

## An analysis of electron beam evaporation of SrTiO<sub>3</sub> on Si substrates

This article has been downloaded from IOPscience. Please scroll down to see the full text article.

1994 J. Phys.: Condens. Matter 6 L445

(<http://iopscience.iop.org/0953-8984/6/31/004>)

View [the table of contents for this issue](#), or go to the [journal homepage](#) for more

Download details:

IP Address: 171.66.16.147

The article was downloaded on 12/05/2010 at 19:04

Please note that [terms and conditions apply](#).

## LETTER TO THE EDITOR

# An analysis of electron beam evaporation of SrTiO<sub>3</sub> on Si substrates

Sanjit K Das, P K Ashwini Kumar and S K Sarkar

National Physical Laboratory, Dr K S Krishnan Road, New Delhi 110012, India

Received 6 June 1994

**Abstract.** Thin films have been prepared by electron beam evaporation of strontium titanate (SrTiO<sub>3</sub>) on bare (111) p-type silicon substrate held at room temperature. The as deposited films were annealed at 700 °C in flowing oxygen to compensate for any loss of O from the sample. The as deposited and the annealed samples were analysed by Auger electron spectroscopy (AES). The AES analysis shows that there is no trace of Si present in the bulk of the film and the Si/film interface is fairly sharp. The results are discussed in the light of the usefulness of the e-beam deposition of SrTiO<sub>3</sub> for preparation of a buffer layer on an Si substrate for the deposition of high- $T_c$  superconducting materials in thick- and thin-film form.

Ever since the discovery of the occurrence of a high transition temperature in some cuprates by Bednorz and Muller [1] there has been a spurt of research activity in ceramic superconductors. The system YBa<sub>2</sub>Cu<sub>2</sub>O<sub>7</sub> (YBCO) has been studied extensively both in bulk and film form (thin and thick). The films have been formed on a variety of substrates such as crystalline SrTiO<sub>3</sub> [2], MgO [3], LaAlO<sub>3</sub> [4], LaGaO<sub>3</sub> [5], YSZ [6] and bare and buffered Si [7, 8]. Deposition of an SrTiO<sub>3</sub> thin film has been attempted recently by using magnetron sputtering [9] and pulsed laser deposition [10]. The aim has been to use the dielectric layer in the IC technology. The interest in the last type of substrate is that this is available in large dimensions and that once a YBCO superconductor can be synthesized on such materials, a revolutionary change can be brought about in the technological advantage of high- $T_c$  ceramic. Attempts have been made to grow the YBCO films on buffered Si and some success has been achieved. In this context an attempt has been made to use SrTiO<sub>3</sub> film as a buffer layer on Si for preparing a thick film of YBCO. While the '123' film could be made by the spin on technique, the adhesion of these films has posed a serious problem with a resultant low conductivity of the sample. To understand this situation a preliminary study to analyse the SrTiO<sub>3</sub> thin film prepared by e-beam deposition was undertaken. Some of the salient features of the results are presented in this letter.

In the present study 0.8–1.0 Ω cm (111) p-type Si substrates were used. These were cleaned thoroughly by the standard RCA technique with a final dip in buffered HF. The wafers were loaded into the deposition system immediately after the cleaning step. The SrTiO<sub>3</sub> pellets required for the deposition were made from the powder, which was pelletized to circular discs of about 25 mm diameter. The pellets were sintered at 1600 °C for about 24 h. The deposition was done in the Varian VT 118A UHV system by e-beam evaporation. Before commencing the deposition the substrates were heated to about 200 °C for about 1 h and then allowed to cool down to room temperature. The base pressure was  $2 \times 10^{-8}$  mbar after the heating process. The deposition pressure was  $5 \times 10^{-6}$  mbar. The thickness of the

sample was 1300 Å as measured by a surface profilometer and the rate of deposition was  $1 \text{ Å s}^{-1}$ . Some of the samples were annealed in flowing  $\text{O}_2$  at 700 °C in a microprocessor controlled high-temperature furnace with a temperature stability of  $\pm 0.1 \text{ °C}$  (Tempress Omega Junior-I). The AES spectra were taken of the as deposited and the annealed samples in a Varian surface analysis system equipped with a single-pass CMA and Ar sputter gun for depth profiling.

