

AB 2011

International Conference
on Structural Adhesive Bonding

7 | 8 July, 2011

Faculty of Engineering
University of Porto
Porto, Portugal



Influence of the size and amount of cork particles on the toughness of a structural adhesive

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Objectives

- Cork particles should **create obstacles** to the propagation of cracks, thus improving the **toughness** of the adhesive.
- This technique allows a **new application of a natural product** with an important impact in the Portuguese economy.
- The evaluation of this solution is made by:
 - powder characterization,
 - production of specimens to evaluate adhesion between resin and cork and good particle distribution;
 - mechanical tests.



Methods to improve toughness

Structural adhesives are known for their **high strength and stiffness** but also of their **low ductility and toughness**.

There are three main methods to improve the toughness of adhesives:

- Polymer with phase separation
- Polymer without phase separation
- **Inclusion of particles**



Micro particles of cork powder to increase the toughness of a brittle epoxy adhesive



Cork as reinforcement material

- Cork is a biological material with unique properties



- Cellular structure:
 - Similar to a honeycomb
 - Without empty spaces between contiguous cells
 - Closed cells could work to absorb impact



Cork as reinforcement material

- Cork is a biological material with unique properties

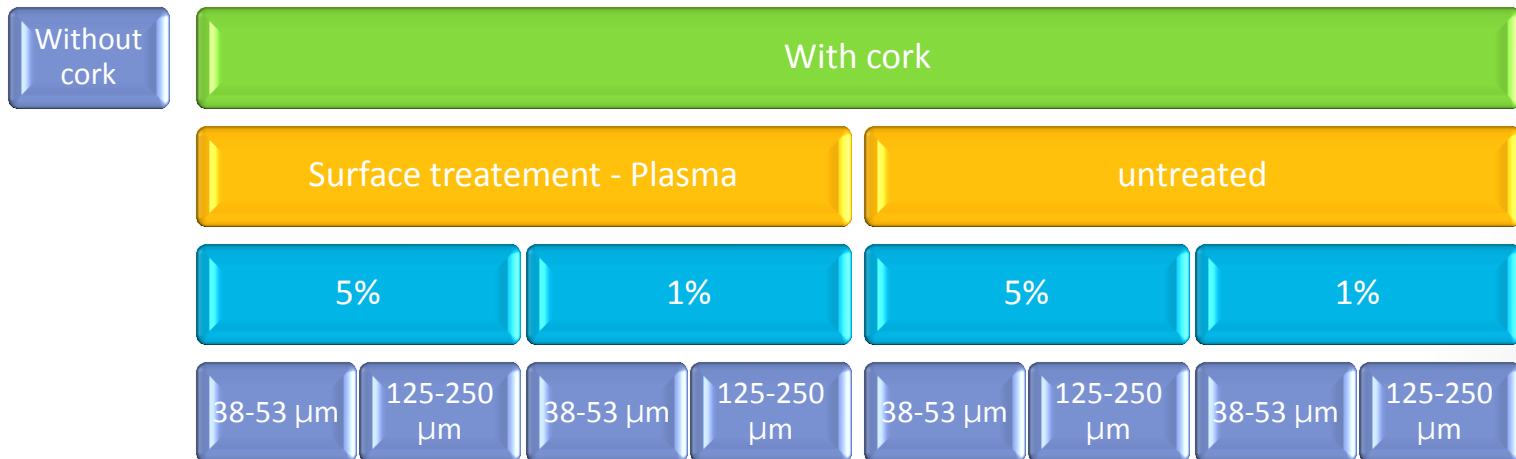


- Composite properties depend on:
 - **interfacial adhesion** between cork and resin
 - **size** and **amount** of cork particles
 - **mixing** conditions



Specimens manufacture

- Materials
 - Cork powder (38-53 μm and 125-250 μm)
 - Epoxy resin – Araldite 2020
- } Cured at 100°C during 15 min
- Mixing with a centrifuge mixing machine (90 seg. at 1500 rpm)
 - Types of specimens :



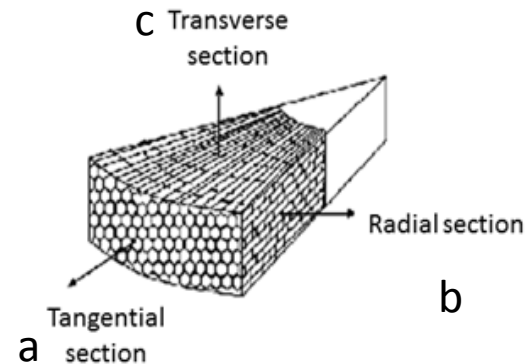
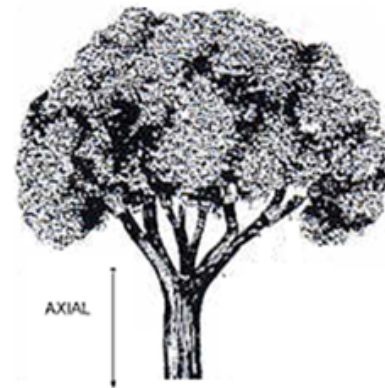
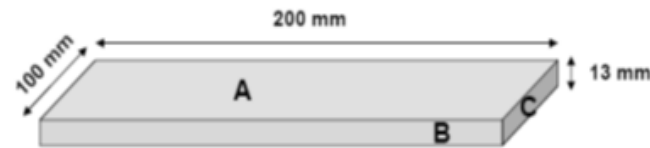


