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AgI-KI THIN FILM SOLID STATE BATTERY

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Solid state batteries are of vital importance for micro electronics development. Attempts are being made to incorporate thin film solid state batteries in integrated circuits as built-in micro power sources. AgI based compounds are promising solid electrolyte materials for such batteries. The AgI-KI thin film solid electrolyte obtained by electrolytic method is studied for its suitability as a battery electrolyte and the results are reported in this paper.

The system Ag/AgI/KI thin film I^+_2 C gave V_{oc} = 655 mV and I_{sc} = 300 A cm^{-2}. To avoid iodine in the cathode as it reduces the life of the battery due to its instability, tellurium has been tried as cathode. The discharge characteristics of these two cells are studied and compared.

Key words: Thin film, AgI-KI system, battery

INTRODUCTION

Solid state batteries can be made either in pellet form or in thin film form. The great majority of papers and patents reported on this subject deal only with pellet type of batteries. The ultimate aim is miniaturization in addition to long shelf life. By adopting this film technique, it is possible to achieve this. A few review papers [1-3] highlight the importance and variety of solid state batteries. Apart from Ag^+ conducting thin film batteries, those based on Li^+ [4-5], F^- [6], Cl^- [7] conductors have also been reported.

There are several methods to prepare thin film solid electrolytes. Chemical vapour deposition (CVD), flash evaporation, activated reactive evaporation (ARE), rf-sputtering, electrodeposition and ion plating are some of the widely used techniques [8-9]. The electrodeposition method is used in the present study on AgI-KI.

It is well known that cation substituted AgI based compounds of type MAg_4I_5 show high conductivity [10]. Thin films of KAg_4I_5 has been prepared [11] by electrolytic deposition and its various characteristics have been studied. The conditions for obtaining KAg_4I_5 film having conductivity comparable to those of the bulk material have been optimised. The same conductivity values have also been reported [12] for thin film of this compound obtained by vacuum evaporation. The present study is aimed at making a thin film cell with KAg_4I_5 as electrolyte and suitable electrodes.

EXPERIMENTAL

KAg_4I_5 film was deposited on a silver substrate by electrolytic method. All the conditions were similar to those reported earlier [11]. A dilute aqueous solution of KI was the electrolyte and it was maintained at 318K during electrolysis. A constant current of 2 mA cm^{-2} was passed using a current regulator for about 80 minutes. The thickness of the deposited film was around 20μ m.

The following two cell configurations were tried:

$Ag/KAg_4I_5/I_2$ + C .. Cell I
$Ag/KAg_4I_5/Te$ .. Cell II

The silver substrate on which the KAg_4I_5 film was deposited acts as the anode. The cathode of Cell I was a thin film of a mixture of aquadag (colloidal solution of graphite) and iodine. The cathode of cell II was a thin film of tellurium obtained by vacuum evaporation method.

The optical absorption spectra of the thin film was recorded using a Hitachi U-3400 spectrophotometer.

DISCUSSION

The phase of AgI-KI system has already been studied [13] and it was found that the compound KAg_4I_5 is stable between 311 and 526K. Electrodeposited films of AgI + MI have been characterised [14], and the formation of the compound MAg_4I_5 has been confirmed. In the present study, even though the film was obtained at 318K, all measurements were made at 303K (room temperature).

Cell I gave an open circuit voltage (V_{oc}) of 655 mV and short circuit current (I_{sc}) of 300μ A cm^{-2}. The discharge characteristics at two different loads and two different currents were studied. The voltage of the cell dropped to 250 mV within 15 minutes when it was connected to a load of 50 kohm and this is shown in Fig.1. The cell can be used continuously for nearly 3 hours at 200 mV under a load of 50 kohm and 1½ hours under a load of 25 kohm. Fig.2 shows the variation of voltage with time when the cell is discharged at constant currents of 10 and 20μ A. In this case also, the cells gave a current of 10 and 20μ A continuously only for 3 and 1½ hours respectively at the working voltage of 200 mV. Therefore the current capacity of the cell is approximately 30μ Ah.

