

Fig. 6 Effect temperature on the cyclic voltammograms recorded on a platinum electrode in ChCl:2urea ionic liquid containing  $0.1 \text{ mol}\cdot\text{L}^{-1} \text{ CrCl}_3\cdot 6\text{H}_2\text{O}$  with a scan rate of  $10 \text{ mV}\cdot\text{s}^{-1}$ .

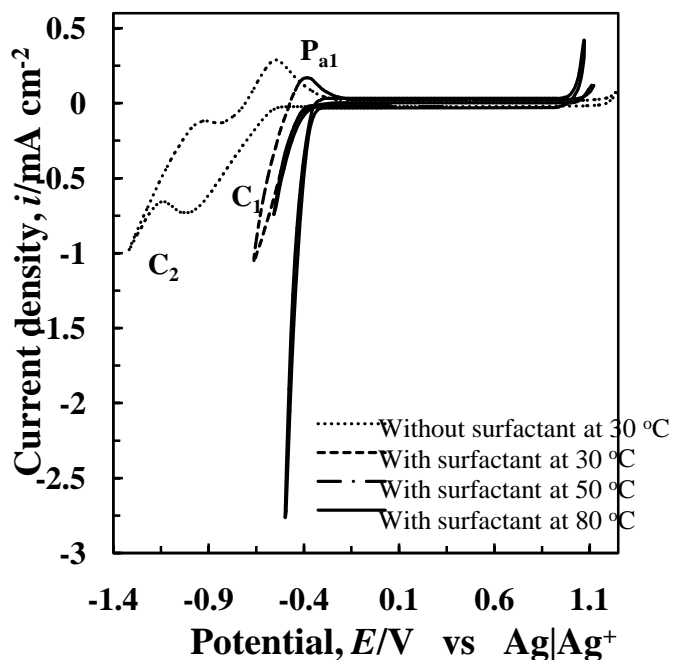


Fig. 7 Effect of surfactant and temperature on the cyclic voltammograms recorded on a platinum electrode in ChCl:2EG ionic liquids containing  $0.10 \text{ mol}\cdot\text{L}^{-1} \text{ CrCl}_3\cdot 6\text{H}_2\text{O}$ .

Figure 6 shows the temperature effect of ChCl:EG:  $\text{CrCl}_3\cdot 6\text{H}_2\text{O}$  ionic fluid with a scan rate of  $10 \text{ mV}\cdot\text{s}^{-1}$  on the cyclic voltammograms measured on a platinum electrode in 1:2:0.10 (mole ratio). From voltammograms it is readily seen that the starting potentials of chromium deposition and dissolution are unchanged with temperature rise. At the other hand, with the rise in temperature the magnitudes of the deposition and dissolution current densities decrease. This implies inert metallic complex being formed to increase the temperature.

Figure 7 shows the effect of surfactant ( $0.10 \text{ g}\cdot\text{L}^{-1}$  polyethylene glycol and  $40 \text{ mL}\cdot\text{L}^{-1}$  formic acid mixture) and temperature on the cyclic voltammograms obtained on a platinum electrode in 1:2:0.1 mole ratio of ChCl:EG: $\text{CrCl}_3\cdot 6\text{H}_2\text{O}$  ionic liquid with a scan rate of  $10 \text{ mV}\cdot\text{s}^{-1}$ . From the voltammograms it is easily shown that the capacity for chromium deposition and dissolution starts in anodic and cathodic direction, respectively on the addition of  $0.10 \text{ g}\cdot\text{L}^{-1}$  polyethylene glycol and  $40 \text{ mL}\cdot\text{L}^{-1}$  formic acid mixture as surfactant and with the rise of temperature. The difference between the onset voltage of chromium deposition and dissolution is  $0.168 \text{ V}$  ( $0.354 \text{ V}$  without surfactant) suggesting the quasi-reversible existence of improvements in the reversible form of chromium deposition in this ionic liquid by applying a surfactant at  $80 \text{ }^\circ\text{C}$ . The explanation behind this may be due to the high change in temperature of the metallic complexes in this ionic liquid. At the other hand, with the introduction of surfactant and the increase in temperature, the magnitudes of the reduction and oxidation current densities are also rising. Cathodic sweeping potential studies on the cyclic voltammograms (inside of Fig. 7) show that the first ( $C_1$ ) and second ( $C'_1$ ) reduction waves correspond to the first oxidation peak ( $P_{a1}$ ). With the presence of  $0.10 \text{ g}\cdot\text{L}^{-1}$  polyethylene glycol and  $40 \text{ mL}\cdot\text{L}^{-1}$  formic acid mixture as a surfactant at temperatures above  $45 \text{ }^\circ\text{C}$ , pure chromium was extracted from this ionic liquid containing  $\text{CrCl}_3\cdot 6\text{H}_2\text{O}$  by constant potential and constant current methods.

#### 4. CONCLUSIONS

This research shows that ionic liquid can be used as electrochemical solvents, based on eutectic mixtures of choline chloride and hydrogen bond donors such as ethylene glycol. With the increased concentrations of  $\text{CrCl}_3 \cdot 6\text{H}_2\text{O}$  added to the ionic liquids suggest the higher discharge levels of chromium ions at low overpotentials. Inert metallic complex is formed on temperature rises. Regardless of the transition of metallic compounds in this ionic liquid at high temperatures, the quasi-reversible aspect of chromium deposition shifts to reversible in aspect when surfactant is applied at 80 °C. The magnitudes of the existing densities of reduction and oxidation are therefore increased when the surfactant is applied and the temperature rise.

#### ACKNOWLEDGEMENTS

The authors gratefully acknowledge the financial support of the Ministry of Science and Technology, Peoples' Republic of Bangladesh for carrying out this work.

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