Surface treatment and density

- Atmospheric plasma
 - Distance of torch – 8 mm
 - Velocity – 5 m/min



Used to modify cork particles surface

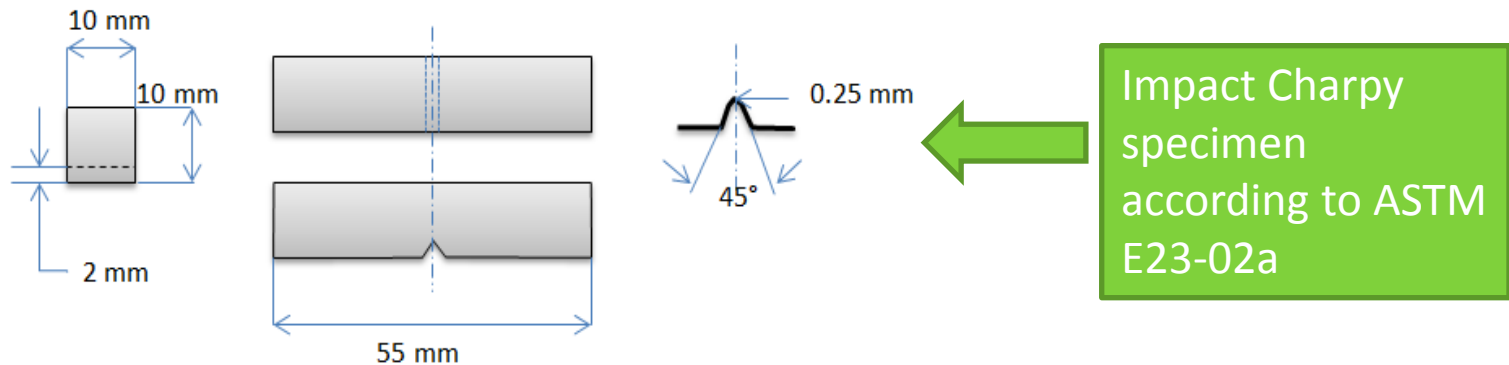


- Density
 - Cork particles – Helium picnometer;
 - Specimens – Archimedes principle (water)



Toughness impact test and SEM

- Toughness impact tests



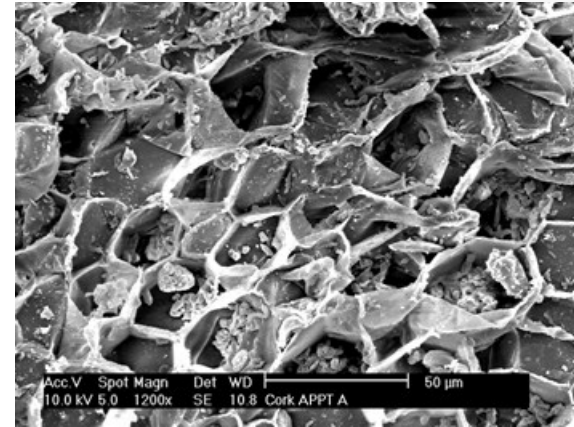
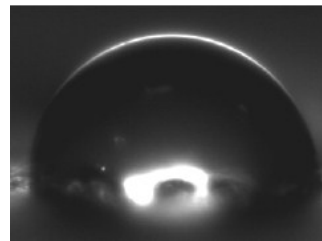
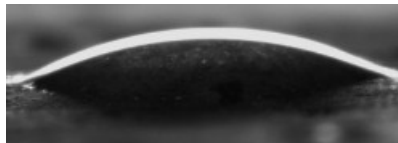
- SEM analysis
 - Cork particles
 - Composite fracture surface



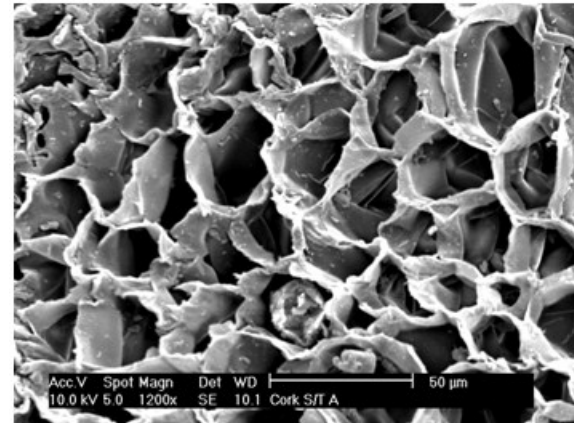
Surface properties

Contact angle

<i>Section</i>	<i>Treated specimen</i>	<i>Untreated Specimen</i>
Radial	30 ± 4	101 ± 11
Tangential	33 ± 7	99 ± 18
Axial	37 ± 2	103 ± 7



