Influence of interfacial layer on contact resistance

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***Abstract*—The contact resistance between two materials is dependent on the intrinsic properties of the materials in contact and the presence and properties of an interfacial layer at the contact. This article presents the difference in contact resistance measurements with and without the presence of a process limiting interfacial layer. These measurements are performed using Cross Bridge Kelvin Resistor (CBKR) test structures on TiW- Phase Change Material (PCM) contacts.**

***Index Terms*— resistance, Phase change materials, Sputter etching, Interfacial layer**

I. INTRODUCTION

The electrical nature of a contact is expressed in terms of interfacial contact resistance and specific contact resistance. The interfacial contact resistance is determined by the properties of materials in contact and also by the presence of any interfacial layer at the contact. The interfacial contact resistance (Ω) is defined as the total resistance encountered at the contact by the interfacial layer as current is forced from one layer to the other. Specific contact resistance (Ω-cm^2) is resistance of unit area of the interfacial layer expressed as the ratio of the voltage drop across the interfacial layer to the current density through the layer [1]. Assuming uniform current flow through the interfacial layer the specific contact resistance (ρ_c) is expressed as

$$\rho_c = \frac{v_c}{j_c} \qquad (1)$$

In this article the effect of interfacial layer on the contact resistance of TiW electrode with PCM for phase change non-volatile memory application is considered. Phase change memory is the concept in which a thin line of chalcogenide alloy (doped Sb$_2$Te) is thermally programmed between the amorphous and polycrystalline states [2]. The state of the memory cell during the read operation is determined by resistance measurement of this programmed cell. The total resistance of the memory cell during programming or read operation includes mainly PCM cell resistance and two times electrode-PCM contact resistance.

The phase change memory line cell with the resistive components is shown in Fig 1.

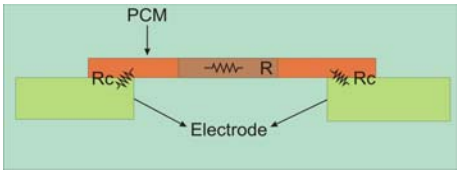

Fig. 1. PCM line cell showing the contact resistance and cell resistance.

II. CBKR PROCESSING AND MEASUREMNTS

The specific contact resistance is extracted from four terminal measurements on CBKR structures shown in Fig 2[3]. The advantage of this measurement structure is that it allows the direct measurement of the interfacial contact resistance as compared with the other contact resistance measurement structures.

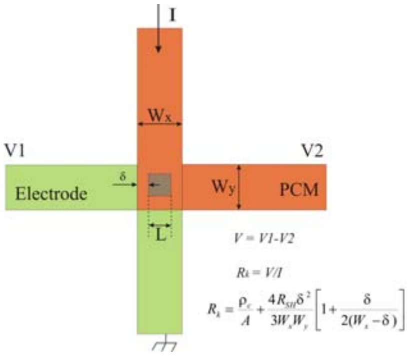

Fig. 2. Cross bridge Kelvin resistor structure for extraction of contact resistance

These CBKR structures are fabricated on silicon substrates with an insulating layer of SiO$_2$ separating PCM from the TiW metal electrode. To process these CBKR structures first the metal is deposited and patterned over an insulating layer to form the bottom electrode. On top of this patterned bottom electrode a layer of insulting SiO$_2$ is deposited. A square contact window of side *L* is opened in this SiO$_2$ layer to define the contact area between PCM and metal. A thin layer of PCM is deposited and pattered over the SiO$_2$ to form a well defined contact area between the metal and PCM.

Contact resistance measurements are performed by forcing a current *I* from the PCM segment to the metal segment and measuring the voltage difference *V1* and *V2* orthogonal to the direction of lateral current flow through the contact opening. Since the voltage measurement taps are orthogonal to the current taps the average voltage drop across the interfacial layer is sensed. From this measured voltage by using Ohms law the interfacial contact resistance (R_k) is calculated. Factors leading to interfacial contact resistance may physical limiting factors of the materials at the contact