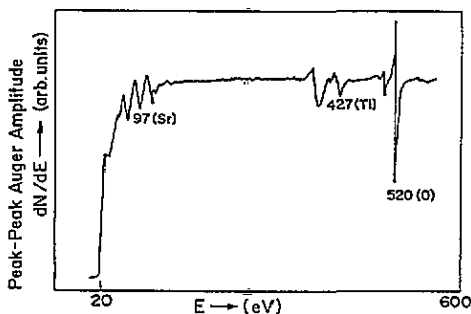
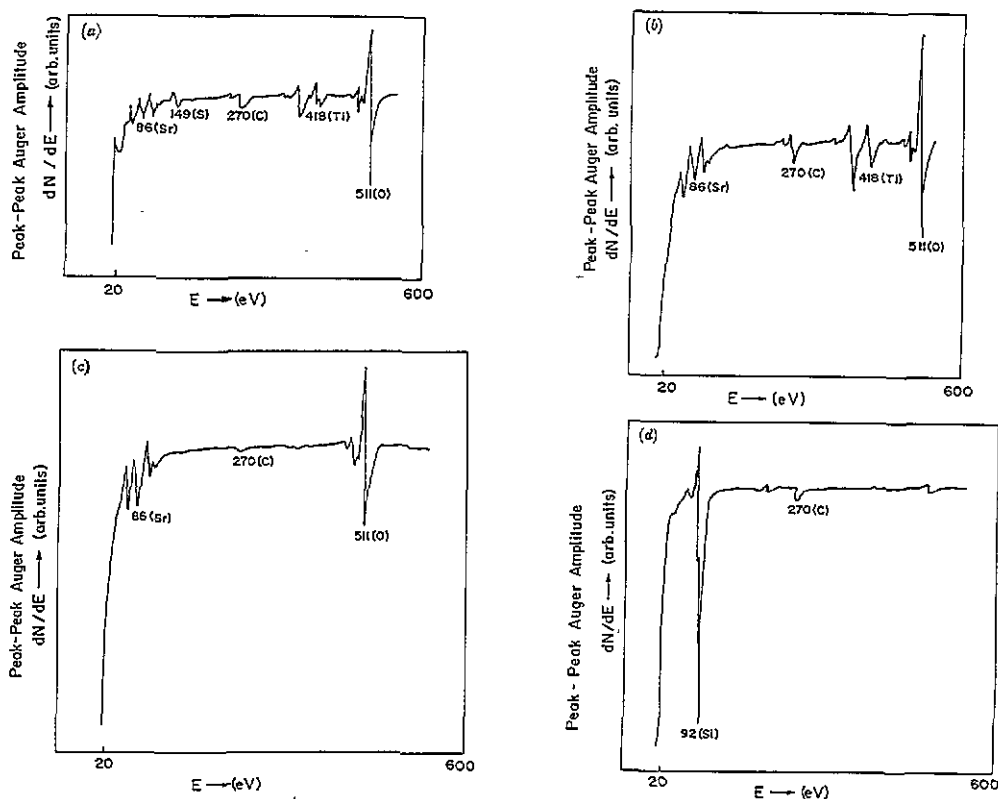


Figure 1. The Auger electron spectrum of the as deposited  $\text{SrTiO}_3$  thin film.