Treated with plasma

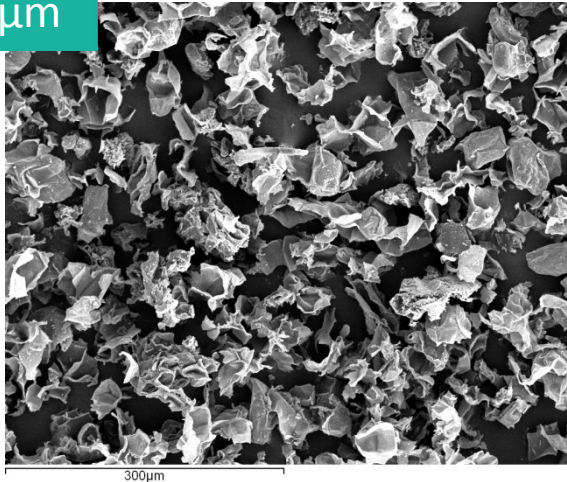


Untreated



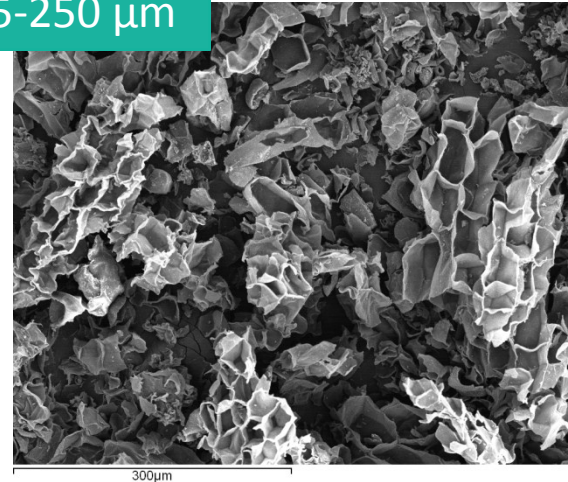
Cork particles characterization

38-53 μm



- Honeycomb cell structure damaged
- Opens cells
- Single cells

125-250 μm

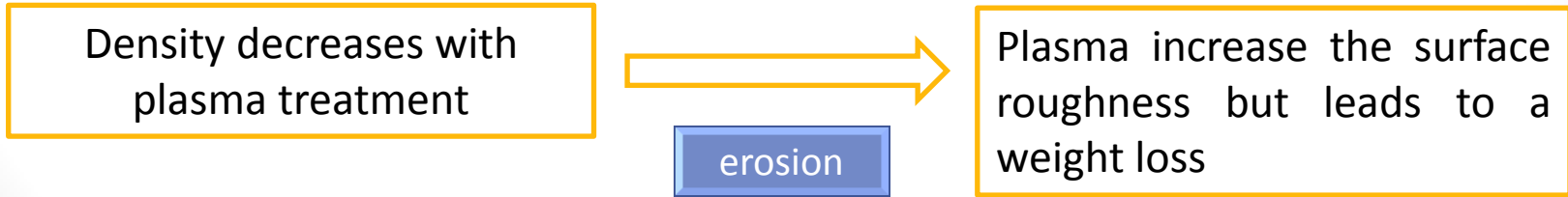
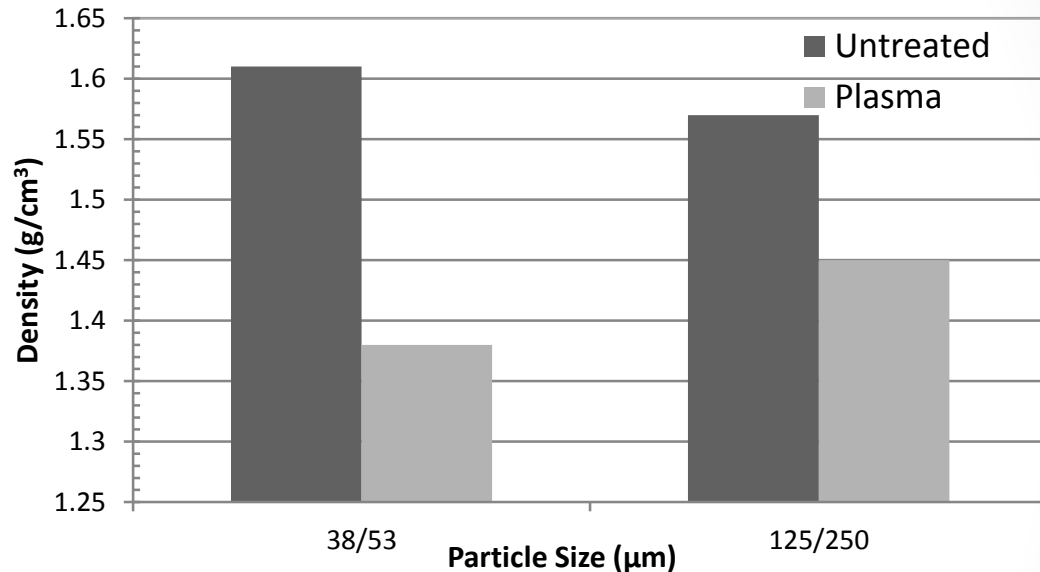


