

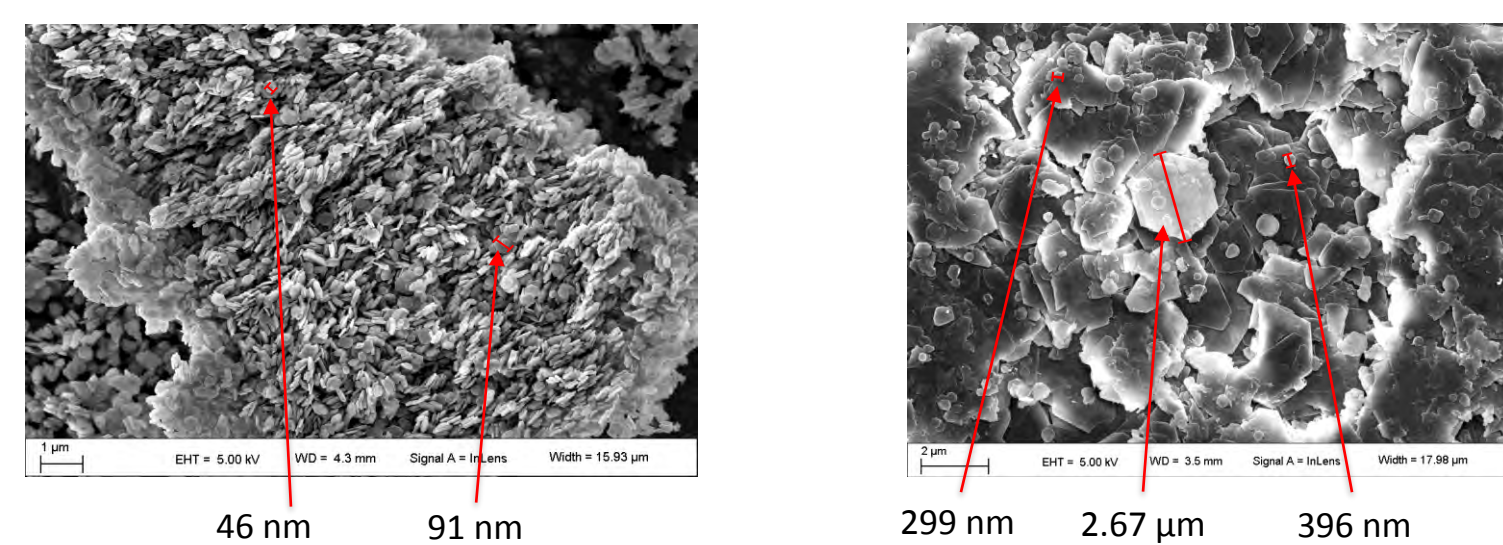
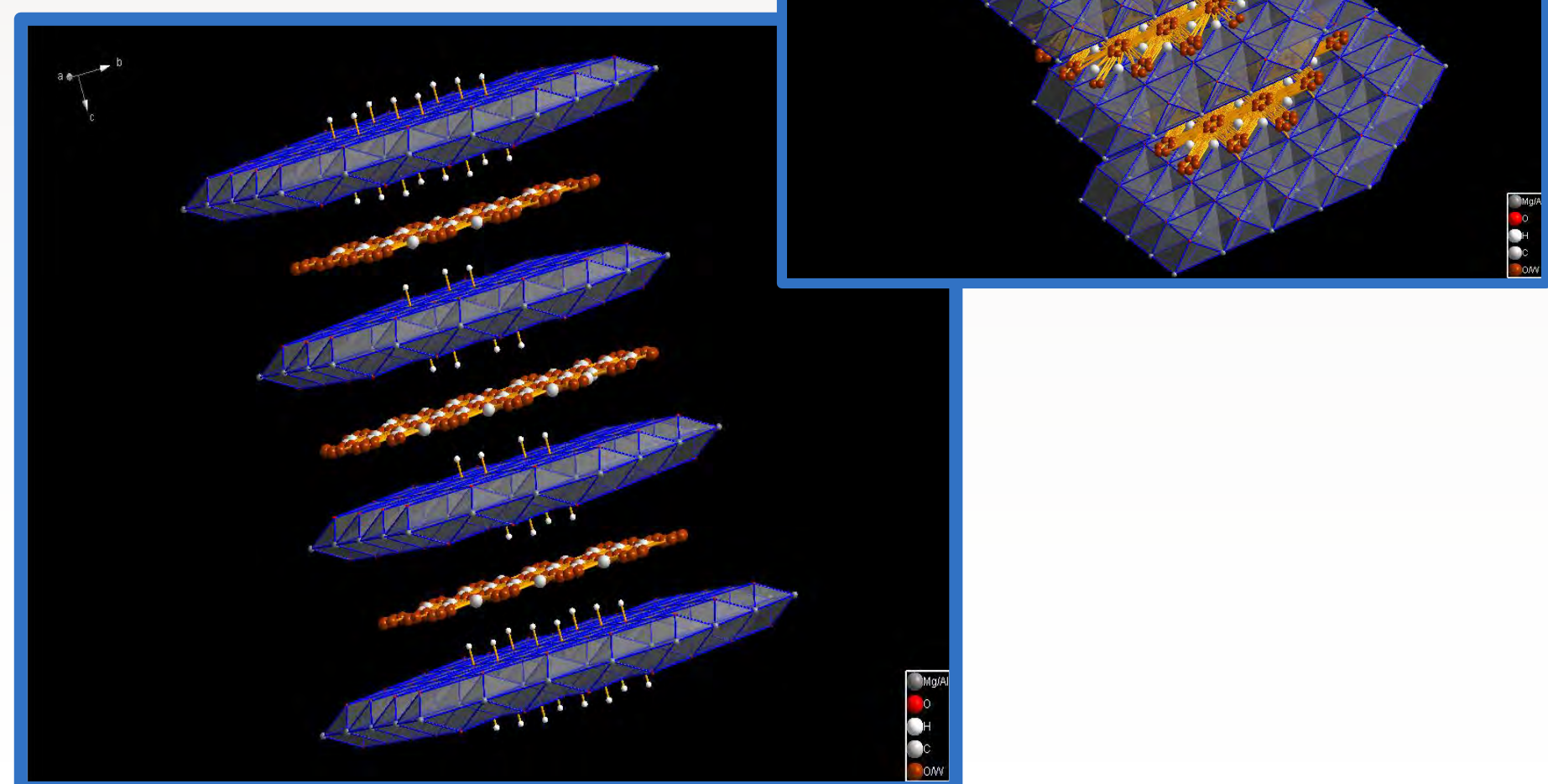
# Polymer Clay Nanocomposite Coatings to Replace or Enhance EVA