Results of the AES studies of the as deposited and the annealed thin films are reported here. Figure 1 shows the Auger spectrum of the as deposited sample at the surface, which is indicative of the presence of all the components, i.e., Sr, Ti and O. It is observed that the surface of the film is free from any impurity, which clearly indicates that there is no incorporation of any foreign element from the vacuum chamber even though the deposition pressure was  $5 \times 10^{-6}$  mbar. The spectrum shown in figure 2(a) is that of the surface of the annealed film. In this case we see that besides the presence of the three constituents of the source material there are two additional elements (sulphur, 149 eV, and carbon, 270 eV) present in the sample. While this can be expected to be due to the environment during heat treatment yet it is surprising that C is present throughout the thickness of the film as seen in figure 2(a)–(d). Figure 2(b)–(d) represents the AES spectra of the annealed film with successive removal of the sample by Ar ions. Now the origin of the two impurities can be envisaged to be due to the high-temperature processing rather than to the film deposition itself. This is based on the reasoning that if the vacuum environment or the source material were responsible for the observed impurities, then even the surface of the as deposited film should have indicated the presence of C and S. However, this was not the case as seen in figure 1. Thus, the only possibility for these impurities to be incorporated remains in the annealing process. The presence of S is seen only in the top surface layer and is thus not of serious concern. On the other hand the presence of C is detrimental to the film preparation of '123' compound on the buffered substrate. The source of this C can be attributed to any trace impurity present in the Ar gas feeder line to the sputter gun of the AES system. This is expected as the concentration of the impurity seems to be fairly constant with each sputter layer of the sample. However, the Auger analysis does confirm one thing, namely, there is no diffraction of Si from the substrate into the film, thus at least confirming the usefulness of the deposited film as a good buffer layer except for the presence of the impurities, which, are, however, not uncontrollable. The depth profile of the annealed sample (figure 3) indicates that the concentration of Ti is constant up to a certain thickness below the surface and then diminishes sharply. In contrast the concentration of Sr is almost uniform throughout the thickness of the film. This can be attributed to the simple fact that the e-beam was focused to a fine spot and that it was not swept across

the sample during deposition. Both these aspects tend to melt the material only in one spot, thus resulting in a non-stoichiometric vapour stream. Also, the local variation in the composition of the sintered pellet will be reflected in the composition variation in the final film deposited on the substrate. Further, the conditions of the e-beam used can result in partial fragmentation of the material with the high-vapour-pressure component evaporating favourably through the deposition time. However, such a situation seems to be favourable, as the initial Sr layer perhaps helps in inhibiting the outdiffusion of Si from the substrate. O is also seen to be present throughout the sample and is partially compensated by annealing. The results of the depth profiling can be approximated to a simple structure comprising of an initial layer of  $\text{SrO}_y$  and then one of Ti-deficient  $\text{SrTiO}_3$  with the possible presence of some  $\text{SrTiO}_3$ . This leads us to conjecture that the e-beam evaporation results in the fragmentation of the pellet with Sr and/or  $\text{SrO}_y$  being predominantly evaporated. The fact that the film partly comprises stoichiometric  $\text{SrTiO}_3$  is confirmed from the x-ray diffraction, which reveals a 211 peak corresponding to the dielectric. This is in agreement with the result obtained by other workers [11], who have deposited  $\text{SrTiO}_3$  on Si using a focused e-beam and subsequently annealed the sample in  $\text{O}_2$  at  $800^\circ\text{C}$ .



**Figure 2.** The Auger electron spectrum of the annealed  $\text{SrTiO}_3$  thin film. Anneal temperature,  $700^\circ\text{C}$ ; 1 h in  $\text{O}_2$ . (a) Surface of the sample; (b) after 400 s Ar ion etching; (c) after 580 s Ar ion etching; (d) after 760 s Ar ion etching.

While this is only a preliminary study a detailed evaluation is being undertaken to assess the utility of the material in thin-film form in VLSI technology and as a buffer layer in the synthesis of high- $T_c$  films.