- Honeycomb cell structure with several cells
- Opened and closed cells



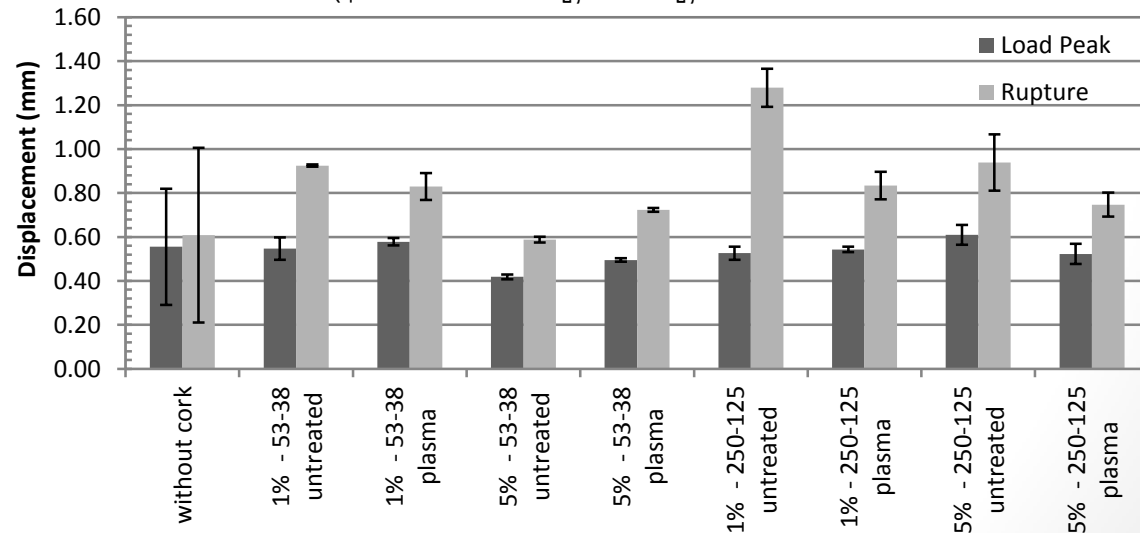
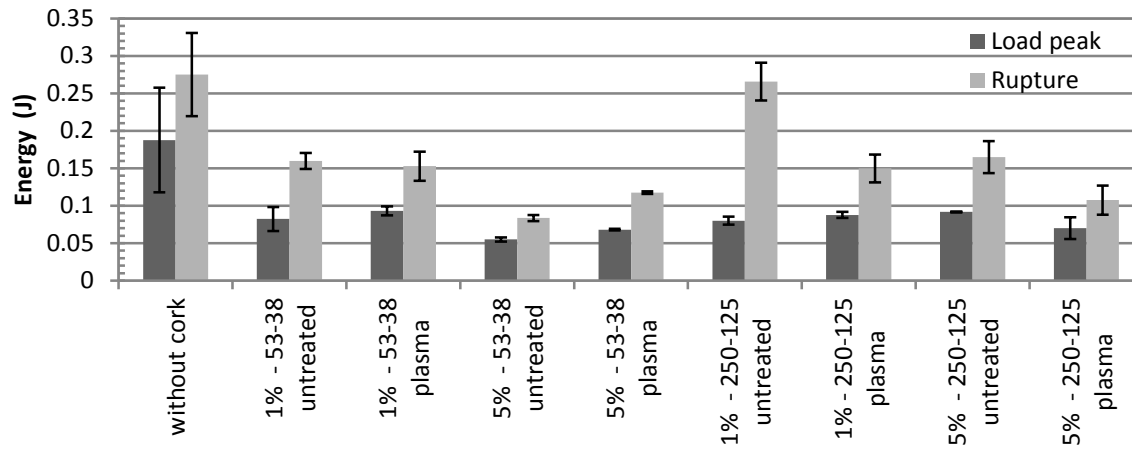
Cork particles characterization

