The Partial Replacement of Glass Fibre with Polarite 102A in Polyamides

Imerys Technical Group

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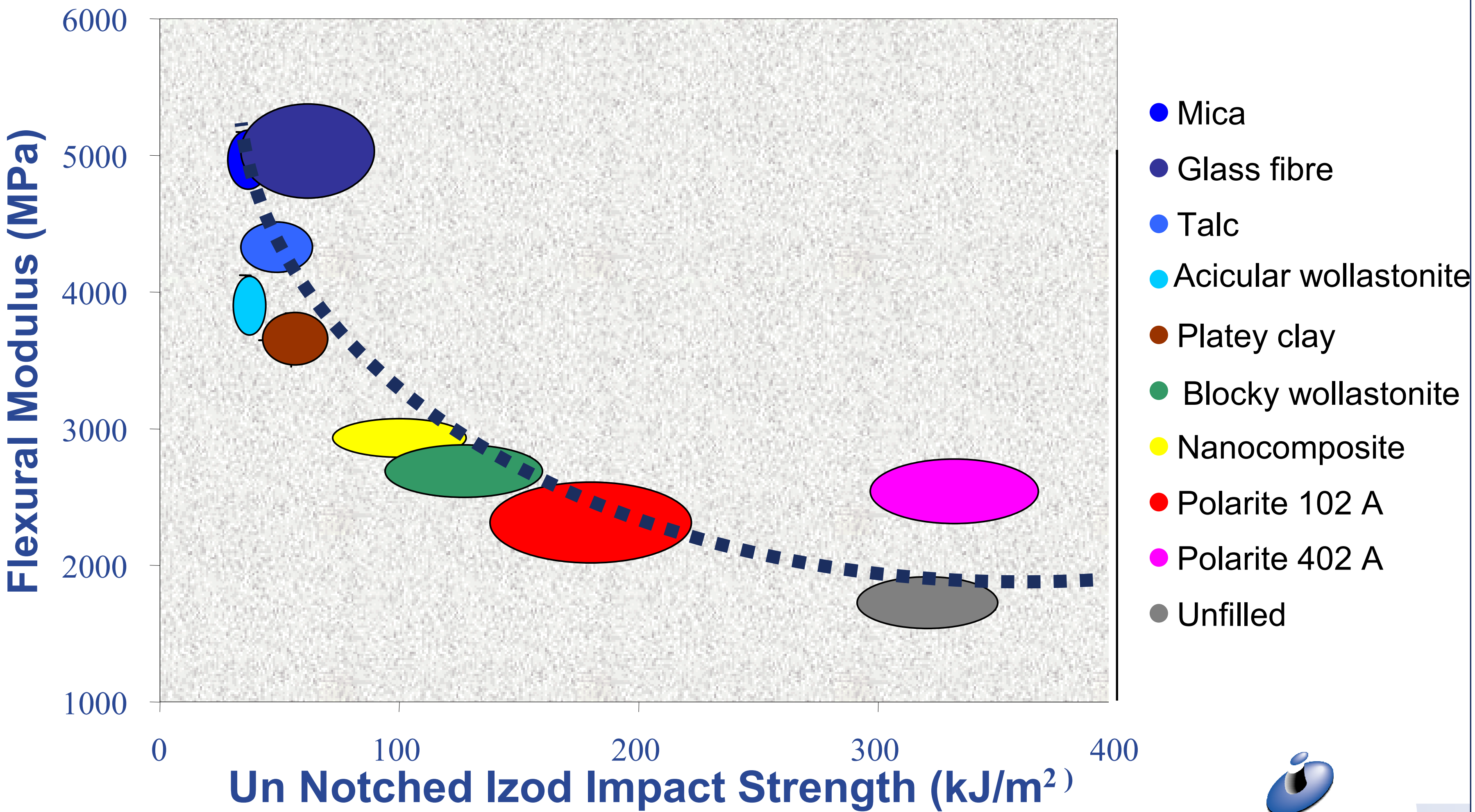
Introduction

Glass fibres are often used in combination with polyamide (typically Nylon 6 and Nylon 6,6) to give high flexural modulus (stiffness).

Glass fibres (GF) costs are around 1.5 Euro/kg?, so by using a lower cost material, such a surface-treated calcined clay, cost savings might be achieved, provided there is no significant loss in performance.

The Effect of Mineral Addition in PA6 (30 wt.%)



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Theory - the hypothesis

Platey minerals have higher modulus, but lower impact strength. Highly anisotropic additives, such as GF, have the highest modulus, but contribute little to impact strength. If blends are used, then it might be possible to achieve "reasonable" modulus with equivalent or better impact strength. Additionally the anisotropy of the moulding may be reduced.

