Developing Earth-Abundant Aluminum-Ion Batteries Using Chloroaluminate Ionic Liquid Electrolytes and Recycled Aluminum Scraps for Electric Vehicles and the Electricity Grid

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Rechargeable batteries are powering the rise in plug-in electric vehicles and intermittent renewable energy storage/transport/utilization in the electricity grid. Aluminum-ion batteries hold great promise for large-scale energy storage based on their fast-charging capability, earth-abundant resources, and lower raw-material cost. Using highly conductive AlCl3/EMIC ionic-liquid electrolytes, this study tested the hypothesis that the compositional fluctuations of electrolytes will effectively modulate their ionic conductivity and charge transfer efficiency. The effects of ionic-liquid electrolyte compositions (AlCl3 to EMIC ratios: 1:1, 1.3:1, 1.5:1) and highly conductive/low-viscosity additives on the chloroaluminate anions concentration and conversion were explored. In this research, a new group of ionic-liquid electrolytes was studied by mixing EMIC with different ratios of AlCl3. Each sample was analyzed using Raman spectroscopy and the concentration of chloroaluminate anions (AlCl4- and Al2Cl7-) were quantified. Dichloromethane was also used as an additive and its effect on the ionic conductivity and viscosity of ionic liquids was examined. Among three ionic-liquid electrolyte compositions with Dichloromethane, AlCl3/EMIC with 1.3:1 ratio showed the highest ionic conductivity (8.6 mS/cm) and a significantly higher discharge capacity (80 mAh/g) compared to the composition without the additive. This study showed that the balanced AlCl4-:Al2Cl7- ratio is critical for the charge/discharge process in high-performance aluminum-ion batteries. These results yield fundamental insights into ionic-liquid electrolyte design for optimal aluminum-ion battery performance and potential applications in large-scale electric vehicles and the electricity grid.