- Density is influenced by:
 - Size
 - Structure integrity



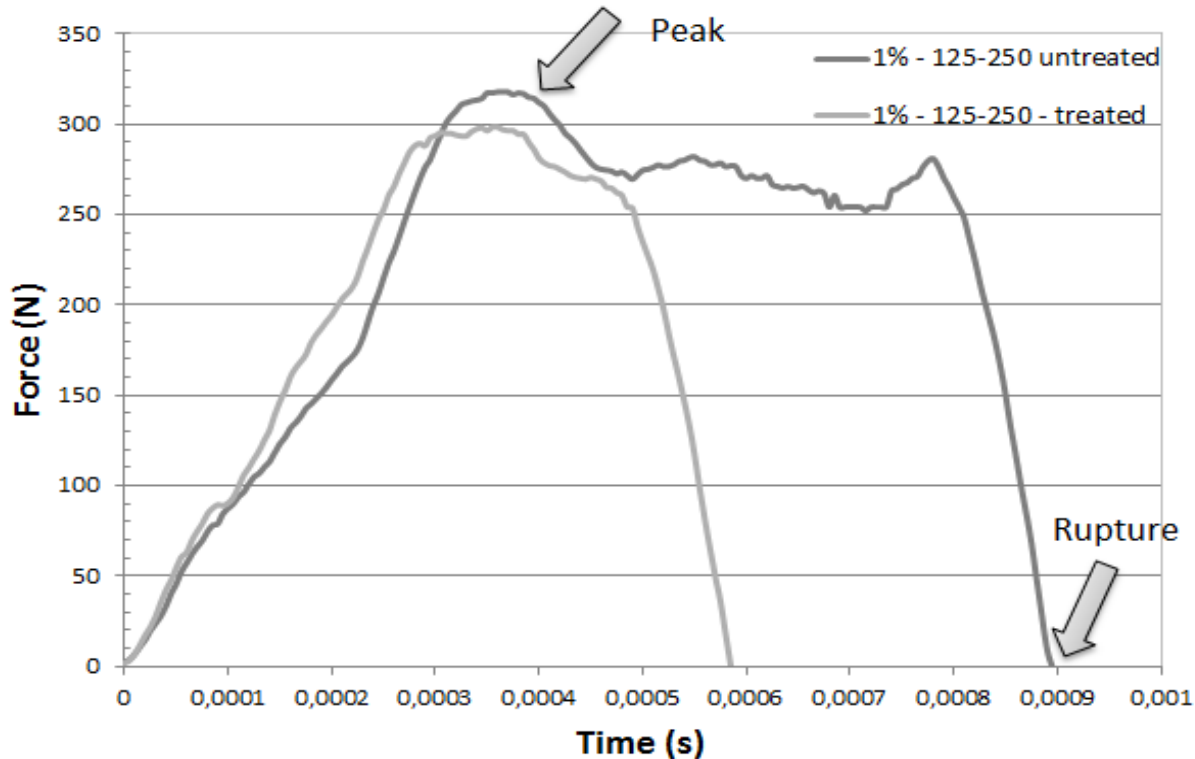


Toughness impact properties





Toughness impact properties

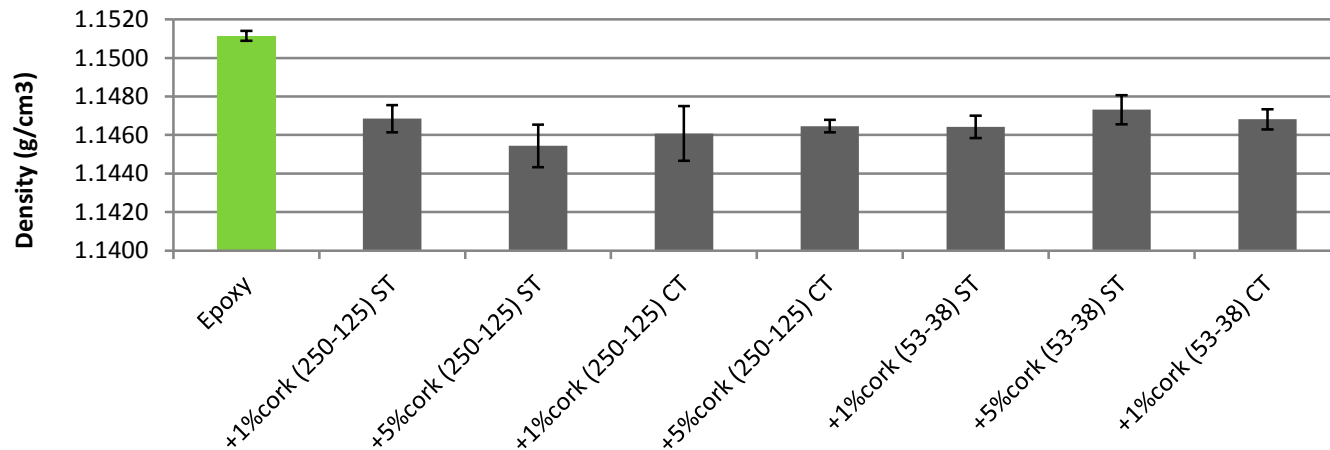




Density of toughness impact specimens

Damaged cells can facilitate the resin penetration, which could decrease the energy absorption.

A possible explanation for this fact is the differences in specimens' density



If resin penetrates the cork cells, specimens density increases.

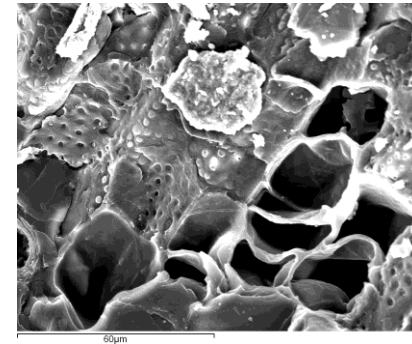
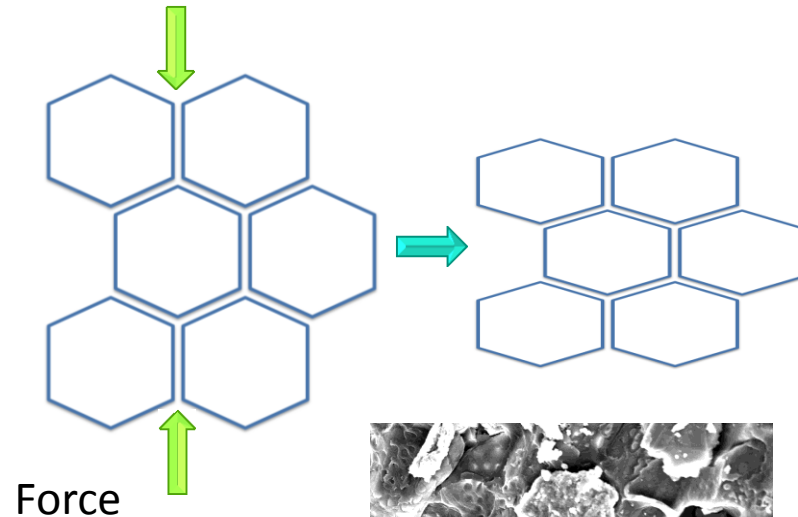
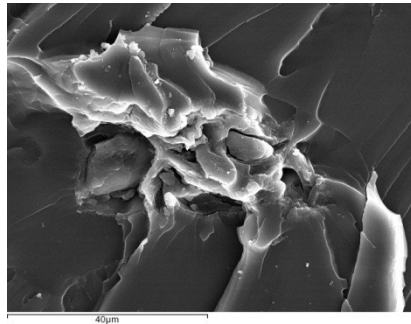
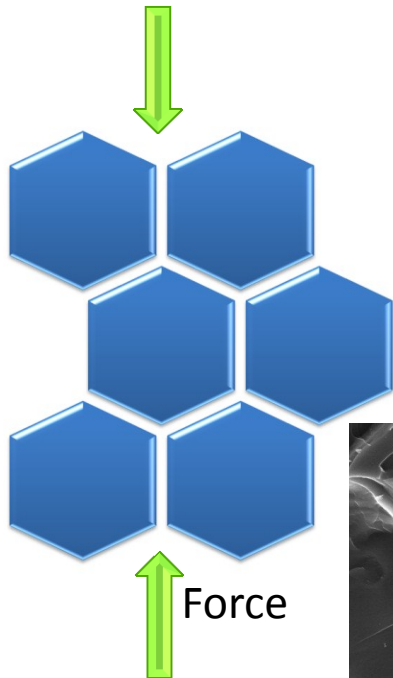


Density variation is not substantial, so this interpretation may be regarded with caution