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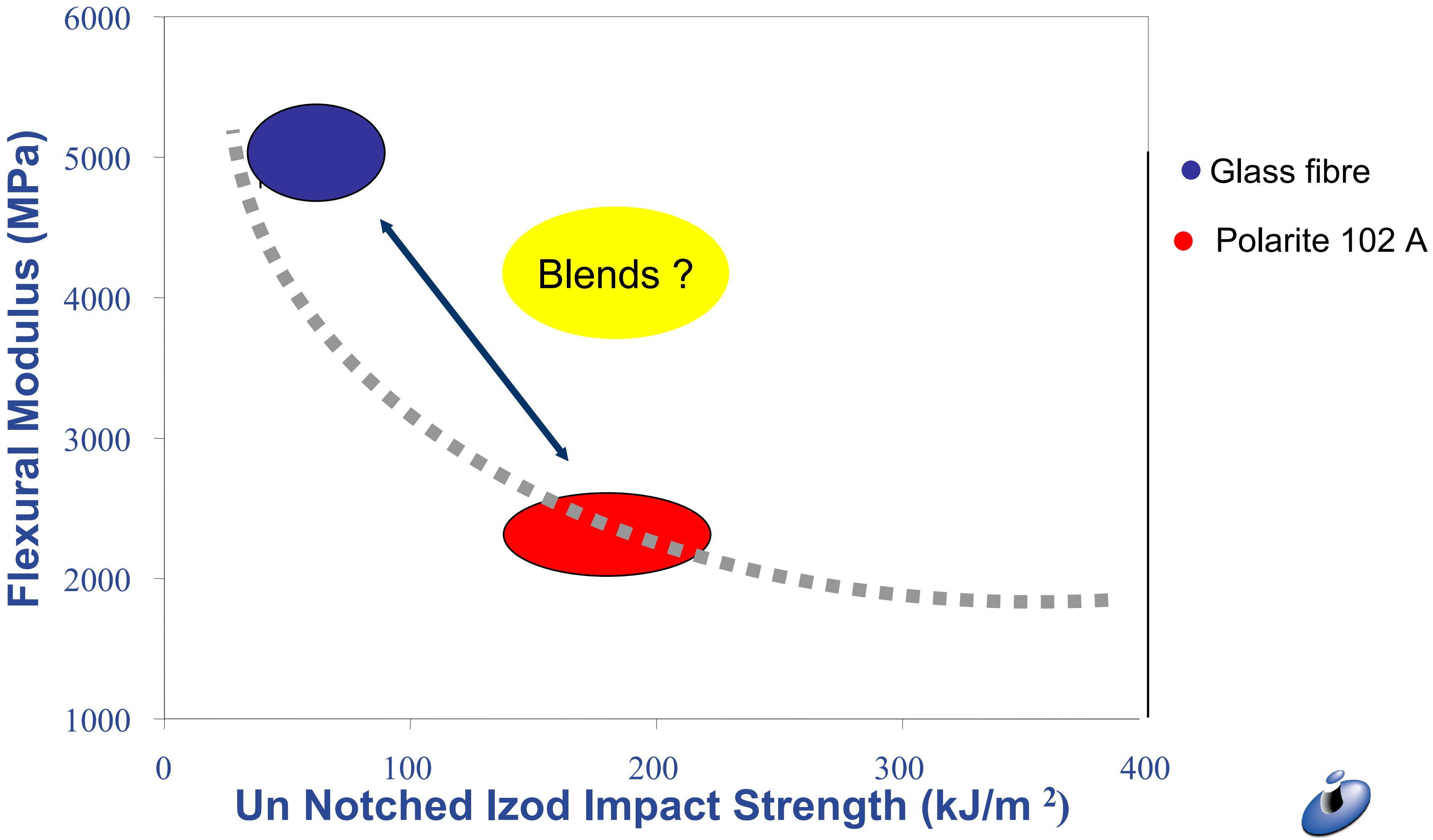
Plot of Flex. Mod. Versus Impact Strength (the "Universal Curve")



Theory

Filler loadings, as volume fractions, can be used to calculate the flexural modulus of a composite by:

$$E = E_f Ø_f + E_m (1- Ø_f)$$

where E_f is the modulus of the filler fraction

$Ø_f$ the volume fraction of the filler

E_m the modulus of the matrix

Thus physical properties, such as modulus and impact strength can be estimated for mixtures, such as minerals combined with glass fibres.

