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Anodic Electrodeposition of Gold from Liquid Ammonia Solutions

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The electroplating of metal and alloys, which is of importance in numerous applications, has always been accomplished by cathodic deposition (1-3). For example the industrially important process of gold electroplating is usually carried out by reduction of the gold(I) species from slightly acidic cyanide media. We report here the first example of anodic electrodeposition of gold by oxidation of auride ion (Au^-) in a liquid ammonia solution.

Recent results have demonstrated the formation of Au^- by reaction of gold metal with coulometrically generated solvated electrons (e_s^-) in liquid NH_3 containing 0.1 M KI at -40°C (4) or by reaction of Au with Cs metal in liquid NH_3 (5). The experimental procedures and apparatus for liquid NH_3 studies have been reported previously (6,7). A typical experiment involved the introduction of Au metal in liquid NH_3 containing excess e_s^- in a large coulometric cell. When the solution was kept at -40°C and stirred, the Au dissolved with the formation of Au^-. Alternately, the Au^- could be produced by starting with a solution of AuI in liquid NH_3. A typical cyclic voltammogram of such a solution at a Pt-electrode is shown in Fig. 1. Controlled potential electrolysis at -0.5 V resulted in the deposition of Au on the Pt working electrode. When the electrode potential was moved to the generation of e_s^- (-2.5 V), the freshly deposited gold was cathodically stripped. The cyclic voltammogram of the resulting solution after excess e_s^- was removed coulometrically, indicated the presence of an anodic wave at -2.15$_0$V corresponding to the oxidation of Au^- to Au. The electrolytic oxidation in the solution (at -2.0 V) resulted in deposition of Au on the Pt anode surface. The gold plate produced in this way was bright and could be polished to a high luster. Examination of the surface by ESCA spectroscopy showed strong bands at binding energies of 82, 85, 332, 350, and 545 eV, characteristic of metallic gold.

While it is difficult to project from these preliminary experiments whether this method of electrodeposition will be of practical use, this procedure does avoid the use of cyanide. Moreover, the oxidation of Au^- occurs with 100% current efficiency without the coevolution of hydrogen which occurs during the cathodic deposition in aqueous media. Finally liquid ammonia provides the unique opportunity to examine the course and nature of deposition of a metal both cathodically and anodically in the same medium.

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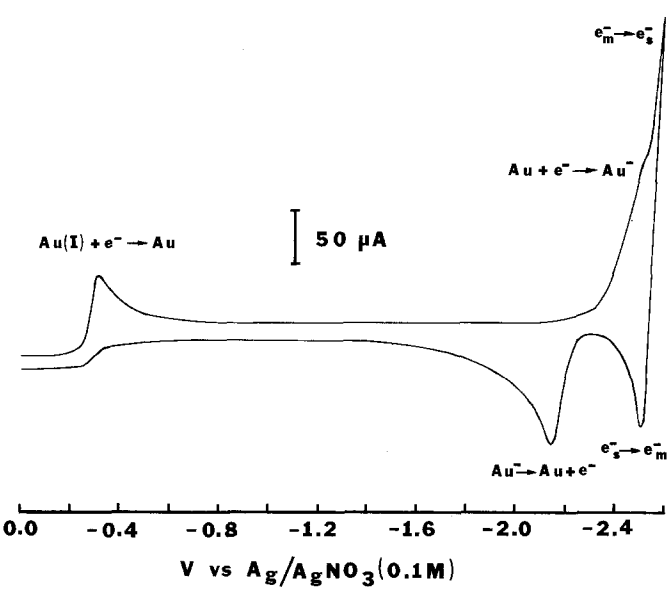

Fig. 1. Cyclic voltammogram of a 6.3 mM AuI in liquid NH_3 containing 0.1 M KI at -40°C. Scan rate 0.1 V/sec. Electrode area 0.039 cm^2.

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