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Invited

Device Physics Ferroelectric Thin Film Memories

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1. Introduction

Two questions of highest priority at present for the development of both ferroelectric dynamic DRAMs and ferroelectric nonvolatile FeRAMs are the band match-ups at the electrode-dielectric interface and the ultimate ability to scale lateral capacitor cell sizes to the submicron lengths required for ULSIs. Recently we determined [1] via XPS and uv absorption band matchups for strontium bismuth tantalate NV FeRAMs and barium strontium titanate [1]. DRAMs (SBT/Pt and BST/Pt) with the results shown in Fig. 1. This result agrees with experimental values of Schottky barrier height [2-6] and involves a large (ca. 0.8 eV image reduction term). We have confirmed the 2.1 eV surface state energy via EELs to be Bi.

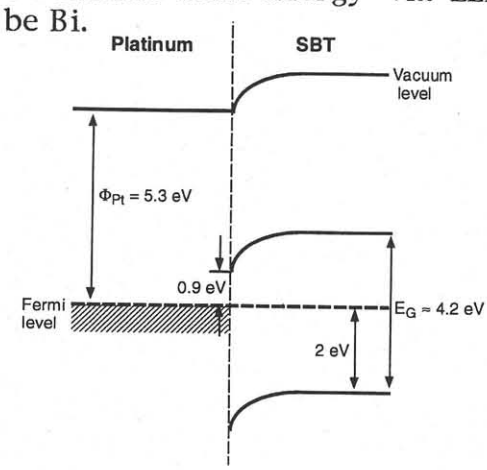

Fig. 1 Band structure of SBT/Pt [1].

2. Non-Schottky Behaviour

With Bi excess or Bi electrodes SBT and BiT [bismuth titanate ($Bi_4Ti_3O_{12}$)] exhibit ohmic contacts up to ca. 0.6-1.0 V and space-charge-limited quadratic current-voltage J(V) behaviour (SCLC) above that. [7] This is especially true of submicron width cells, such as the BiT device shown via TEM in Fig. 2.

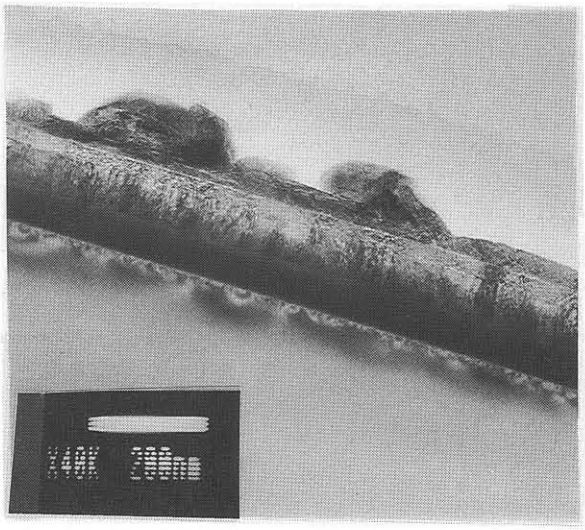

Fig. 2 Cross section of BiT nanophase electrodes (TEM). Marker is 200 nm wide.

Typically [8] these nano-electrodes are 100 x 100 nm in area and 45 nm

high. They are pyrimidal (Fig. 3) and exhibit quadratic dependences (Fig. 4) of their J(V) leakage currents above an initially ohmic response (up to ca. 1 V). These nanoelectrodes arise from simple crystallization of molten Bi (T_m = 643 K; T oxide-reduction = 544 K) that diffuses through the top Pt electrode in the form of elemental metallic Bi (not oxide). In vacuum the nanoelectrodes are pure metallic Bi [9], but in oxygen ambients they are δ-bismuth oxide. It may important that Bi is a hole conductor in thin film form [10]. The leakage current properties (and fatigue) of ferroelectric thin films are known theoretically [11] and experimentally [12] to differ for hole and electron injection. We note that in general Bi reacts violently with Pt to form BiPt and Bi_2Pt, so the interface chemistry may be quite complex in systems such as SBT/Pt [13,14].

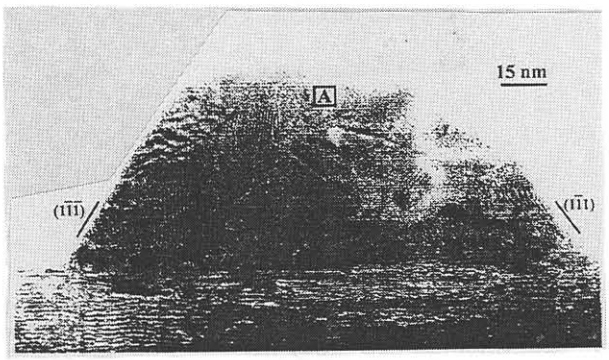

Fig. 3 {111} planes in δ-Bi_2O_3 nanoelectrodes on $Bi_4Ti_3O_{12}$.

3. Conclusions

The band structure of ferroelectric films such as SBT, BST, and PZT on elemental metal electrodes is now well understood and permits device models to be constructed, which give reliable Schottky barrier heights and interface widths (ca. 2 nm in SBT/Pt). Bi surface states pin the Pt work function at 2.1 eV in SBT/Pt. Scaling to submicron, nano-sized 100-nm cells has been demonstrated. Leakage currents in Bi-rich systems are SCLC rather than Schottky.

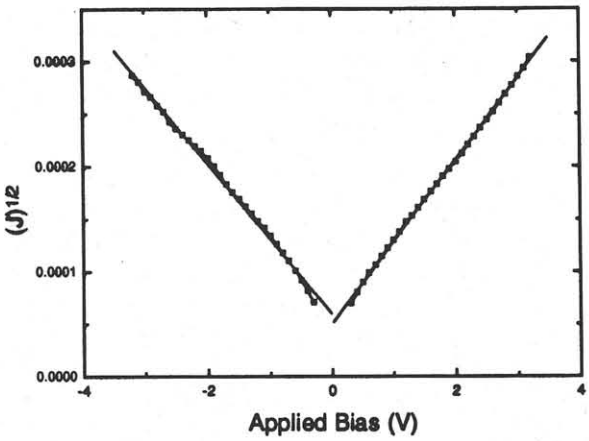

Fig. 4 $J^{1/2}$ versus V for bismuth oxide electroded BiT nano-cells, showing SCLC behaviour..

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