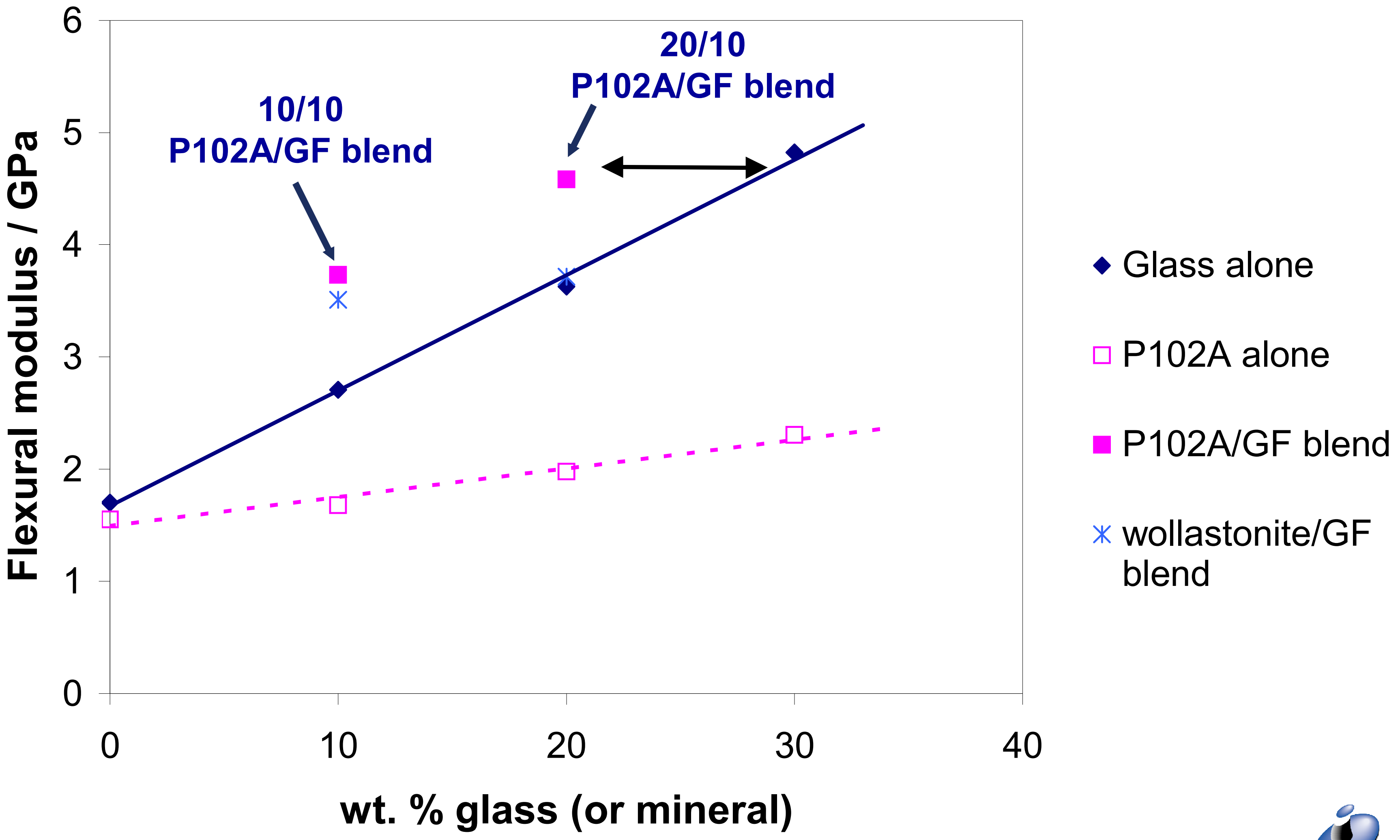
Experimental

30 wt.% filled PA6 compounds were prepared containing chopped strand glass fibre (Cratec 123D), Polarite 102A and an acicular wollastonite as a comparison. The minerals were fed through the main hopper of a twin-screw compounded and the glass fibre was added in a side feeder towards the end of the barrel.

Plaques were injection moulded and conditioned for 21 days at 23 ° C, 50 % rh. The plaques were then trimmed to 75 x 10 x 2mm test pieces both in the direction of flow, and perpendicular to it. These were used to study shrinkage.

Tensile strength and modulus were also measured and results compared with the blend model data.

Modulus versus GF content



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Summary

A 10/20 blend of P102A/GF gave the same modulus as a 20 wt.% GF.

A 20/10 blend of P102A/GF gave the same modulus at a 30 wt.% GF.

The 20/10 wollastonite blend gave the same modulus as the 20 wt.% GF and thus gave no benefits for potential cost savings.

These results were compared with data plots using the rule of mixtures model.

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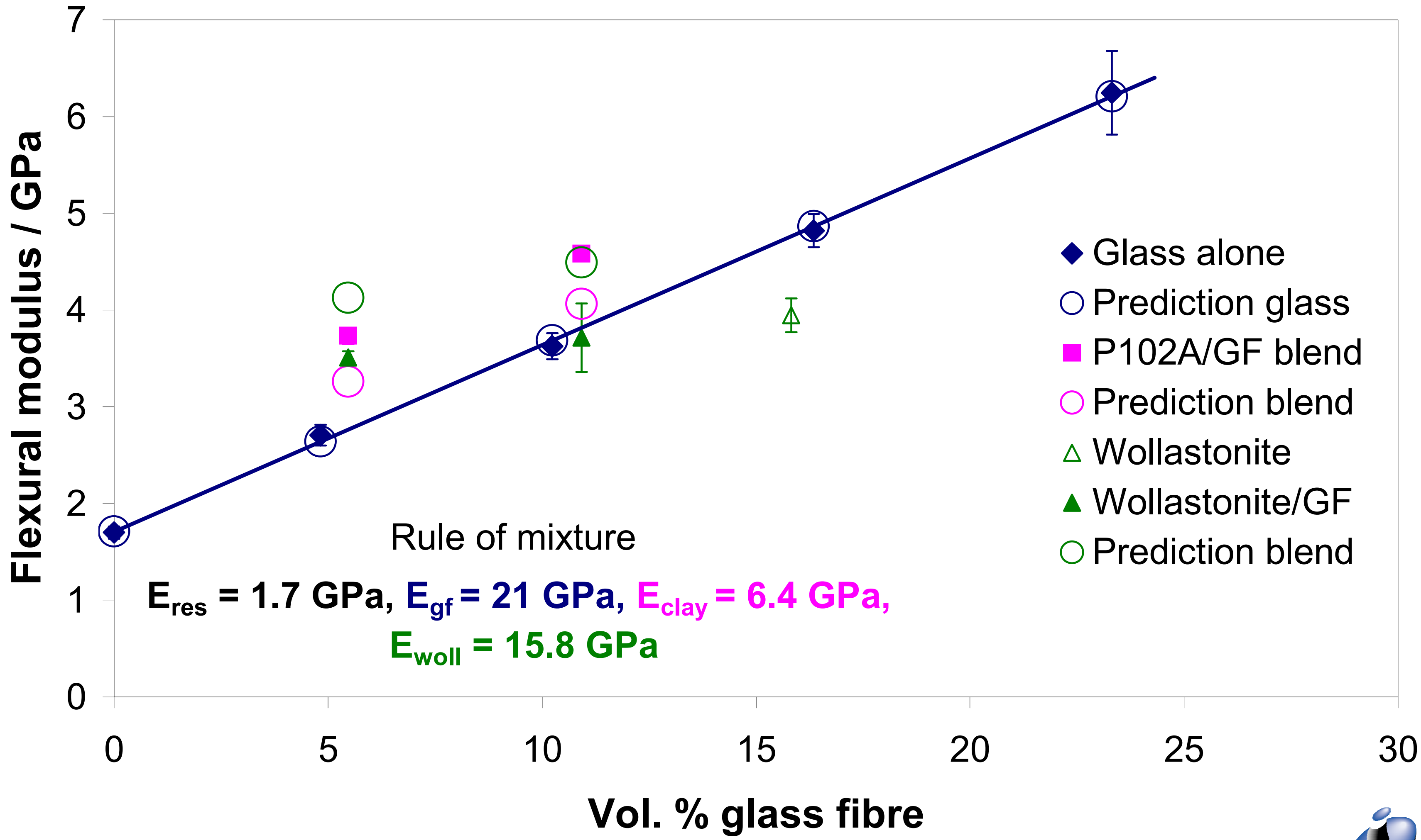
Modulus versus GF vol. content using simple rule of mixtures



