



A Study of Water Vapour Sorption in Cellulose Acetate

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Introduction

Plastics today are recognised as one of the most vulnerable materials in museum collections and the degradation mechanisms involved and their interactions are still not well understood.

Cellulose acetate (CA) is a polymeric material used in the production of video tapes, Lego (until the 60s) [1], many other applications and it is still used in cigarette filter production.

CA is a hard material, with a glass transition temperature close to the decomposition temperature and therefore to obtain a malleable plastic, plasticisers are added to the polymer matrix during the manufacturing process to modify the polymer's characteristics.

The susceptibility of CA to the hydrolysis process is well-known, which can cause the elimination of acetyl groups, chain scission and plasticiser migration as well as cracking and brittleness. Mostly, preventive conservation involves the controlling of environmental parameters to slow down the decay mechanism. The amount of water vapour uptake and diffusion can be related to several factors (fig. 1) such as the type and amount of plasticiser, the thickness and the ageing of the sample.

In this poster, the water uptake of CA samples with different thickness and plasticiser contents at different percentages of relative humidity (RH) are analysed using dynamic vapour sorption (DVS).

Materials and methods

Three samples of cellulose acetate were prepared at the UCL Heritage Science Laboratory for the sorption and diffusion methods carried out at Imperial College London using the DVS Endeavour, produced by Surface Measurement Systems.

CA samples were prepared with 10% and 20% diethyl phthalate (DEP) and triphenyl phosphate (TPP) plasticiser, and with different thicknesses (0.8 mm and 2 mm respectively).

Sorption and diffusion in both unaged and aged (70 °C and 50% RH) samples were analysed using DVS at 25 °C under different RHs from 0% to 90% (in 10% increments). Each RH level was applied for 3 hours. Chemical changes, such as loss of plasticisers, were studied using FTIR and ¹H NMR.

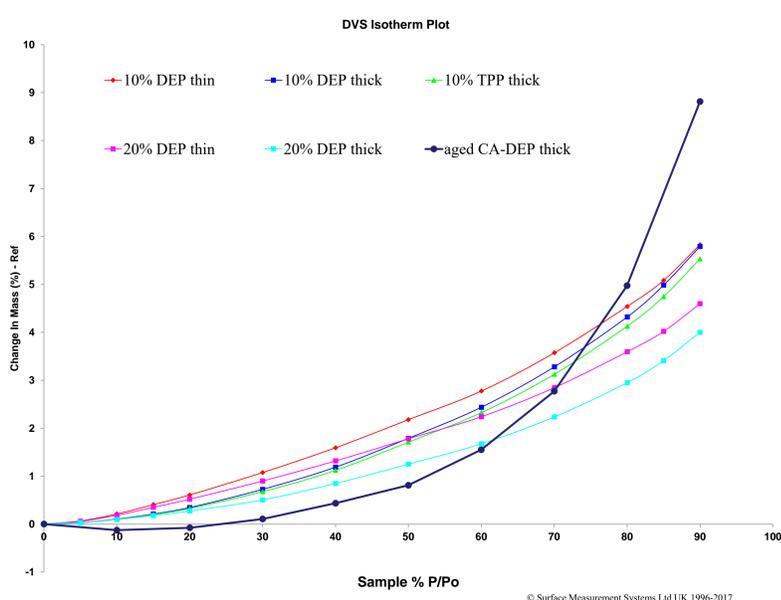


Fig. 2: Sorption isotherms for water at 25 °C in new and aged CA.
Credit: E. Hunter-Sellars.

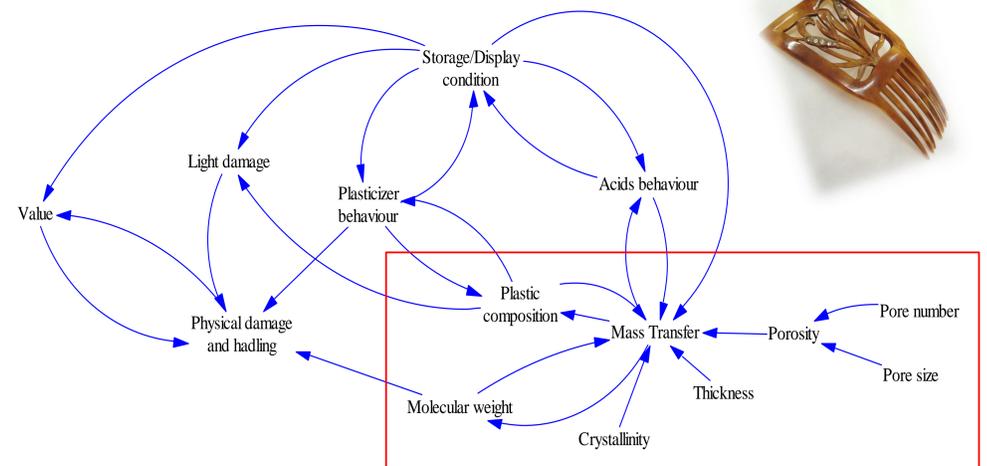


Fig. 1: Simplified example of the system dynamics model used in the project to understand the influence of water vapour sorption and diffusion in museum CA

Results and discussion

In Fig. 1, the change in mass (%) is reported as a function of RH (%) for the cellulose acetate samples.

All the CA plastics present a similar Type III sorption isotherm profile, which indicates strong water-water interactions on the surface and the formation of multi-layers of water [2].

Although DEP and TPP plasticisers have slightly different hydrophobicities (log Kow 2.47 and 4.59 respectively [3]), their behaviour is similar, as it is possible to observe from the thick samples containing 10% DEP and TPP (■—■).

The CA with DEP and TPP show the same profile. As it can be observed, the CA with a higher amount of plasticiser (20%) absorbed a smaller amount of water vapour compared to the samples with 10% plasticiser (▲—■). It is also evident that samples with a higher concentration of plasticiser absorb less water vapour due to the hydrophobicity property of the plasticiser.

The thickness of the sample can act as a barrier to the water uptake mechanism. However, as it is seen in the samples with 10% of DEP (▲—■), at higher percentages of RH, the difference in water uptake between the thin and thick samples of 10% DEP disappears, and water uptake ceases to depend on thickness of the sample. The same however cannot be said for the samples with 20% DEP (■—■).

It is evident that the aged thick CA/DEP (●—■) has an uptake amount of more than 8.81% due to the hydrolysis process. This suggests that the migration of plasticisers is already underway.

Conclusion

This study has shown how the sorption mechanism in a hydrophilic polymer is related to the amount of plasticiser and thickness of the sample which can work as a barrier against water vapour.

The preliminary DVS studies have revealed that the hydrolysis process and the consequent migration and evaporation of the plasticisers results in an increase in the hydrophilicity of the plastic.

DVS has demonstrated to be a suitable technique for the study of water sorption in plastics, providing information on the material's water sensitivity, which can provide guidelines for the conservation of plastics in museums.

References

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