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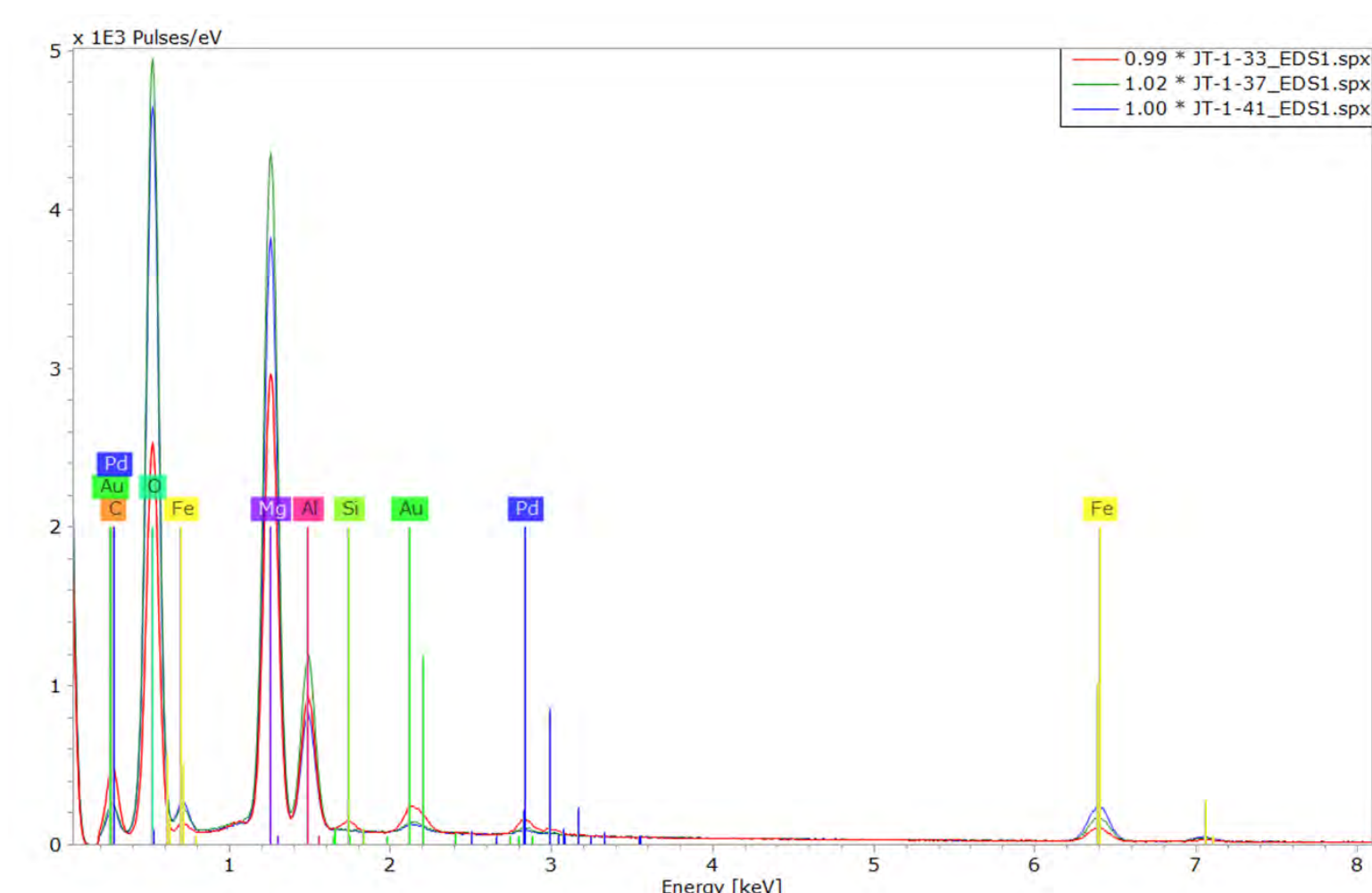
Nanocomposite thin film coatings deposited using a layer-by-layer (LbL) solution process is an emergent technology being used for a variety of applications. Highly ordered LbL polymer-clay nanocomposite (PCN) coatings are produced by alternately dipping a substrate in solutions of charged polymers and then in suspensions of exfoliated, oppositely charged clay platelets. Here we demonstrate layer-by-layer (LbL) deposited polymer clay nanocomposite (PCN) thin films as protective coatings, both to improve O<sub>2</sub> and H<sub>2</sub>O barrier properties of existing encapsulants such as EVA, and to reduce arc-fault flammability of polymer substrates. Two different nanocomposite coatings were synthesized, characterized, and assessed during arc-fault flammability testing. Subject materials included a bilayer (BL) composite coating formed from alternating layers of chitosan and vermiculite clay, and a quad layer (QL) coating formed by repeated sequential deposition of polyethylenimine, poly(acrylic acid), polyethylenimine, and montmorillonite clay. Coated polyethyleneterephthalate (PET) films were exposed to 175 W sustained arcs. The 10 QL (1397 nm thick) and 50 BL (163 nm thick) coatings, those with the highest number of layers, increased the time to combustion relative to bare 175 μm thick PET controls by a factor of three, from 90 seconds to up to 275 seconds. SEM and EDS evaluation revealed the persistence of the coatings to short term arc exposure, with the BL coating displaying a partial peel-away mechanism and the QL coating becoming disorganized at the surface but retaining coverage.