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Summary

There is a linear variation in modulus with GF loading, in line with the predicted model.

Due to density differences between the resin and mineral (1.4 vs. 2.6 gcm^{-3}) the relative volume of GF in a 10/20 P102A/GF blend is higher than 20 % GF alone, as the mineral occupies relatively less volume than the resin.

In blends the modulus is also increased due to the “intrinsic” stiffness of the mineral. For P102A the model undervalues this by about 10%. For wollastonite, the experimental data are greater by 20 % than the predicted model.

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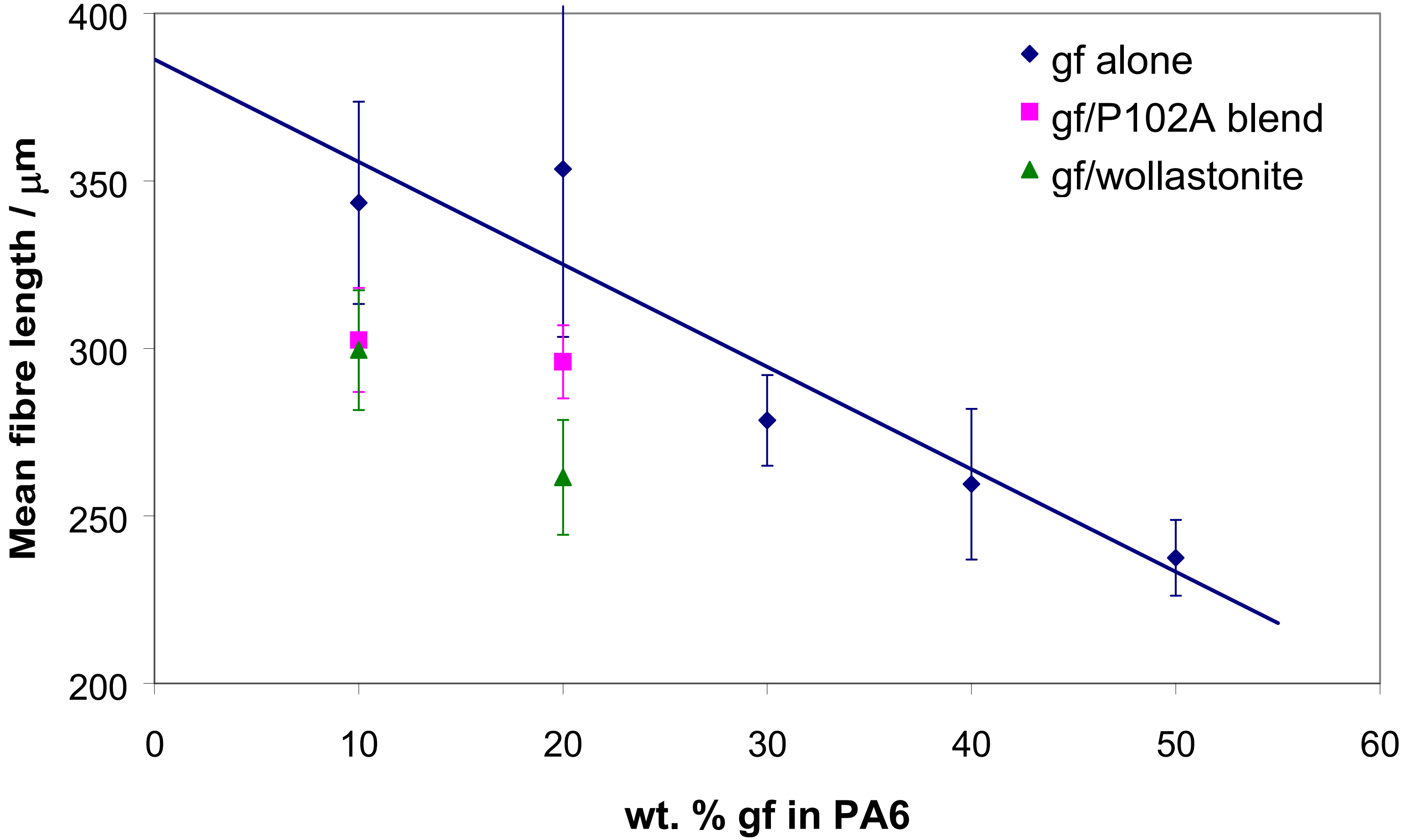
Plot of Average GF length vs. GF content



