Mechanistic Insights into the Piezoelectric effect in Ionic Liquids. Implications for Sensing Applications

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The piezoelectric effect is well established in solid state materials that possess a center of inversion, and in a variety of composite materials. The piezoelectric effect has found extremely broad utility in sensing, with the ubiquitous deployment of accelerometers and as actuators in STM and AFM instruments, for example. Until our recent report,[1] the piezoelectric effect was not known to exist in liquids. Our work with ionic liquids has demonstrated both the direct and converse piezoelectric effects. The existing theory for the piezoelectric effect in solids couples Hooke's law and the displacement of charge in a dielectric, both of which are not easily reconciled with the physical properties of ionic liquids. Through an examination of several ionic liquid, we have determined that the application of compressive force to the ionic liquid causes a liquid-to-solid phase transition, and it is the solid form of the ionic liquid that is responsible for the piezoelectric response.

We have developed a means to quantitatively evaluate the piezoelectric coefficient, d33, of room temperature ionic liquids (RTILs) and use this methodology to understand how d33 varies with RTIL cation structure. The d33 quantitation method we developed also enables evaluation of the average size of pressure-induced, piezoelectrically active RTIL crystals. We evaluated d33 for RTILs composed of seven different cations and the common anion bis(trifluoromethylsulfonyl)-imide (TFSI–) and find that its magnitude varies predictably with the extent of conjugation and the length of the cation's aliphatic chain. These findings offer insight into how the constituent ion structures of RTILs can be rationally optimized to enhance piezoelectric activity. With this information in hand, we consider some of the most promising areas for the application of the piezoelectric response of RTILs.