## Tailored Clay Platelet Size and Composition

LDH clays are comprised of easily exfoliated layers separated by exchangeable anions. Each platelet is less than 1 nm thick.

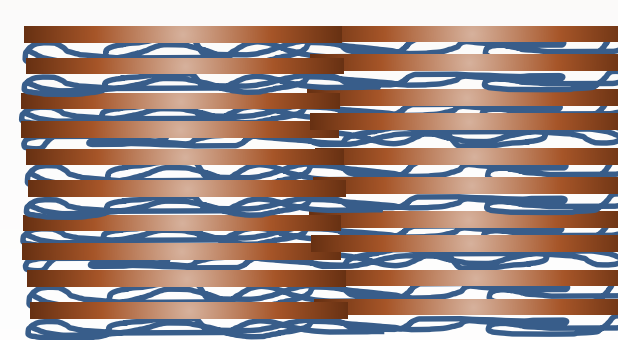
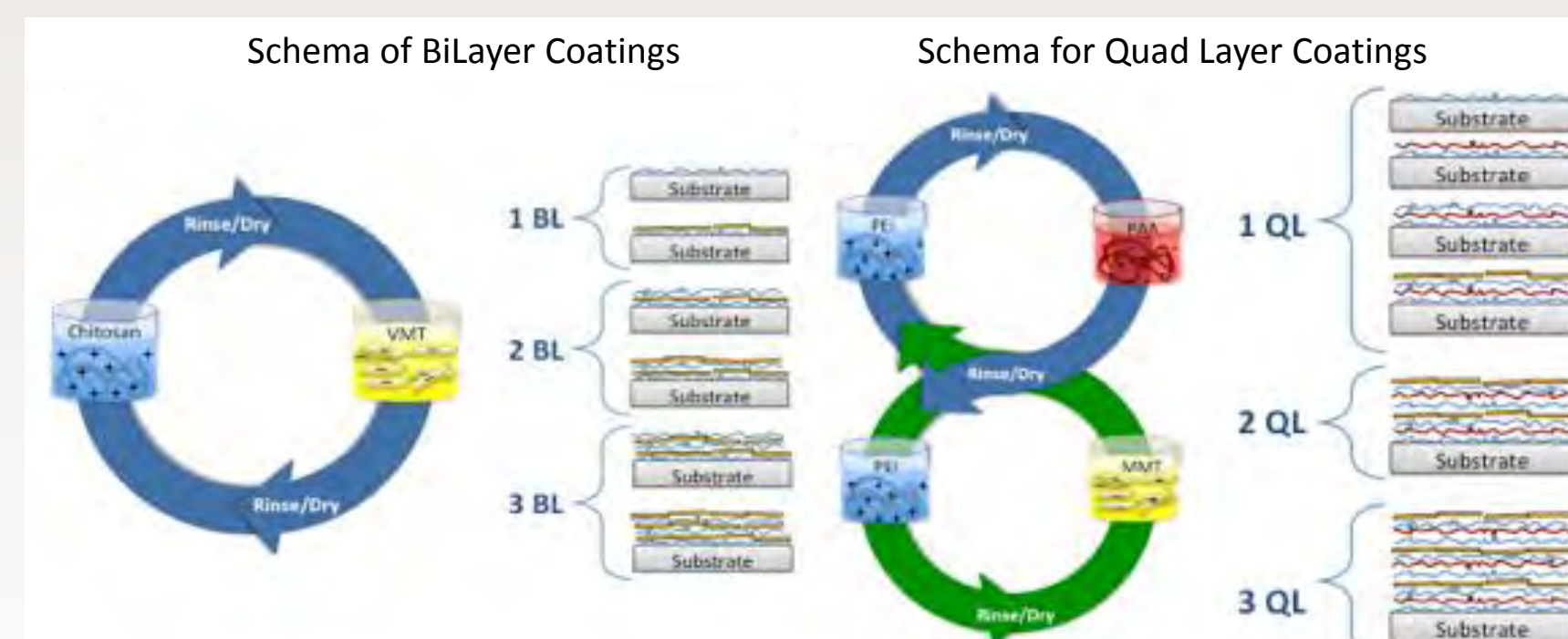


Synthesis temperature and time controls size of clay platelets. Narrow size distribution of 50-90 nm results from low temperature synthesis. Wide size distribution of 300 nm to 2.6 microns results from high temperature synthesis. These clays are now being tested in films to determine the optimum size platelet to enhance the already excellent H<sub>2</sub>O barrier properties of LbL films (<10<sup>-5</sup> g/m<sup>2</sup>/day).