Cork particles in epoxy resin

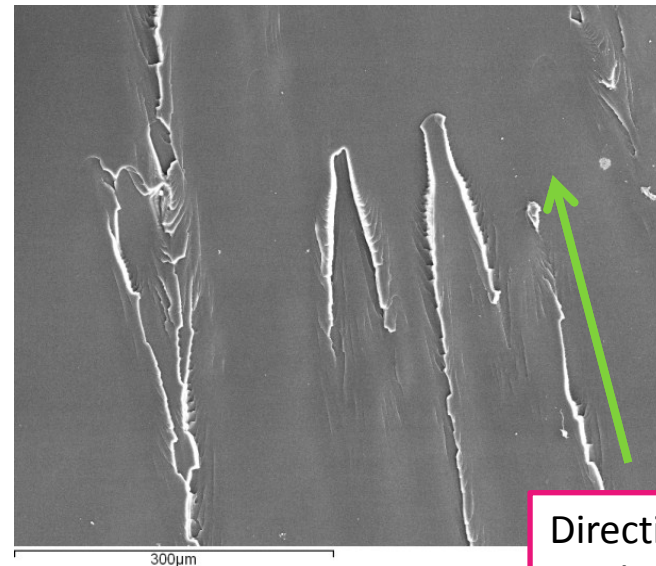
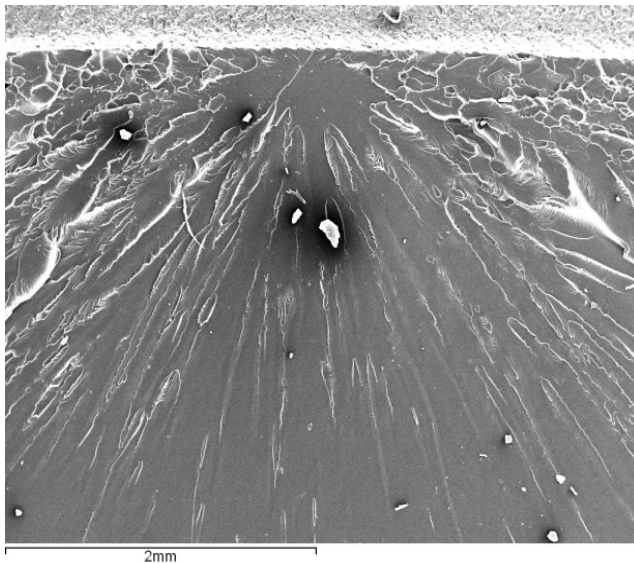
Cork has good impact behaviour due to its cell structure disposition, giving a **pillow effect**.





SEM Surface analysis

Without cork particles

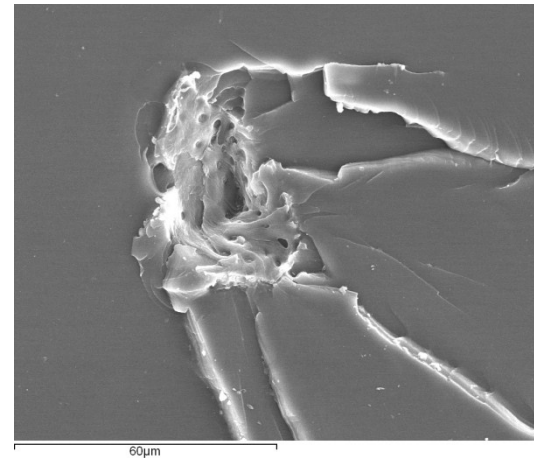
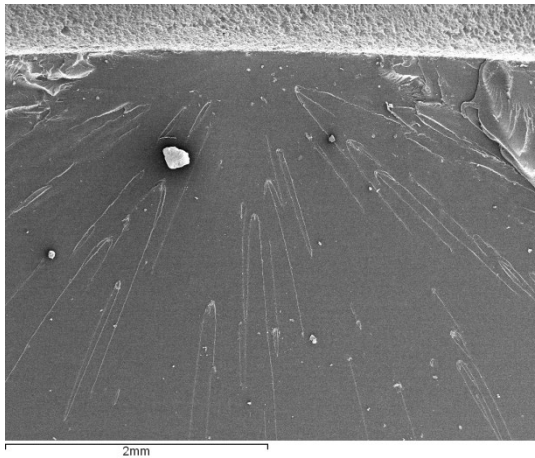


Direction of
crack
propagation

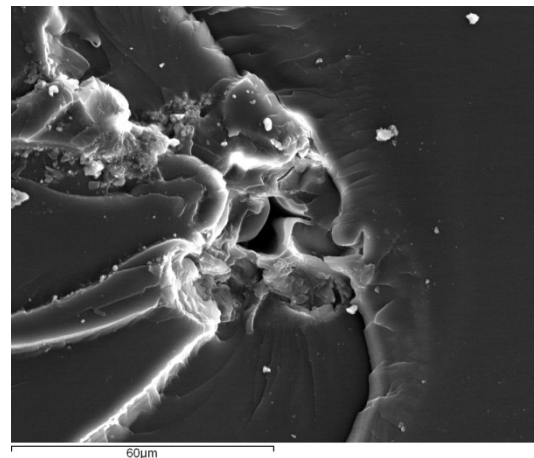
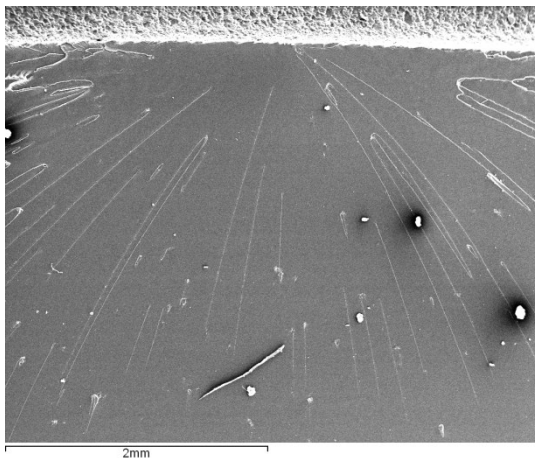