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Summary

The average GF length decreases with increasing loading.

At 10 wt.% mineral blends the fibre length is reduced by approximately 50 µm. At 20 wt.% wollastonite it is reduced further by 50 µm. The P102A GF length does not change.

The deviation from the blend model for **wollastonite** can be explained in terms of attrition of the GFs, resulting in a lowering of the modulus.

P102A also results in some attrition of GFs, although to a lesser extent. These results cannot explain the higher results obtained by experiment. The structure of the blends was then considered.

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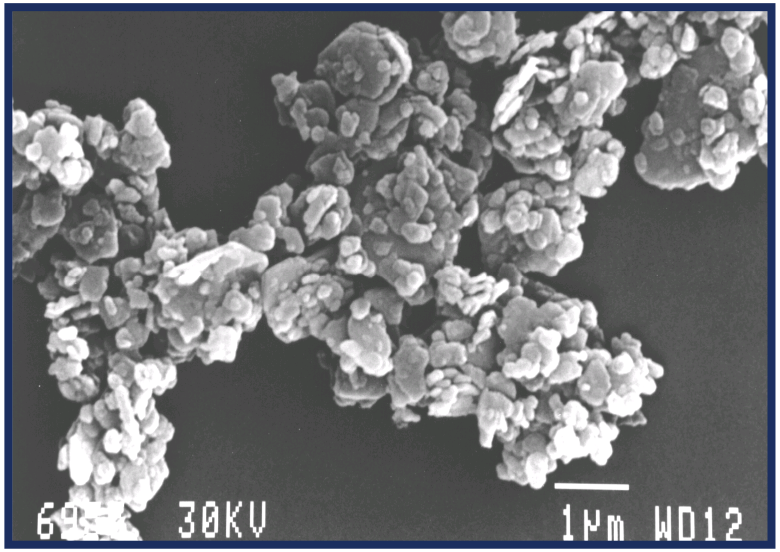
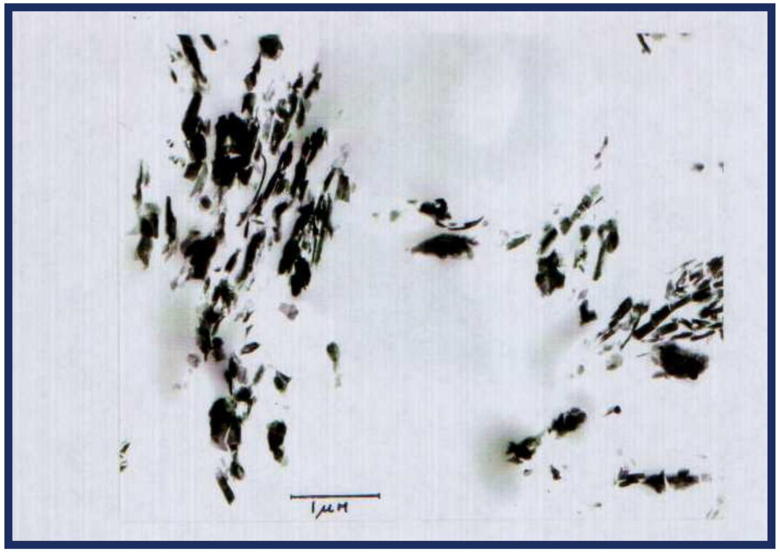


SEM and TEM Images showing the structure of Polarite (calcined kaolin).