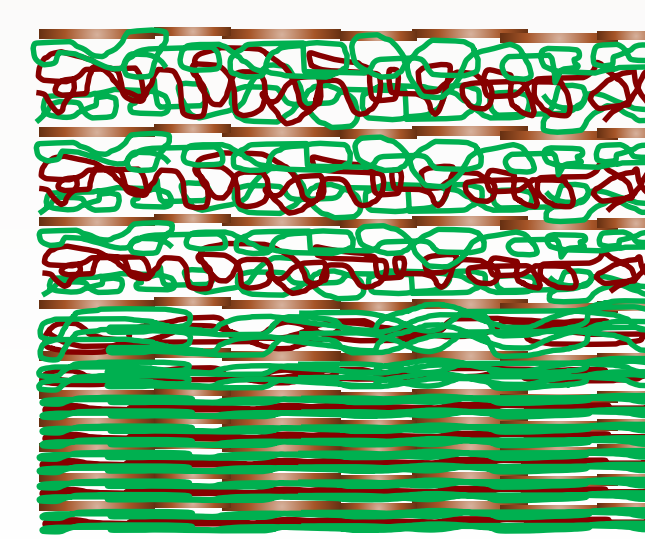


Clays, such as LDH's, readily accept substitution atoms in the metal oxide layer. We have successfully created Fe, Ni, and V partially substituted clays. Substituted Metal oxide layers can be tailored to trap permeating O<sub>2</sub> and H<sub>2</sub>O molecules.