SEM Surface analysis

1% cork (38-53 μm)



Untreated

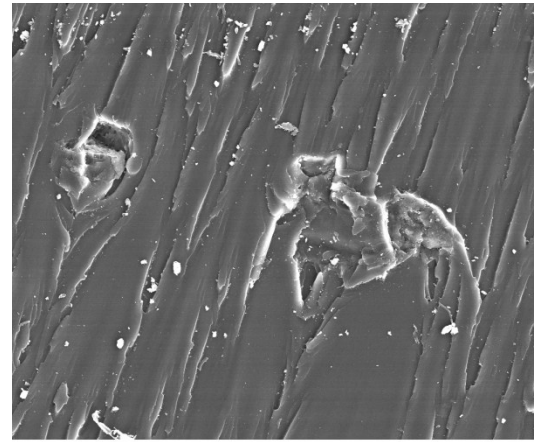
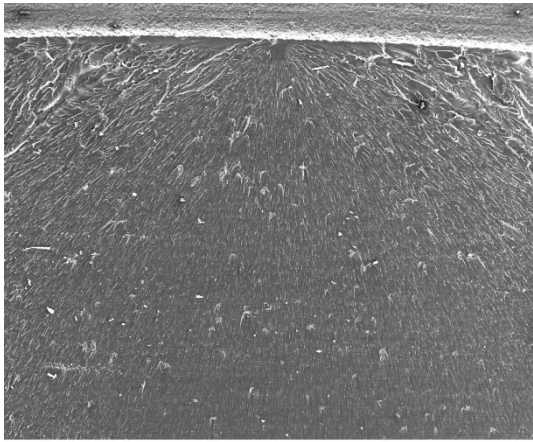


Plasma

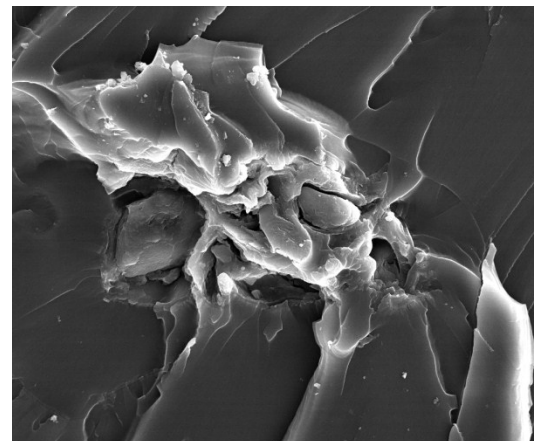
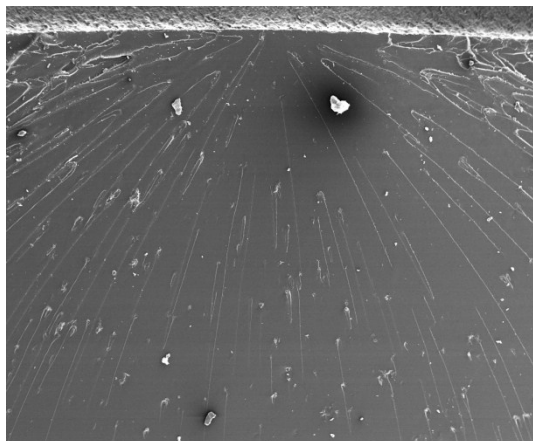


SEM Surface analysis

5% cork (38-53 μm)



Untreated

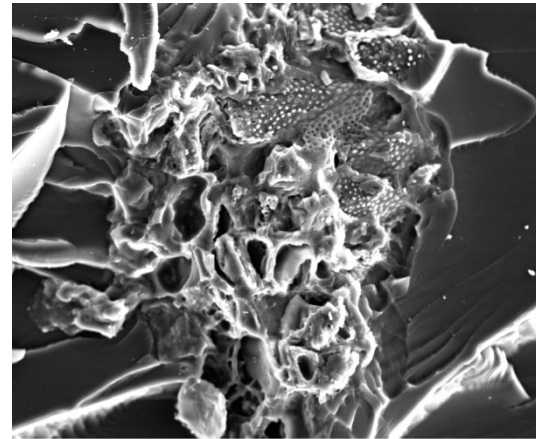
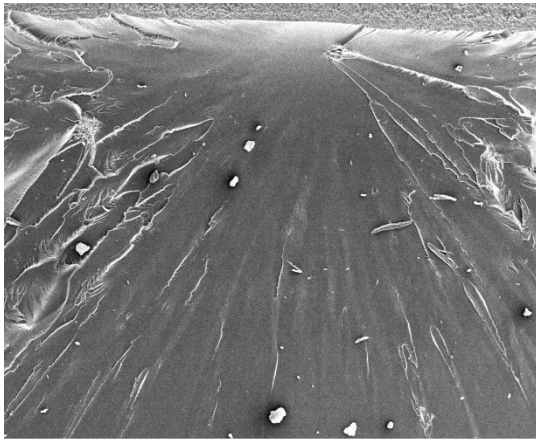


