# Characterising viscosity modifiers under high pressure and shear in the elastohydrodynamic lubrication regime

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Viscosity modifiers (VMs) are polymers added to lubricants to improve their viscosity-temperature relationship, making oils less sensitive to temperature changes. It is not fully understood how these polymeric molecules affect the rheology of the lubricant under high pressure and shear. In this study we develop optical methods, to assess the role of polymer architecture on lubricant rheology in a ball-on-flat contact under elastohydrodynamic conditions. Fluorescence lifetime and phosphorescence lifetime are implemented to perform *in situ* viscosity and flow measurements of the contact in a controlled environment. Viscosity maps of the contact and through-film flow profiles are then reconstructed, to describe the lubricant behaviour.

**Keywords:** viscosity modifiers, rheology, elastohydrodynamic lubrication, fluorescence lifetime, phosphorescence lifetime

## 1. Introduction

The development of high-performance viscosity modifier (VM) additives is crucial to control the viscosity-temperature response of lubricants, hence to ensure the durability of engines and improve fuel economy. Therefore, there is currently a significant interest in understanding the behaviour of these lubricants, especially under shear and pressure [1]. This work contributes to this understanding by assessing the local viscosity and flow profile of a VM containing lubricant in a non-conforming contact under elastohydrodynamic conditions.

## 2. Methods

The local viscosity and flow profile of model lubricants containing viscosity modifiers are measured in a ball-on-disc apparatus using respectively time-resolved fluorescence lifetime and phosphorescence lifetime spectroscopies.

2.1. Apparatus with optical access

An EHD1 Ultra Thin Film Measurement System by PCS Instruments (Acton, UK) is used to create a ball-on-flat contact as the test platform. The optical access is enabled by using glass or sapphire specimens. The mean pressure in the contact ranges from 125 to 700 MPa. The entrainment speed, slide-roll ratio and temperature are controlled.

2.2. Fluorescence lifetime measurements

A molecular rotor, Bodipy C10, is used as a viscosity sensor. Using the calibration shown in Figure 1, the local viscosity in the contact is derived from fluorescence lifetime measurements [2]. The dye is excited at 800 nm with a femtosecond Ti:sapphire laser (Tsunami, Spectra Physics), which frequency is doubled.

2.3. Phosphorescence lifetime measurements

Flow profiles are reconstructed from phosphorescence imaging velocimetry [3]. The fluids are doped with a tris(dibenzoylmethane) mono(1,10-phenanthroline) europium(III) dye and excited with a 349 nm pulse laser (Explorer, Spectra Physics).

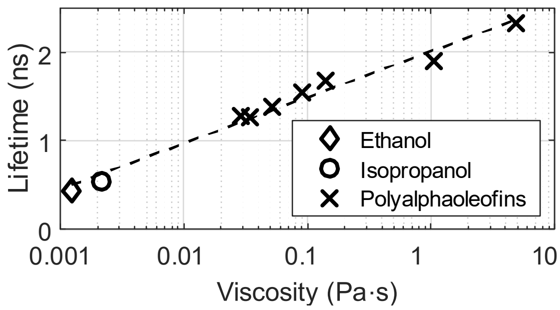


Figure 1: Viscosity - fluorescence lifetime calibration of Bodipy C10 in bulk solutions under static conditions.

## 3. Discussion

Fluorescence lifetime and phosphorescence lifetime measurements provide information of different length-scales. The former provides local viscosity at the molecular scale, while in the latter, viscosity is inferred in a sub-micron level. Mapping the viscosity in the contact adds to our understanding of viscosity modifiers behaviour under high pressure and shear. Complemented with flow profiles, it will give us valuable insights on how the architecture of these polymeric additive influence the rheology of the lubricant.

## 4. References

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