The porous nature of the material is apparent from the micrographs

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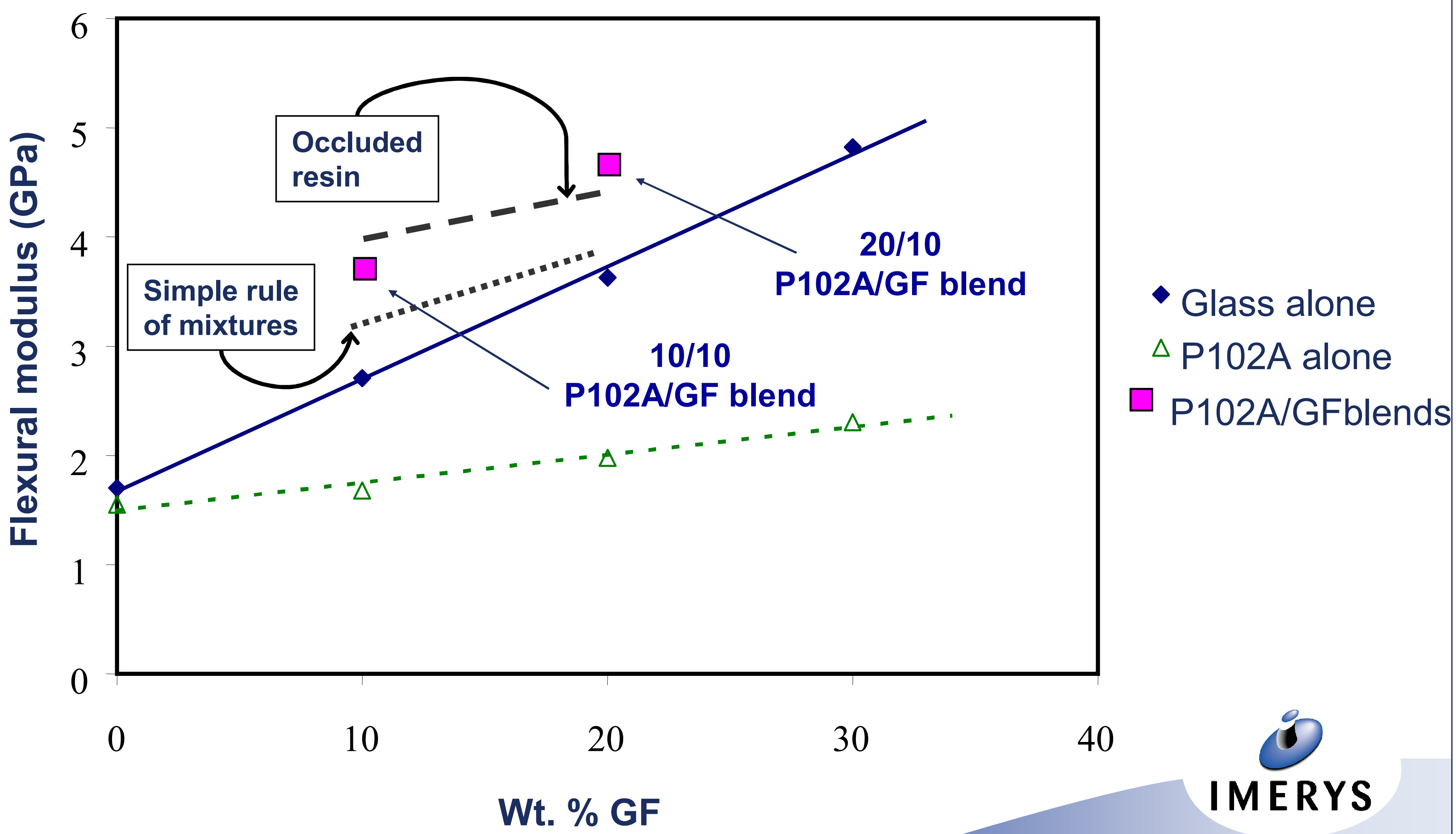
Hypothesis

If the resin penetrates the pore structure of the calcined clay (which is known to occur from previous studies), then the effective volume of resin is reduced, and thus the GF volume increases relatively. This can also be modelled and the modulus compared with experimental data. This is known as the “occluded resin” hypothesis.

The plots fit well will experimental data.

Stiffness versus Fibre Content in Blends



Summary of Flexural Modulus Data

Good stiffness can be achieved with glass fibre / mineral blends

- Due to higher effective volume of glass, if resin is trapped within the calcined clay pore structure
- Due to reduced fibre attrition
- Due to ‘higher’ volume fraction of glass (density differences)

The study then went on to look at the effects of shrinkage and isotropy.

