

# Nanoparticle characteristics of exhaust and soot-in-oil from gasoline direct injection automotive engines

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## Introduction

What are **exhaust soot** and **soot-in-oil**?

- Carbon nanoparticles formed in the combustion chamber
- Emitted in part with the exhaust gases
- Transfer to the engine oil and contribute to its degradation
- Common problem in direct injection engines

Exhaust soot generated in Gasoline Direct Injection (GDI) internal combustion engines has been widely investigated; soot-in-oil less so. Although soot is typically only a fraction of a comparable diesel engine, this is certainly a new challenge for the modern GDI engine as soot-in-oil raises concerns on wear and engine durability.

## The Problem

Over one billion of soot-in-oil nanoparticles can be found in a single 1ml drop of used engine oil. They are invisible to the naked eye and can only be seen by the most powerful electron microscope.

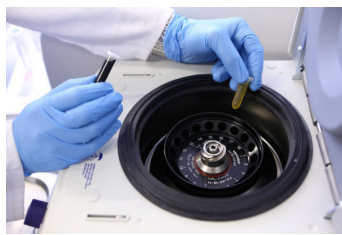
There is a considerable interest within the automotive industry to better understand the complex interactions between soot morphology and properties of lubricating oil.

The morphology, agglomeration and other characteristics of soot-in-oil are likely to be quite different to exhaust soot.

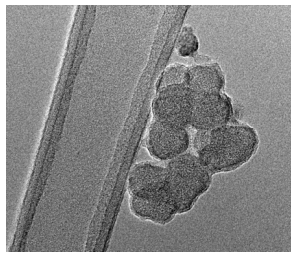
A clearer understanding of soot structure-property relationships could lead to extending oil changing intervals avoiding engine failure and poor performance.

## Methodology

The soot samples used in the study were collected from a modern wall-guided GDI engine.

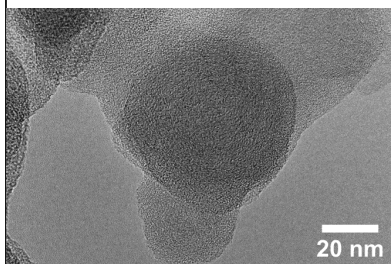


Solvent extraction and centrifugation have been used to prepare suitable samples for TEM analysis onto graphene oxide TEM support films.



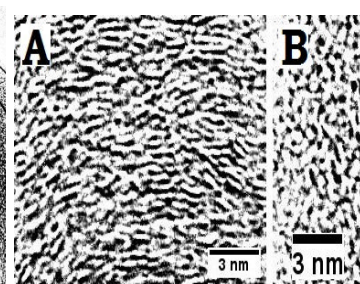
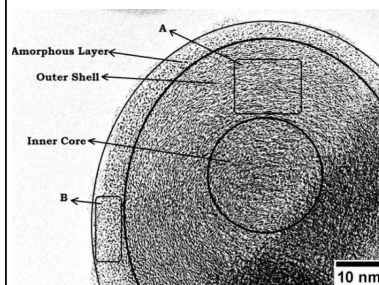
## Results

Soot primary particles appeared mostly as spheroids with distortions and irregularities assembled into chainlike and small cluster aggregates.

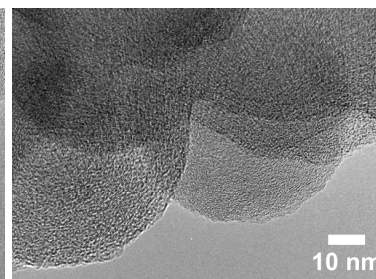
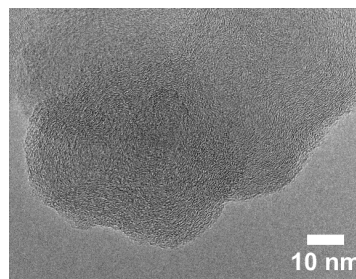


Exhaust primary particles were found in the range 20-70nm, with a mean diameter of 38.6nm. Only 1.2% were smaller than 30nm. Exhaust soot exhibits a nearly amorphous nanostructure.

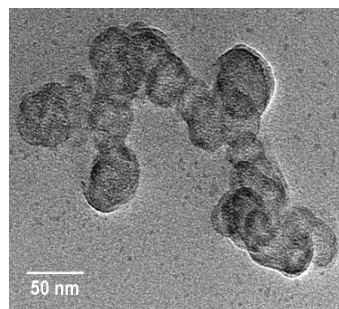
Soot-in-oil possesses a radial variation. Typically, a core comprised of short, disorganized segments (nuclei) followed by a layer of fringes viewed edge-on on TEM projections (2-6nm) and in some cases a thin amorphous layer of 2-3nm.



Differences in nanostructure may reflect a combination of different operating conditions, combustion temperatures and chemical species contributing to particle growth at various stages.



GDI soot agglomerate size was found to be comparable to diesel engine soot-in-oil.



Soot agglomerates have a modest branched morphology, and exist in clusters and chainlike structures in a range from 40 to 400nm. Agglomerates show an average length of 150nm and are composed of spherical primary particles of 18-60nm.

