.

**Market report:**
Global Electrorheological Fluids Market was valued at USD 12 billion in 2022 and is projected to reach a market size of USD 55.14 billion by 2030. with a CAGR of 21%.

### Research Lab

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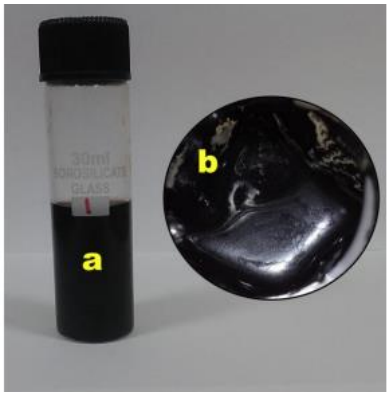


**Figure: Illustration of (a) the preliminary nano graphene water–PEG colloid and (b) graphene nano-gel post synthesis.**

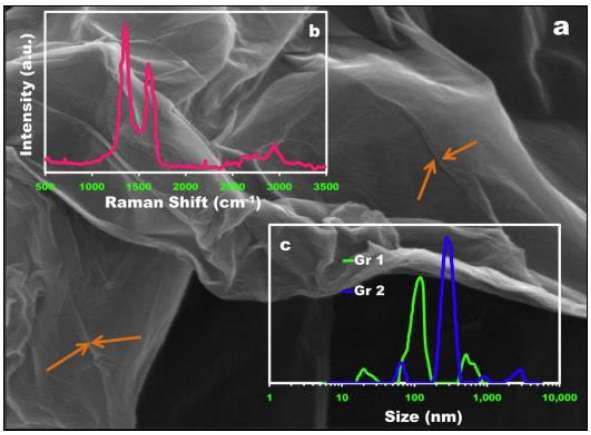


**Figure:** Characterization of the graphene sample utilized in the present case. (a) SEM image of the nano flakes (b) Raman spectra of the Graphene sample (c) DLS spectra of two representative samples.

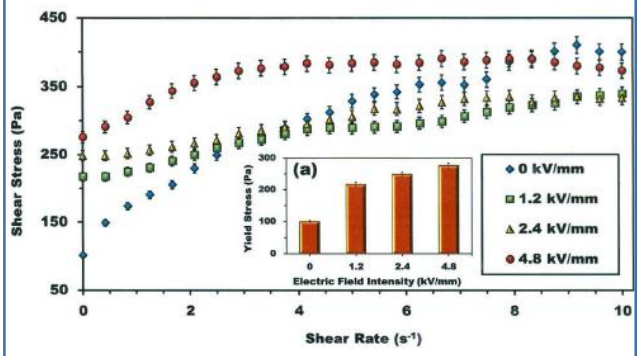


**Figure:** illustrates the electrorheological effects in a Sample with 1 wt. % of graphene in PEG 400. Inset **(a)** illustrates the enhancement in yield stress with electric field strength in the same sample.

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## Technology Transfer Office
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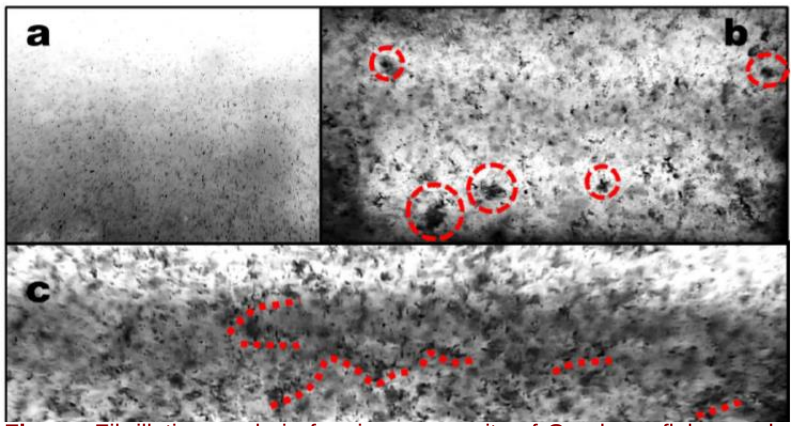


**Figure:** Fibrillation or chain forming propensity of Graphene flakes under the influence of externally applied electric fields. Pictures of ferrography show **(a)** The GNF in absence of field **(b)** the GNF in presence of an electric field of intensity of 0.1 kV/mm and localized grouping/ clustering of the G flakes (illustrated by circles) **(c)** the GNF in presence of an electric field of intensity of 0.2 kV/mm and localized fibrillation is observed (illustrated by dotted lines for guide to the eye). Electro-rheological response occurs due to the resistance to deformation offered due to formation of such fibrils.

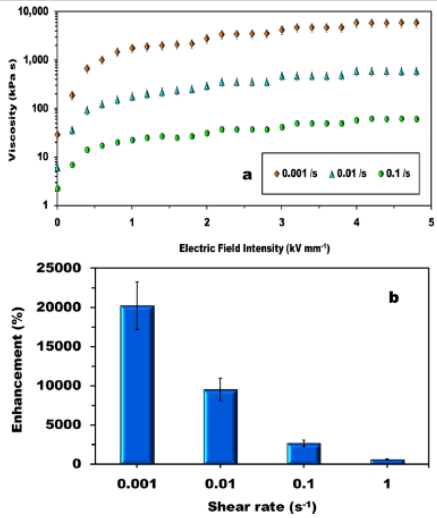


**Figure:** Electroviscous response of a 2 wt. % graphene in PEG 400 **(a)** The response as a function of imposed shear **(b)** The maximum enhancement in viscosity obtained at each shear rate. This sample exhibits mega electroviscous response.

## Technology

**This invention relates generally to electrorheological fluids and in particular to synthesizing graphene-polymer based electrorheological pastes or gels that exhibit electroviscous phenomena ranging from mega to gigantic.**

**Polyethylene Glycol (PEG 400) is mixed with deionized water and the synthesized graphene nano-flakes are added to the solvent-polymer mixture and homogenized to form raw colloids**

**The homogenous raw colloid is heated to a temperature of about 85-95 °C under reflux for about 1-3 hours to yield an intermediate paste or gel.**

**The paste or gel is cooled and held at a reduced temperature for vaporizing water and then cooled to room temperature.**

**The electrorheological paste or gel comprises graphene in a concentration of about 0.5 wt. % to 3 wt. % comprising graphene nano-flakes in a size range of about 50 nm to about 2500 nm dispersed in polyethylene glycol (PEG 400)**

**The electrorheological paste or gel comprising graphene nanoflakes in a size range of about 50 nm to about 2500 nm has a viscosity of about 1 kPa under electrical field of near-zero, increasing to about 250 kPas under electrical field of 5 kV/ mm under shear rates greater than about 0.001 s-1.**

## Key Features / Value Proposition

- The electrorheological paste or gel has a maximum attainable viscosity in the range of about 100 kPas to 180 kPas with increase in actuation time interval from 1 to 2 second. The viscosity of the electrorheological paste or gels reverts back to its original form on removal of the externally applied electric field.
- The lubricating properties of the graphitic systems eliminate the corrosive effects of particles that is observed in conventional electrorheological fluids.
- The invented electro-rheological gel exhibits infinite shelf life and does not have the issue of sedimentation of graphene flakes.
- Handling and removal issues associated with conventional oil-based fluids are also eliminated. The gels of the present disclosure can easily be handled and removed/replaced via washing with water.
- The PEG 400 based graphene gel can be used to obtain highly accurate and controllable electro-viscous effects for utility in dynamic devices and systems at lower particle concentrations and eliminated particle settling compared to conventional electrorheological fluids.


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