It has been shown that the  $\text{SrTiO}_3$  films can be deposited successfully by direct e-beam evaporation of a sintered pellet of the ceramic. It has been seen by AES analysis

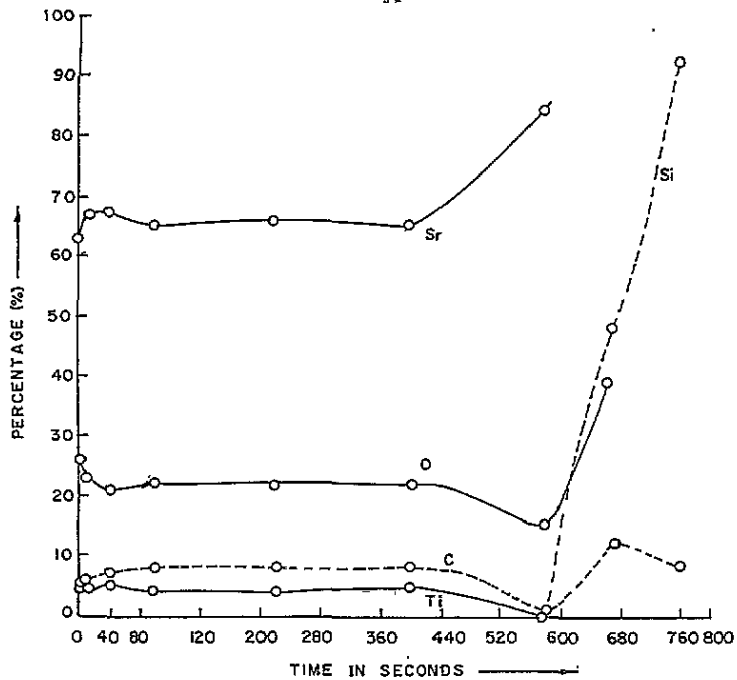


Figure 3. The percentage atomic concentration as a function of sputtering time (depth) of the annealed  $\text{SrTiO}_3$  thin film on Si.

that the deposited films when subjected to high-temperature treatment do not contain Si thus confirming the integrity of the layer for use as a buffer for high- $T_c$  thin-film synthesis. Detailed investigations are under way to study the system by high-energy nuclear techniques.

The authors are thankful to the Director of the National Physical Laboratory for his continuous encouragement to undertake this work. One of us (SKD) is thankful for the award of a senior research fellowship. Special thanks are also due to Dr J K N Sharma and his staff for taking the AES spectra.

## References

- [1] Bednorz J G and Muller K A 1986 *Z. Phys.* B **64** 189
- [2] Buda J D, Chisorlin M F, Feenstra R, Lounds D H, Norton D P, Boatner L A and Christen D K 1991 *Appl. Phys. Lett.* **58** 2174
- [3] Ushida T, Higashiyama K, Hirabayashi I and Tanaka S 1991 *Supercond. Sci. Technol.* **4** 445
- [4] Kuhn M, Horn R, Klinger M and Hinkin J H 1991 *Supercond. Sci. Technol.* **4** 471
- [5] Levy A, Fisk J P, Kastner M A, Gallagher W J, Gupta A and Kleinsassar A W 1991 *J. Appl. Phys.* **69** 4439
- [6] Venkatesan T, Chase E Q, Wu X D, Inam A, Chang C C and Shokohi P K 1988 *Appl. Phys. Lett.* **53** 243
- [7] Magero Campero A, Turner L G and Kendall K 1988 *Appl. Phys. Lett.* **53** 2566
- [8] Chourasia A R, Chopra D R, Bensoula A and Ruzakowskim P 1992 *J. Vac. Sci. Technol.* A **10** 115
- [9] Neung-Ho Cho, Seung-Hee Nam and Ho-O Kim 1992 *J. Vac. Sci. Technol.* A **10** 87
- [10] Roy D, Peng C J and Krupanidhi S 1992 *Appl. Phys. Lett.* **60** 2478
- [11] Moni H and Ishiwara H 1991 *Japan. J. Appl. Phys.* **30** L1415