As iodine vaporization is considered to be the main cause of the short life of such a cell, a layer of Te was used as cathode in cell II. This cell gave V_{oc} = 180 mV and I_{sc} = 30μA cm^{-2}. The discharge characteristics of this cell were not studied as the voltage and current were very much lower than those obtained for those cell with iodine.

To confirm the composition (4AgI + KI) in the thin film, the electronic absorption spectrum was recorded in the diffuse reflec-

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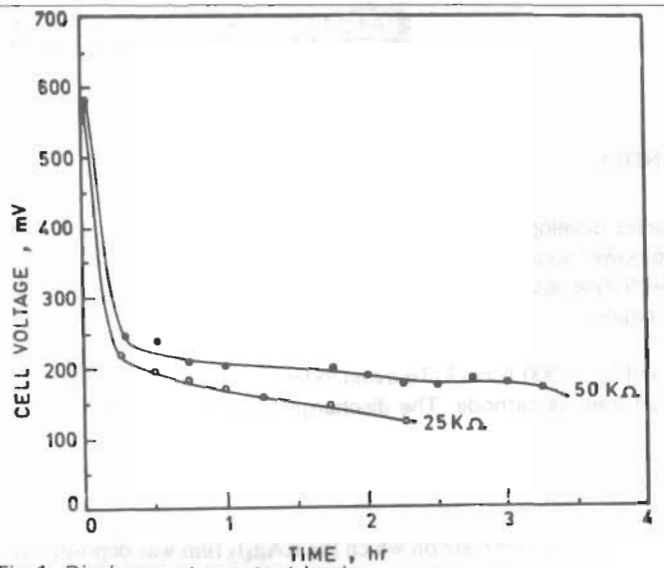


