Aging Characterization of Polymeric Insulation in Aircraft Wiring

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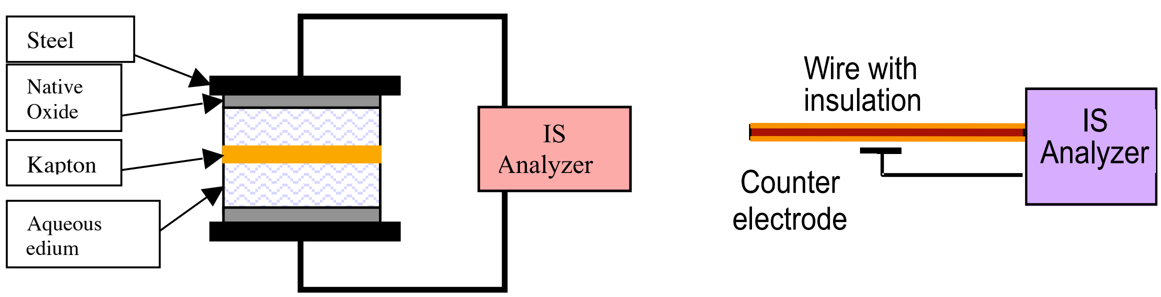
This effort focuses on the problem of aging of electric wire insulation, where our work is to determine the best methods to routinely characterize insulation integrity in existing aircraft as well as to provide insight as to how health monitoring could be installed as an integral component of new aircraft. The project is centered around the development of an impedance spectroscopy technique that could be used as an *in situ* test method for intact wiring. Supplementary characterization methods are also used, such as Fourier transform infrared spectroscopy (FTIR), optical microscopy and scanning electron microscopy. Both naturally aged and laboratory aged wires are being evaluated and several aging mechanisms are being investigated. Results of the research effort will help define the impact of aging factors on wire insulation and provide tools to predict and detect critical degradation levels.

In this talk, we will describe our results utilizing impedance spectroscopy (IS) to evaluate the aging characteristics of two important aircraft wiring polymers, Kapton and PVC. Two key experimental geometries have been investigated to date. The planar aqueous electrode setup (figure 1a) has been developed to investigate polymer film samples in order to obtain a baseline of the dielectric properties of the wire insulation. Further steps have been taken towards developing a reliable geometry for testing single wire (figure 1b).



(a) (b)

Figure 1 Planar aqueous electrode (a) and single wire geometry (b)

Equivalent circuit modeling has been employed to characterize dielectric properties of the insulation materials (figure 2a) as well as the influence of the experimental apparatus. The results agree with experimental data well, where the dielectric permittivity of Kapton can be calculated from the data after removing the influence of the aqueous medium. The results have indicated significant changes in resistivity of Kapton due to moisture absorption, prompting a study of the ionic diffusion phenomenon (figure 2b), where it is seen that the small ionic species degrade the insulating ability of the polymer.

Experiments have also been conducted on PVC to examine the changes in dielectric properties in response to various aging factors including physical aging (figure 3a), chemical aging and temperature. Here we see that the slow volume collapse associated with physical aging results in a slow increase in the impedance of the polymer. The influence of physical aging on the mechanical properties has also been examined where shifts in the timescale of the creep response correlate with the impedance spectroscopy result (figure 3b).

Existing phenomenological and molecular theories are being reviewed to describe the electric behavior of the insulation material under the influence of various aging factors and encouraging results are obtained. Future goals include further efforts on material behavior characterization, experiments on wire samples and development of predictive modeling.

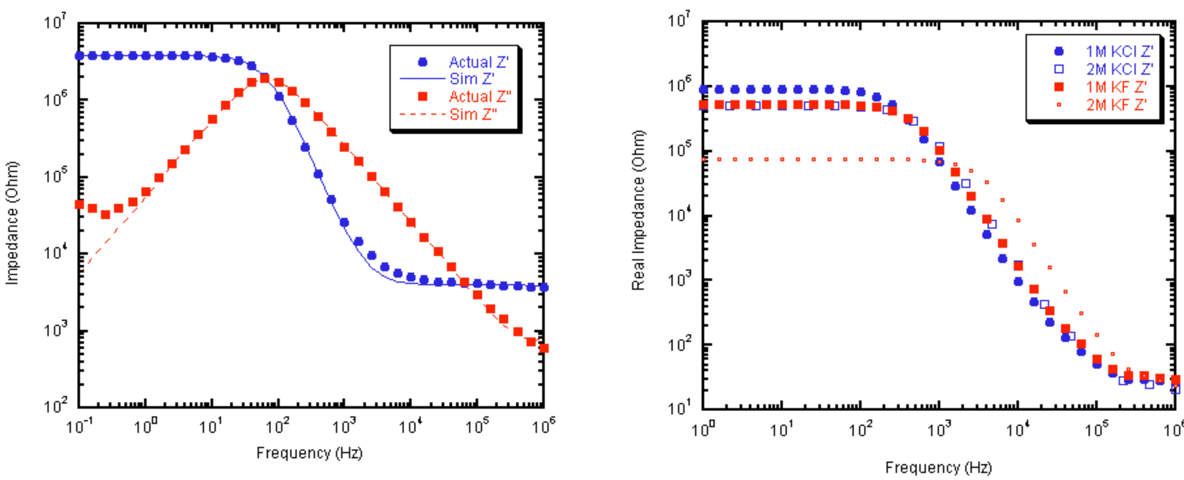


Figure 2 (a) Fit to Kapton impedance data using Equivalent Circuit Model (b) Ionic diffusion with Kapton "swelling" effect – decreased resistance with increasing absorbtion

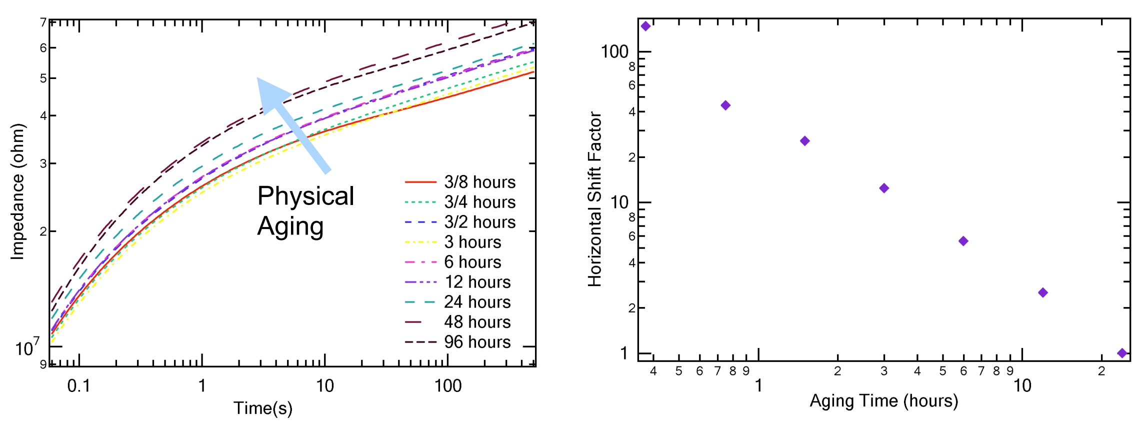


Figure 3: Results for PVC undergoing Physical Aging: (a) Impedance Spectroscopy data shows increase in resistivity with aging
(b) Time-aging Time Superposition of Mechanical Creep Data shows increasing stiffness, embrittlement of polymer with aging