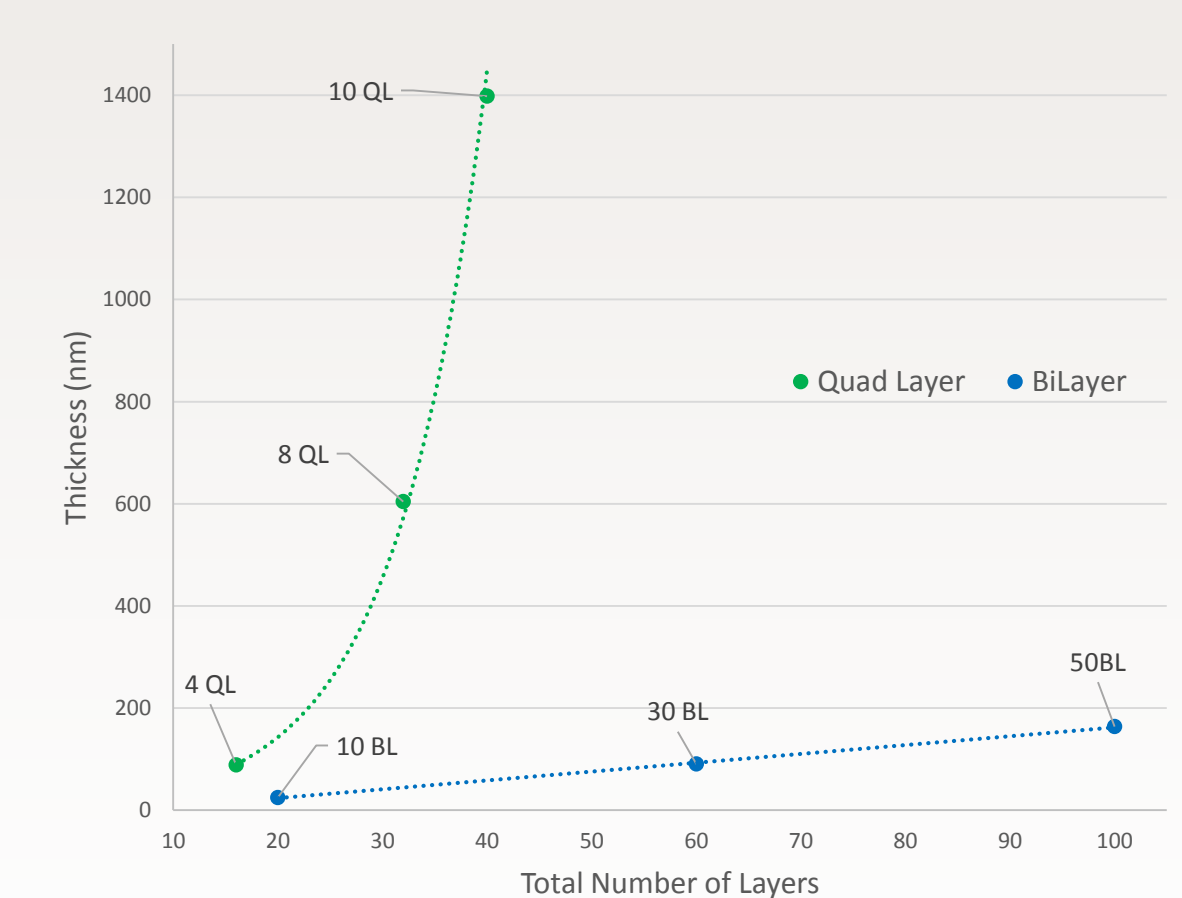
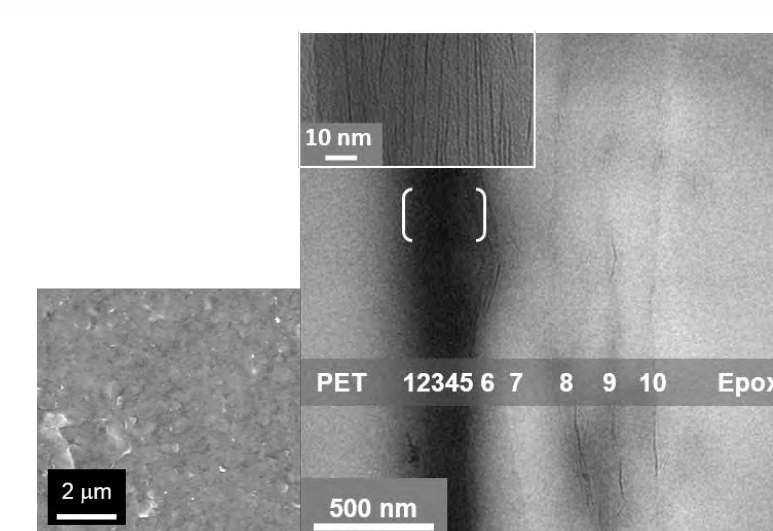
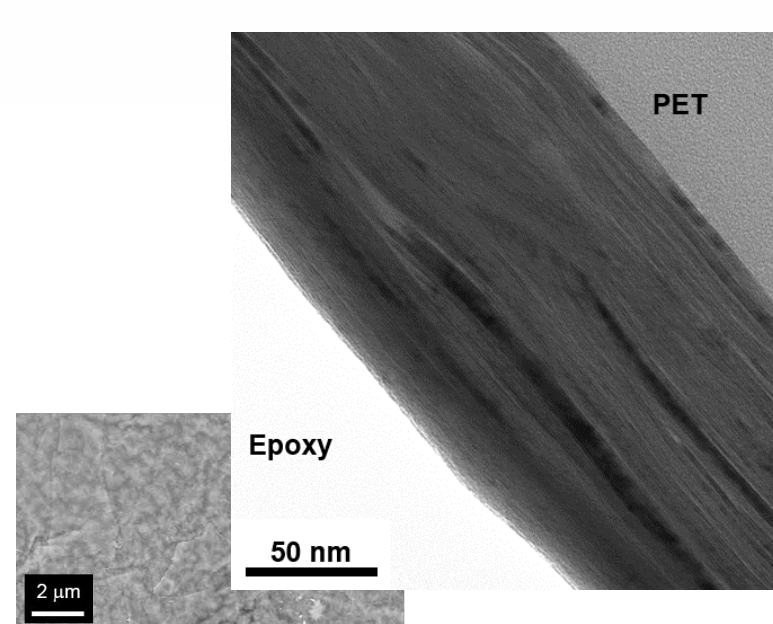
## Layer-by-Layer method of Film Growth



