Integrating Rheology and Dielectric Spectroscopy for Polymeric Materials Characterization

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INTRODUCTION: Polymeric materials and composites are essential across various industries, and their complexity demands a deep understanding of their behaviour across different lengths and time scales. Our research focuses on investigating the dielectric and mechanical properties of various polymeric materials by combining rheology and dielectric spectroscopy. Dielectric spectroscopy is a technique employed to study the electrical properties and segmental dynamics of specific polymers, while rheology allows us to analyze bulk mechanical properties and gain insights into the conformational changes in polymeric materials.

METHODS: In this poster, we present the electrical traits of various materials. In Fig. 1 we are showing an example of five different materials of various thickness: BoPET (0.25mm), epoxy (1mm), Carbon black (CB) composite (1mm), graphene composite (1.3mm), and air (1mm).

We used a Dynamic Mechanical Analyzer, MCR702e (Anton Paar), equipped with an Impedance Analyzer to capture the electrical properties of selected materials. Although the measuring system allows capturing both, mechanical and electrical properties in this case, we have used only electrical properties. Through measurement of parallel resistance and capacitance, we determined the complex conductivity of materials in the electrical frequency range between ~1 Hz and $5 \cdot 10^6$ Hz.

RESULTS: Fig. 1 shows the real, $\sigma'(f_e)$ and imaginary part, $\sigma''(f_e)$ of complex conductivity. As expected, air exhibited the lowest dielectric conductivity across all frequencies, maintaining consistent values throughout the mid-frequency range. In the low-frequency range, values become unstable. For BoPET and Epoxy, their dielectric properties are higher than air. Their σ' values were relatively close, with only minor deviations across the examined frequency range. CB Composite and Graphene Composite both filled composites exhibited considerably higher σ' values than pure polymers. Additionally, they showed distinct behaviours from each other, especially in the lower frequency range.

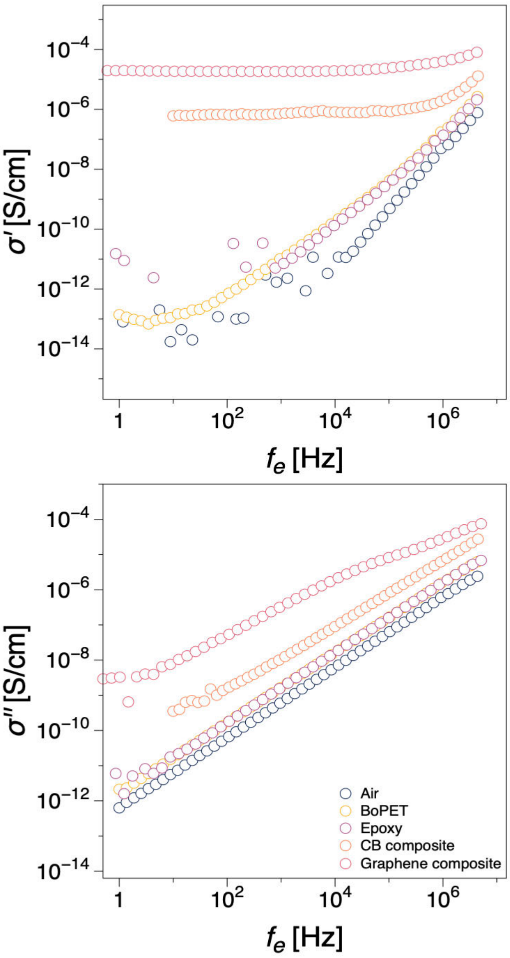

Fig. 1: Complex conductivity.

DISCUSSION & CONCLUSIONS: This example clearly shows that adding (conductive) nano-filler completely changes materials' dielectric properties. While the pure polymeric materials are closer to air (isolator). We can also use the real part of conductivity, $\sigma'(f_e)$ on the low-frequency side and extrapolate it to obtain the DC conductivity $\sigma_0(f \to 0)$.

In the future, we will combine electric and DMA measurements. This will provide valuable insights into the multifaceted characterization of polymeric materials, as we will probe different lengths and timescales within the polymeric material, emphasizing the complementary nature of these techniques.