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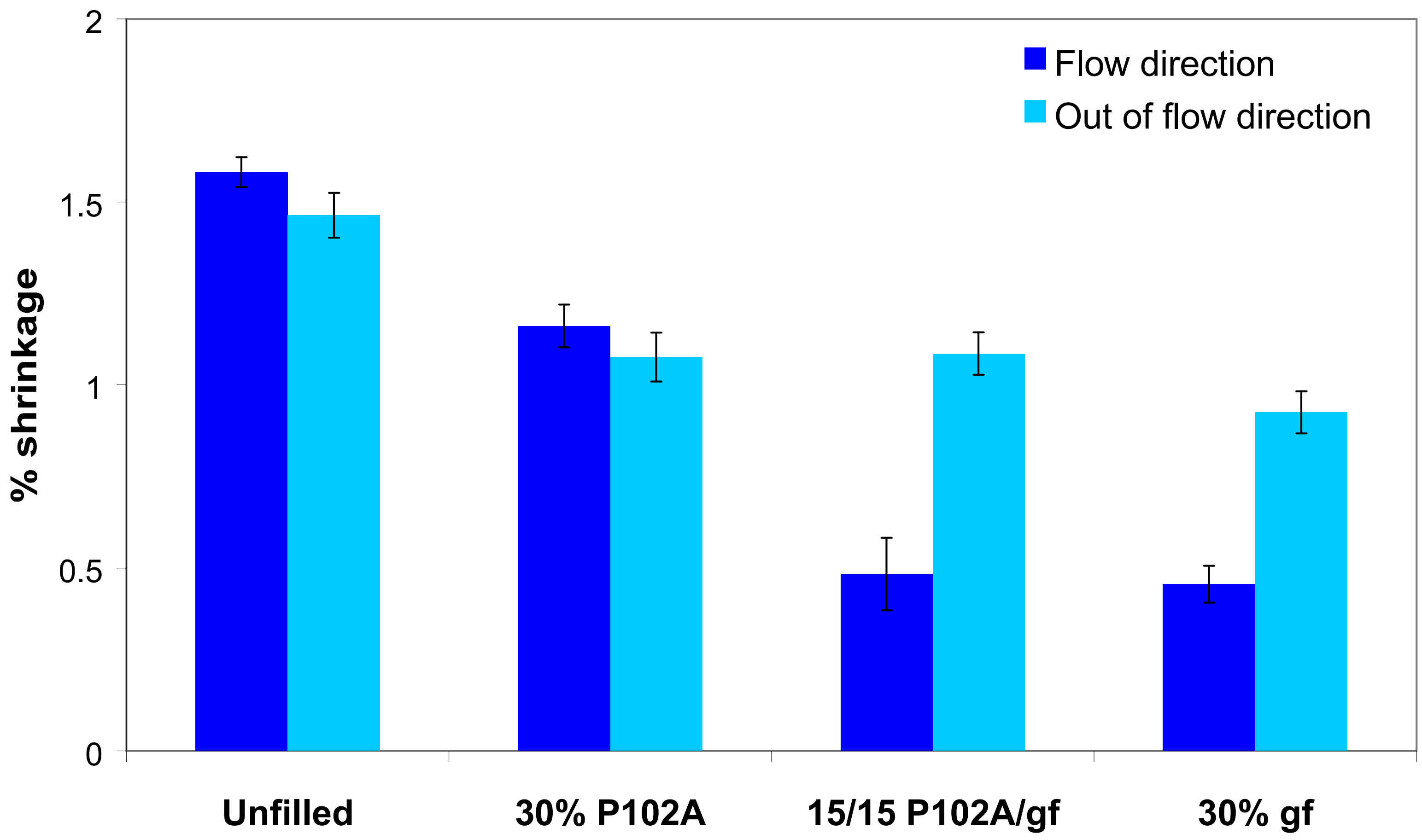
Plot of Shrinkage for GF/P102A Blends



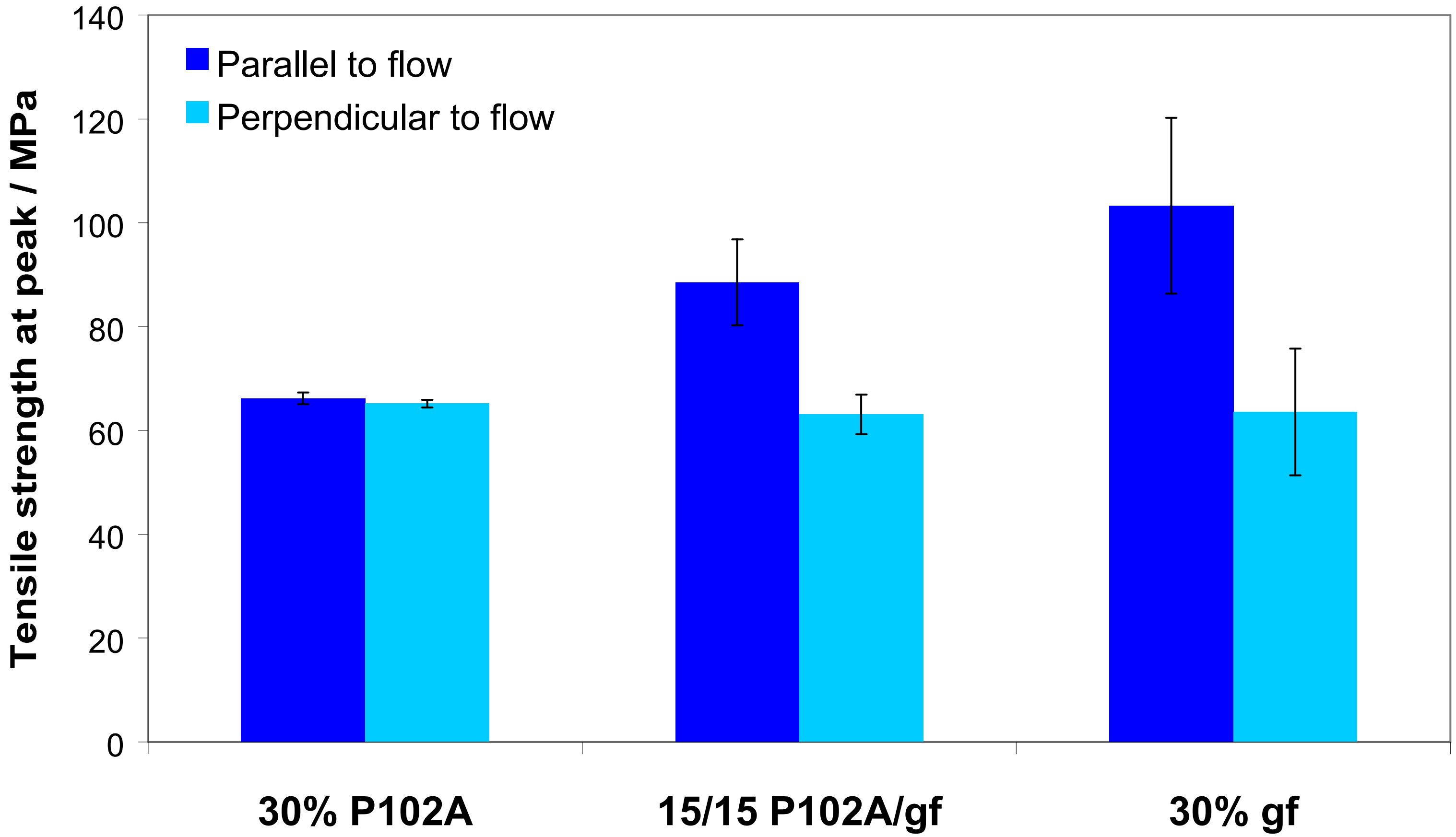
Summary

The addition of mineral and GF reduced the total shrinkage.