Fig.1: Discharge at constant loads

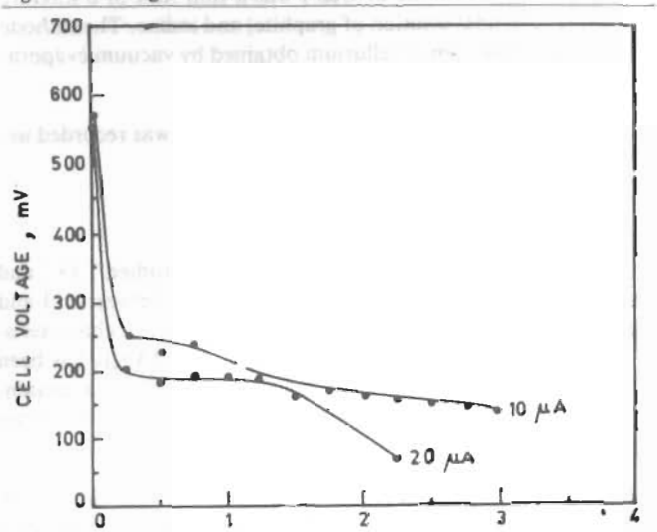


Fig.2: Discharge at constant currents

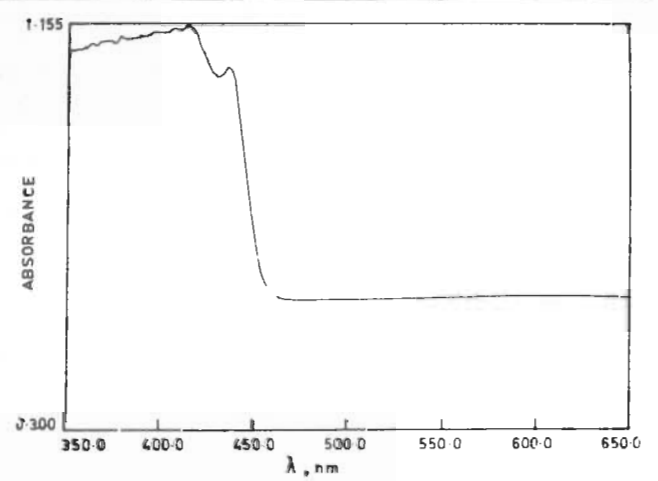
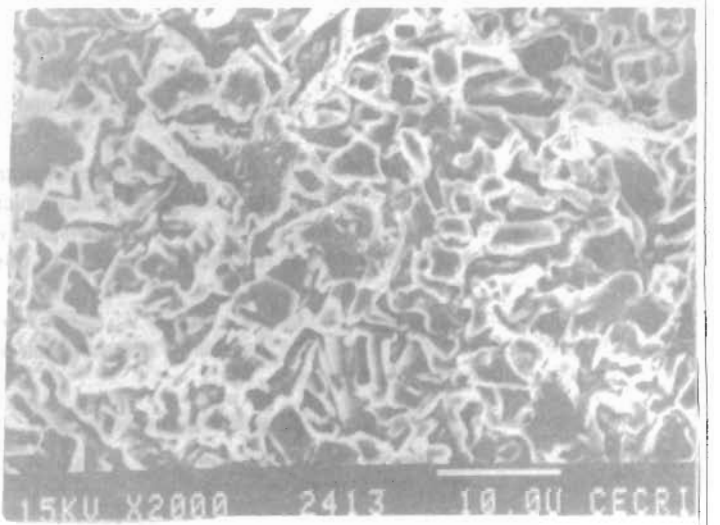
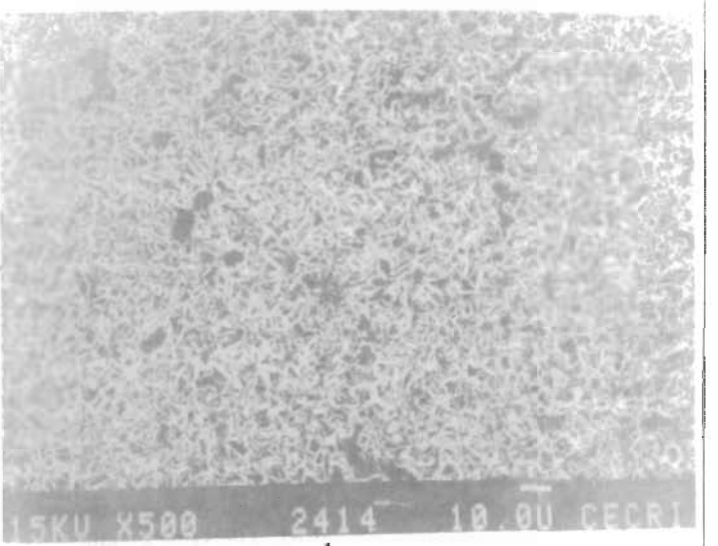


Fig.3: Absorption spectrum of KAg_4I_5 thin film



a



b

Fig.4: (a) and (b) SEM photomicrographs at two different magnifications.

tance mode. An absorption peak around 4350 A was observed as expected [13] and the spectrum is shown in Fig.3. This peak corresponds to a band gap of 2.85 eV, which satisfies the condition [15] that the electronic band gap of a good solid electrolyte must be always larger than (T/300) eV.

Figs.4(a) and (b) are the SEM photomicrographs of the film at two different magnifications. The high magnification figure indicates that the film consists of polycrystalline material and individual crystallites/grains are recognizable. The low magnification figure shows that the electrodeposited film has more or less uniform grain size throughout the specimen.

The short life of this thin film cell may be attributed to the following factors. The temperature of operation must be above 311K. But in the present study, the measurements were taken only at room temperature, which might have resulted in deterioration of the material. The second factor is the use of free iodine as cathode. The free iodine gets easily vaporized shortening the life of the cell. The tellurium cathode also has not improved the performance of the cell. Therefore, suitable long lasting iodine based cathode must be developed. Iodine in either organic or inorganic complex form may improve the cathode performance.

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