10 CONCLUSIONS

The first aim of this project was to characterise the cure of several epoxy resin systems using dielectric spectroscopy, DSC, FT-IR spectroscopy and rheology measurements. It was hoped to build up an understanding of the cure process and correlate the results produced by the different methods to establish whether dielectric spectroscopy can be used to monitor the cure of epoxy resins in the field without specialist training in interpretation of the results. The second aim was to quantify moisture ingress through gravimetric measurements and dielectric spectroscopy.

The systems studied were chosen after collaboration with the ACLAIM partners, and in particular the partners at Birmingham University. Four commercial systems were supplied through the ACLAIM partners. Additionally, a model system was chosen to be studied by both universities as well as each university having its own model system to study.

Although all of the systems investigated were epoxy-amine-based there were important differences in the functionalities of the systems that may have affected the cure. The main difference being the ratio of the primary to secondary amine which affects the tendency for creation of linear rather or branched chain structures to be formed, and hence affects the network structure.

10.1 Epoxy Resin Characterisation

Although in certain systems a close correspondence between the activation parameters obtained using different methods was observed this cannot be generally assumed to be true in all cases. It would appear that differences can be observed which reflect the ways in which the physical property changes are connected to the controlling molecular processes. As a consequence a reasonably close correspondence is observed between the DSC and FT-IR measurements as these are both measuring directly the conversion of the monomer to the polymer. However,

differences are observed between the measurements based on observations of the extent of reaction and the changes in the rheology (curemeter). The rheology depends on the type of structure that grows in the mixture and depending on whether it is a linear or branched chain growth so the changes in the viscosity will be slightly different. However the values are typically of the same order of magnitude as those found for the measurements of the monomer conversion. The dielectric measurements, although sensitive to the cure process, exhibit activation parameters which can be significantly different from those obtained by other methods. The differences observed can be rationalised on the basis of the influence of the short range molecular mobility of the matrix on the electrical properties.

Each system was characterised using a variety of methods, although due to the viscous nature of two of the systems it was not possible to study them using all of the methods, and differences in the results were observed as noted above. It was hoped to build up an understanding of the cure process and correlate the results produced by to establish whether dielectric spectroscopy can be used to monitor the cure of epoxy resins in the field without specialist training in interpretation of the results. From the results it would seem unlikely that this would be the case, and further development of the equipment as well as better understanding of the behaviour of the epoxy-amine material is required.

10.2 Water Ingress

The water ingress study involved with the investigation of the effect of exposure to water on cured epoxy resin blocks of two of the previously studied systems (Prime20 and the shared model system). Dielectric spectroscopy was used to analyse the blocks, which were periodically removed from the water, and the results were then compared to those generated from gravimetric analysis. Prior to immersion, the glass transition temperature (T_g) of each of the samples was found by using differential scanning calorimetry (DSC). The DSC measurements were also performed to determine the extent of cure which had been achieved.

The gravimetric data and dielectric measurements showed a progressive increase with time reflecting the moisture entering the matrix. An estimated percent uptake of water was calculated from the dielectrics data, and compared to the gravimetric results, with consideration given to the scaling factor (Kirkwood coefficient) required to directly compare the results from each method. Both methods showed a general decrease in water uptake with increasing cure temperature, although effects due to matrix topography and where the cure temperature of the blocks was close to the glass transition temperature, were evident.

For the water ingress study, the dielectric studies indicate the type of water and its distribution whereas the gravimetric data indicates how much moisture is absorbed. Using a combination of the two measurement methods it is possible to obtain a greater insight into the nature of the moisture uptake than using either alone.