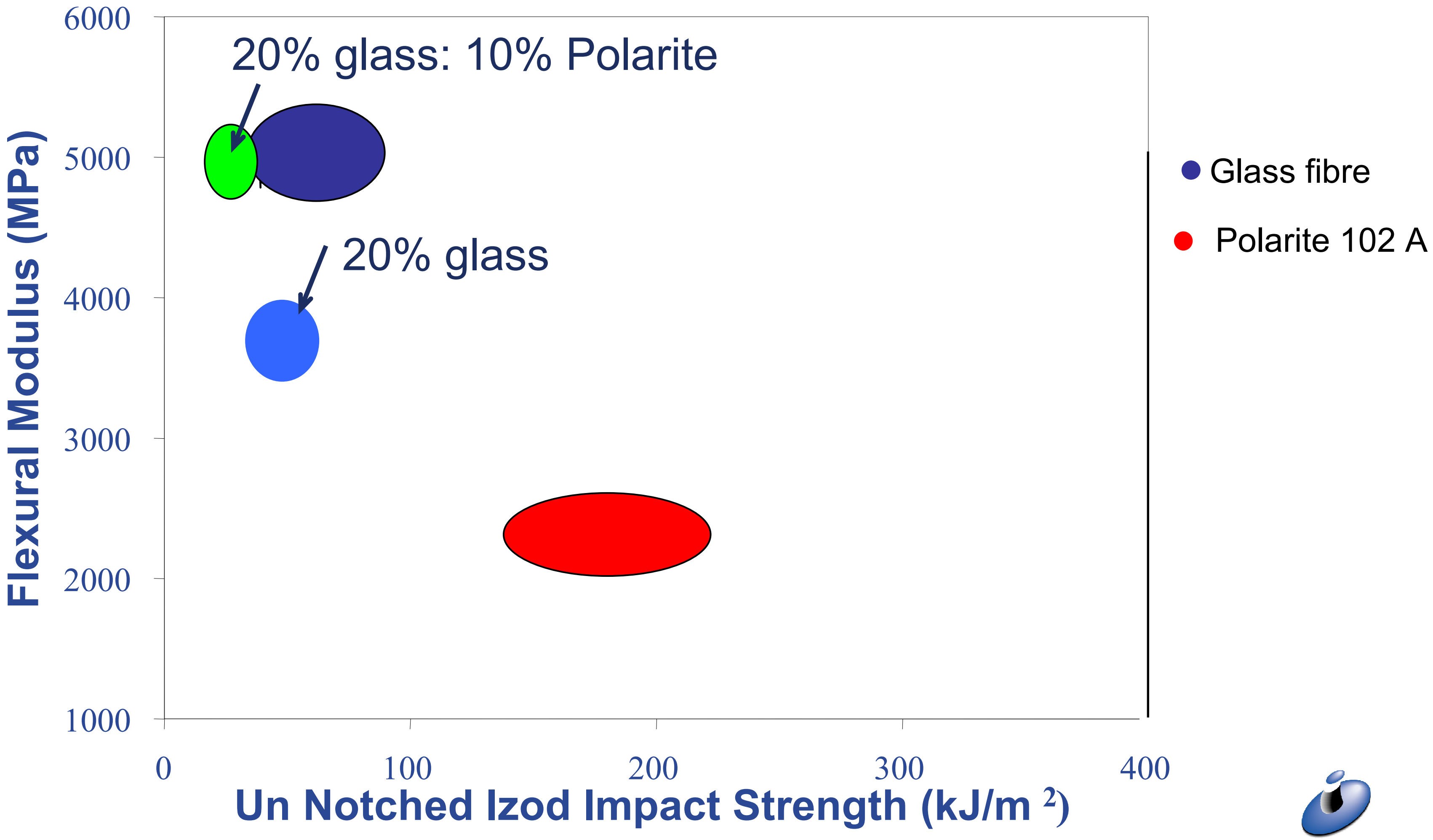
The addition of 30 wt.% P102A gave similar shrinkage in both flow directions.

The P102A/GF blends and the GF alone both showed anisoptropic behaviours, dominated by the GF.

Tensile Strength data



Flex. Mod. Data versus Unnotched Izod Impact Strength



Conclusions and Recommendations

The addition of P102A to glass fibres in PA results in a higher flexural modulus (at 10 % replacement) and similar tensile strength and impact strength when compared with glass fibre alone.

This substitution could result in cost savings, depending on the current pricing of glass fibre. An example using pricing of € 1.5/kg for GF and € 0.9/kg for P102A would result in a saving of € 55 per T.

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