Plasma

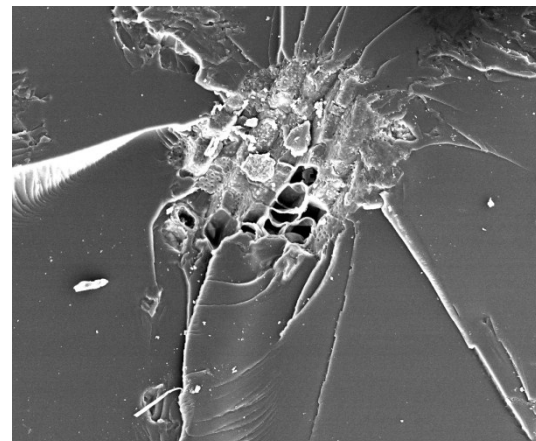
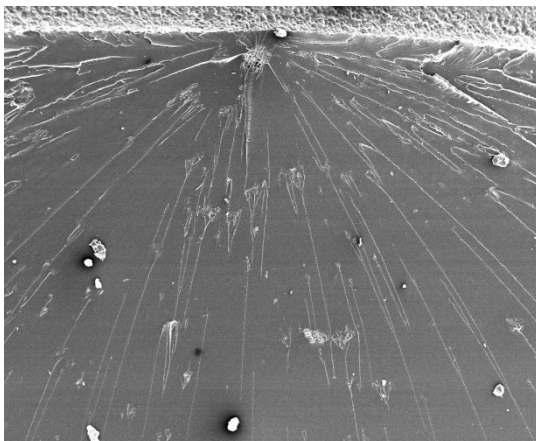


SEM Surface analysis

1% cork (125-250 μm)



Untreated

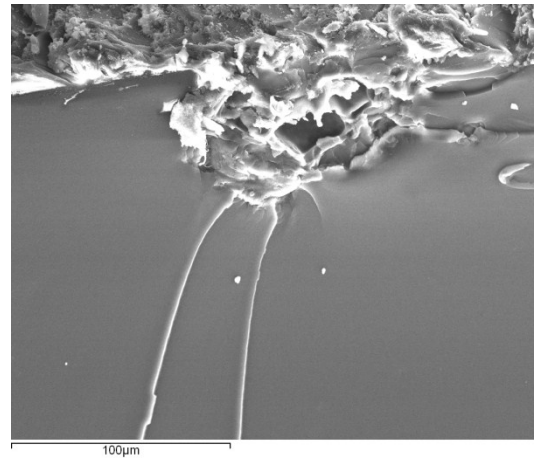
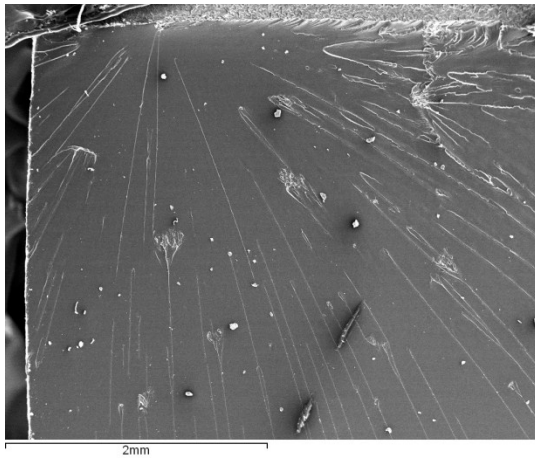


Plasma

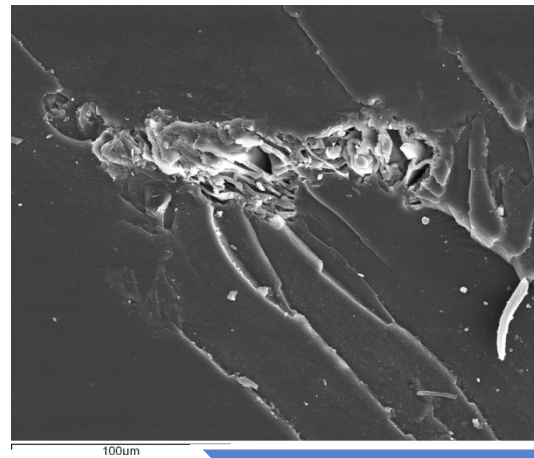
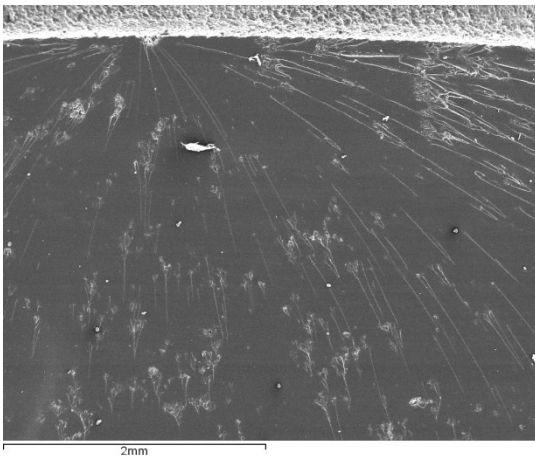


SEM Surface analysis

5% cork (125-250 μm)



Untreated



Plasma



Conclusions

- Atmospheric plasma surface treatment increases the contact angle and wettability of cork, but treated particles in the composite had an unexpected behaviour;
- SEM and OTM analysis show that most cells are not filled with resin and randomly distributed in the matrix and specimens with these properties show better results;
- The influence of the amount and particle size is notorious.



Acknowledgements

- Financial support by Portuguese Foundation for Science and Technology (PTDC/EME-TME/098752/2008)
- Professor José Pissarra and D. Helena from Biology Department from Science Faculty of Porto University are greatly acknowledged.