Liquid metal salts

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Although ionic liquids are often touted as supersolvents and although they possess remarkable solvent properties such as the ability to solubilize the high-molecular weight fraction of bitumen (kerogen), ionic liquids with weakly coordinating anions (e.g. Tf2N-, BF4-, PF6-, TfO-) are poor solvents for metal salts and metal oxides. This is a disadvantage for applications that require high concentrations of dissolved metal ions, e.g. the electrodeposition of metals. However, high concentrations of metal ions in ionic liquids can be obtained by designing ionic liquids with a metal complex as an integral part of their chemical structure. Most known ionic liquids of this type contain anionic metal complexes and these ionic liquids are not very interesting to electrodeposit metals from. The concentration of anionic complexes close to the cathode is potential-dependent and at the very negative potentials required for the electrodeposition of reactive metals the metal concentration can be too low to initiate nucleation of the metal at the cathode. Compounds with the [Cu(CH3CN)4]+ cation and BF4-, PF6-, ClO4-, or OTf- anions have been described in the literature and they are useful precursors for the synthesis of other copper(I) coordination compounds or as catalysts. In general, these compounds have high melting points or even decompose without melting. We have discovered that by a suitable choice of the anion it is possible to obtain complexes with much lower melting points. For instance the tetrakis(acetonitrile) copper(I) complex with the bis(trifluoromethylsulfonyl)imide ligand, [Cu(CH3CN)4][Tf2N], melts at 65 °C. [Cu(CH3CN)4][Tf2N] can be considered as a genuine ionic liquid and also as a liquid metal salt. This compound with a central copper(I) ion is an inorganic analogue of tetraalkylammonium or tetraalkylphosphonium cations. Two CH3CN ligands are removed at elevated temperatures to give [Cu(CH3CN)2][Tf2N], which can be used as a concentrated non-aqueous electrolyte. Because the copper(I) ion is a main component of the ionic liquid cation, the copper concentration is the highest achievable for an ionic liquid and this permits to obtain a good mass transport and high current densities for electrodeposition. Pure, crack-free copper layers can be deposited from these copper-containing ionic liquids in unstirred solutions at current densities up to 25 A dm−2. Several liquid metal salts other than [Cu(CH3CN)4][Tf2N] have been obtained.