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like work function difference of the two materials in contact, or process limiting factors due to the presence of a thin layer at the contact. This thin layer could be introduced at the contact by the residues from the previous processing steps or by oxidation of the material surface prior to establishment of contact. This leads to deviation of the contact behaviour to non-ohmic behaviour. The contact resistance due to the process limiting factors could be eliminated by additional process steps. The lowest limit of the contact resistance that could be achieved is the contact resistance with the physical limiting factors. The specific contact resistance is then calculated from the interfacial contact resistance by using the 2D approximation formula

$$R_k = \frac{\rho_c}{A} + \frac{4R_{SH}\delta^2}{3W_xW_y}\left[1+\frac{\delta}{2(W_x-\delta)}\right] \qquad (2)$$

The presence of a process limiting interfacial layer at the contact between TiW electrode and PCM is characterized by CBKR measurements. The TiW electrode formation and PCM deposition take place as two different steps with additional process steps in between. At the time of PCM deposition the metal electrode surface can be oxidized or could have some process residues. Additional argon pre-clean (sputter etching) step is introduced on the metal surface to remove a few monolayers from the contact region before deposition of PCM. The result is a clean metal-PCM contact without any process limiting interfacial layer at the contact. CBKR structures are made with and without sputter clean to result in contacts without and with an interfacial layer, respectively. The current-voltage characteristics and contact resistance with and without sputter cleaning is shown in Fig 3. With sputter clean the current and voltage shows a linear dependence resulting in a constant contact resistance throughout the sweep. With out the sputter clean the I-V characteristic is non-linear. The extracted specific contact resistance for a CBKR structures having a contact square of dimension L= 1 µm and with $\delta = 0.5$ µm with sputter clean (in the order of 10^{-7} Ω-cm^2) is two orders of magnitude lower than the one without sputter cleaning, taken from the linear part of the curve.

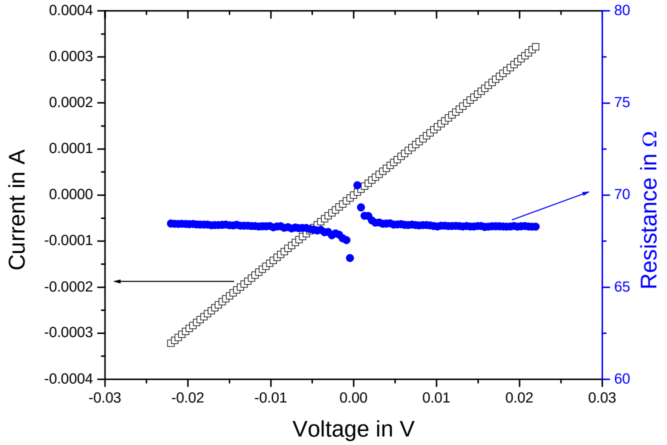

Fig. 3a. I-V characteristics with sputter cleaning

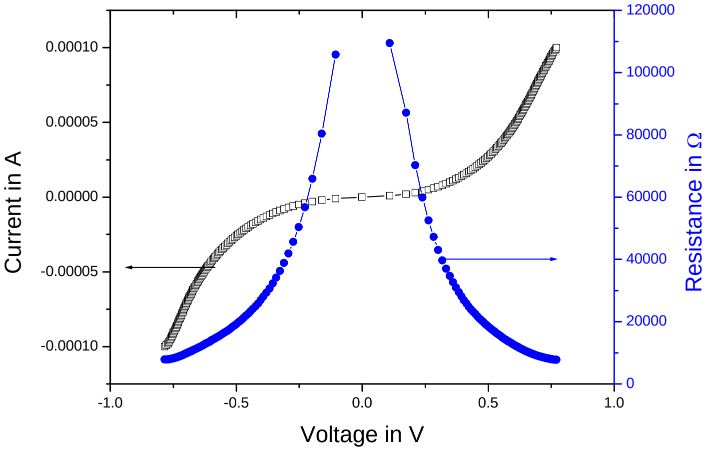

Fig. 3b. I-V characteristics without sputter cleaning

III. CONCLUSIONS

Direct measurement of the contact resistance by CBKR structures can be used as a tool to detect the presence of and interfacial layer at the contact. The interfacial contact resistance and the extracted specific contact resistance increase by two orders of magnitude with the presence of a process limiting interfacial layer

IV. ACKNOWLEDGMENT

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