Bilayer Coating

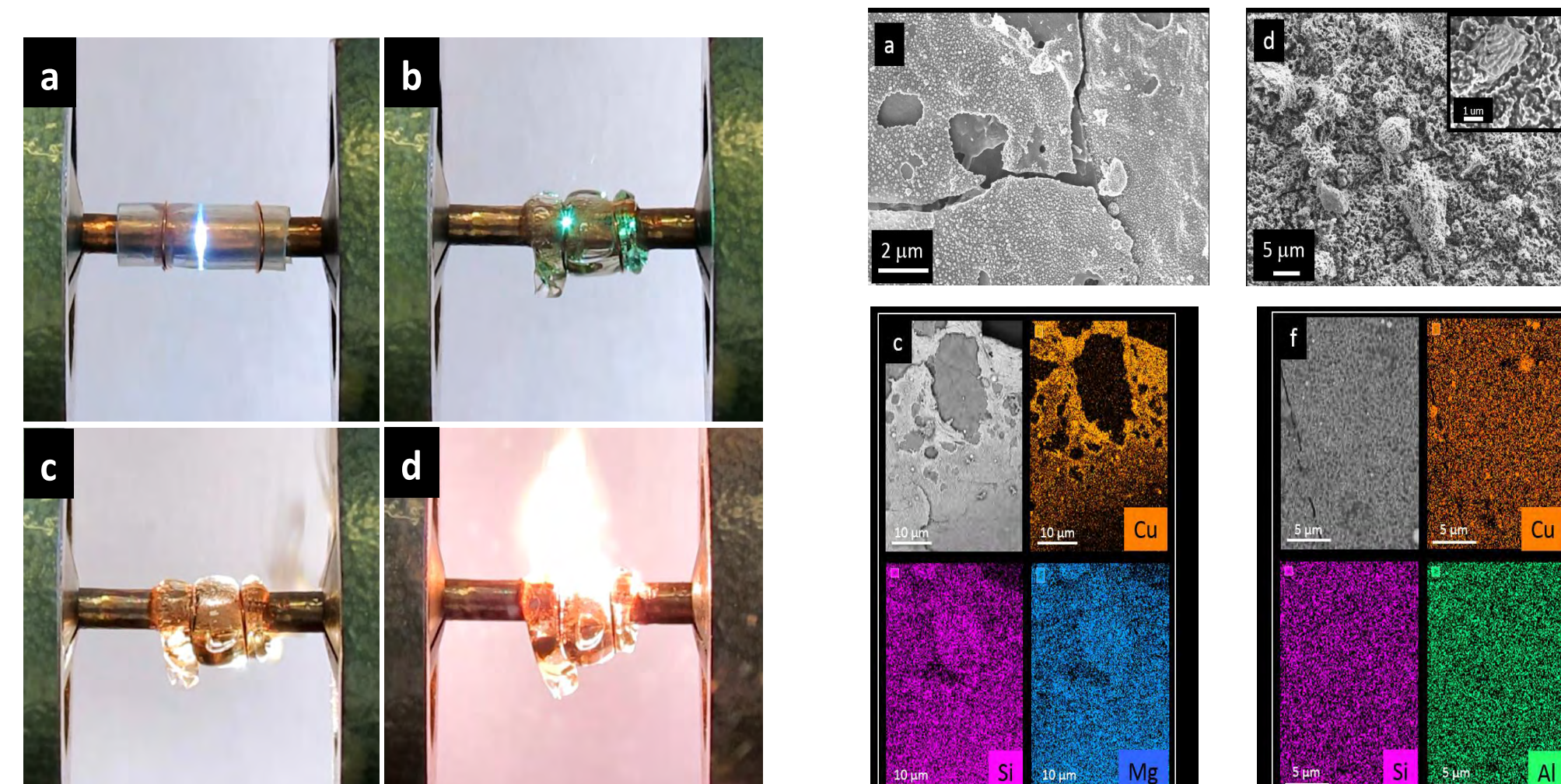


Quad Layer Coating



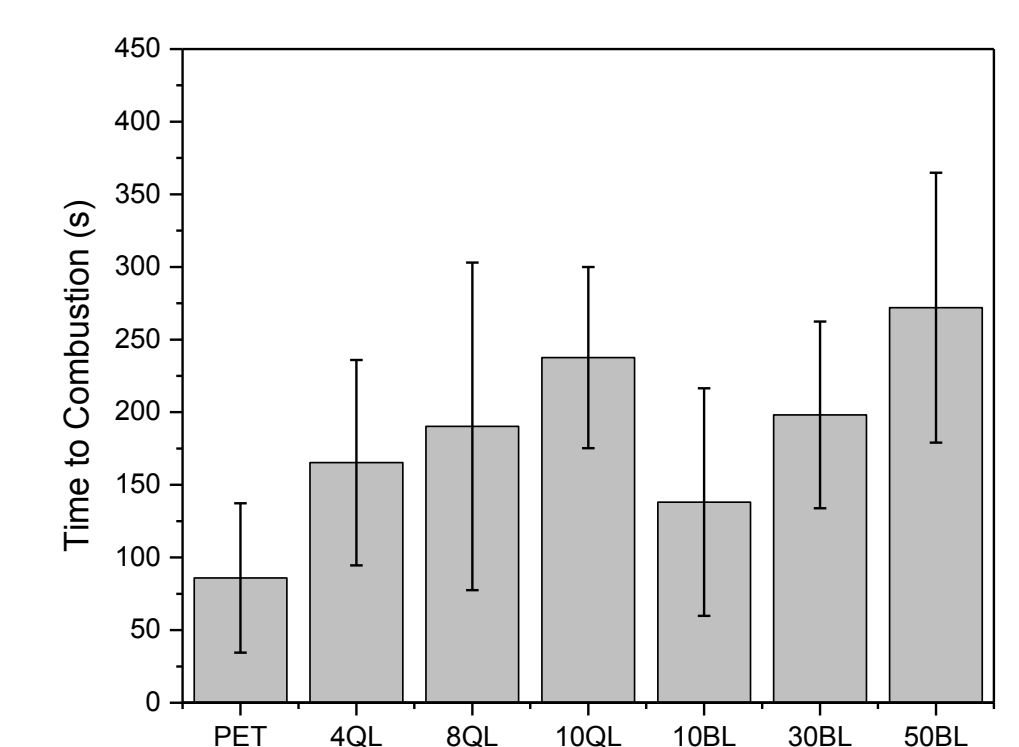
Both BL and QL films exhibit relatively smooth, flat surfaces. The BL films, comprising chitosan and large, exfoliated Vermiculite clay particles, appear as an assembly of large overlapping layered plates several micrometers across. In contrast, the relatively smaller MMT particles in the QL sample create a more finely textured surface. The cross-sectional TEM images highlight two other notable differences between these films. Each image shows the layered structure of the PCN films, where the dark stripes in each image reveal the presence of the strongly oriented, exfoliated clay platelets separated by layers of polymer. In the BL film, these platelets appear consistently spaced through the thickness of the film. The cross-sectional TEM image of the QL sample shows a relatively dense packing of platelets for the first 5-6 layers (clearly visible in the inset image), followed by a much wider spacing between platelets in subsequent layers, likely due to polyelectrolyte inter-diffusion.

## Arc Fault Passivation with PCN Coatings



Sequence of events during an arcing experiment. Pictured here is a test carried out on a 4QL-coated PET film in a tubular EVA sheath. In image (a) a blue plasma is present at the start of a sustained arc between the two copper electrodes. Image (b) was taken 145 s after arc start and just prior to transition to a yellow plasma, shown in image (c). Image (d) was taken upon first appearance of a flame (195s).

Post 10 s arc analysis of BL and QL coatings. a.) SEM surface image of 30 BL coating. c.) BL coating EDS color maps showing resilient coverage of clay (note Si and Mg coverage still complete). d.) SEM surface image of 10 QL coating. c.) QL coating EDS color maps showing resilient coverage of clay (note Si and Al coverage still complete).



Best coatings (10QL and 50BL) resist combustion of substrate by three times as long as bare PET, for 275 seconds as compared to 90 seconds.

Graph depicts average times to combustion for bare PET and PET coated with increasing layers of QL or BL coatings. Error bars represent one standard deviation.