Article

Understanding the Thermal Properties of Precursor-Ionomers to Optimize Fabrication Processes for Ionic Polymer-Metal Composites (IPMCs)

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Abstract: Ionic polymer-metal-composites (IPMCs) are one of many smart materials and have ionomer bases with a noble metal plated on the surface. The ionomer is usually Nafion, but recently Aquivion has been shown to be a promising alternative. Ionomers are available in the form of precursor pellets. This is an un-activated form that is able to melt, unlike the activated form. However, there is little study on the thermal characteristics of these precursor ionomers. This lack of knowledge causes issues when trying to fabricate ionomer shapes using methods such as extrusion, hot-pressing, and more recently, injection molding and 3D printing. To understand the two precursor-ionomers, a set of tests were conducted to measure the thermal degradation temperature, viscosity, melting temperature, and glass transition. The results have shown that the precursor Aquivion has a higher melting temperature ($240{\degree}C$) than precursor Nafion ($200{\degree}C$) and a larger glass transition range ($32–65{\degree}C$ compared with $21–45{\degree}C$). The two have the same thermal degradation temperature (~$400{\degree}C$). Precursor Aquivion is more viscous than precursor Nafion as temperature increases. Based on the results gathered, it seems that the precursor Aquivion is more stable as temperature increases, facilitating the manufacturing processes. This paper presents the data collected to assist researchers in thermal-based fabrication processes.

Keywords: precursor ionomers; material characteristics; Nafion; Aquivion; 3D printing

1. Introduction

 Ionic polymer-metal composites (IPMCs) are one of the smart materials that have been studied by many researchers [1–4]. IPMCs have an ionomer base with a noble metal plated onto the surface. When a voltage is applied to the IPMC, the cations within the membrane are pulled towards the negatively charged side, causing it to swell and forcing a bending motion. The smart material can also act as a sensor when it is deformed [5–7]. The movement of the cations within an ionomer can generate a small amount of voltage that can be amplified.

 Nafion is usually the ionomer chosen for IPMCs. Nafion is an ideal option, as it is chemically stable and has good conductivity and material properties [8–10]. Many have studied ways to improve the properties of Nafion. However, the most critical characteristic of Nafion is its ionic conductivity and ion exchange capacity. Since there has not been a way to change this value directly other than in-depth chemistry approaches, a convenient solution is to choose another ionomer with a higher