Effect of substrate type on critical Temperature for BiSrCaCuO superconductor thin film prepared by dc –Sputtering

Suzan Malike Shakouli, Department of physics, college of education, university of AL-Mustansiriyah / suzanmzlek2011@yahoo.com
Athraa Naji Jameel, Department of physics, college of education, university of AL-Mustansiriyah / athraanaje@yahoo.com
Sana Jumaah Ali, Department of physics, college of education, university of AL-Mustansiriyah

Abstract:

In this search show the actual influence for substrate kind on critical temperature Tc, which the material converts from normal Resistivity to superconductor (absent resistivity), and the role of substrate on epitaxial growth for thin film. The important results which have been getting, the structure of the substrate play great role on occurrence match between deposited film and substrate.
Introduction:

Grove first observed sputtering in a dc gas discharge tube in 1852. He discovered that the cathode surface of the discharge tube was sputtered by energetic ions in the gas discharge, and cathode materials were deposited on the inner wall of the discharge tube. At that time, sputtering was regarded as an undesired phenomenon since the cathode and grid in the gas discharge tube were destroyed. Today, however, sputtering is widely used for surface cleaning and etching thin film deposition, surface and surface layer analysis, and sputter ion sources.[1-3]

There are various types of sputtering, namely dc sputtering, rf sputtering, magnetron sputtering and reactive sputtering. [4]

In the sputtering process, the target is composed of the metal, whose oxide is required to be deposit on the substrate. A voltage bias is maintained between the target and the substrate. The deposition chamber is evacuated, and the process gas is injected into the chamber. The process gas is typically a noble gas mixed with oxygen. The target is maintained at a negative voltage. As the voltage between the substrate and the target is increased, the process gas gets converted into high-energy ions. These ions attracted to the negatively charged target, bombard it, and knock off atoms from the target. These target atoms react with the oxygen present in the chamber and form their respective oxides[3]. These oxides are electrically neutral, and are, essentially, a vapor. This vapor deposits itself onto the surface of the substrate in the form of a thin film.[4-6] The energetic particles in sputtering may be ions, neutral atoms, neutrons, electrons, or photons. Most relevant sputtering applications are performed under bombardment with ions. This text deals with that particular process - the mean number of atoms removed from the surface of a solid per incident ion, influenced by energy of incident particles, Target materials, incident angles of particles, crystal structure of the target surface. [7-9]

In this work the target is composed of poly crystalline materials BiSrCaCuO (Bi – 2223).

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الهدف من البحث:

ان الهدف من بحثنا نبين دور الأرضية المناسبة والملائمة لنمو غشاء السوبر، والتوافق الشبيكي بين الأرضية والغشاء وهذا الأخير يؤثر تأثيراً واضحاً على درجة حرارة Tc.

Experimental work:-

The target preparation plays an important role in achieving the required superconducting properties. The targets were prepared by conventional calcination at 810°C for 24 h using bismuth, strontium carbonate and copper oxide as the starting materials, pressed as a pellet at 0.5 GPa, diameter of pellet is 13mm and thickness from 2 to 3 mm and sintering procedures at 860°C for 140 h, this pellet used as a target to deposited as a thin film on MgO, Si substrates using dc-sputtering technique at high oxygen pressure. The deposition conditions, substrate target distance 3cm, chamber pressure $10^{-2}$ m torr and dc voltage 400 V. These followed by a suitable thermal treatment of film at 840°C for 2h. MgO substrate has been prepared in laboratory:-

The first stage to prepare MgO as a pellet is powder forming where put powder with require conformation and final volume by pressing at 0.3 Gpa, diameter of pellet is 15 mm, in this process depending on cold compressive to act on increasing surface area between particles due to displacement for these particles. The second stage is sintering process at 810°C for 2h, this stage important for constrict and collection the particles where converts the resultants to hard solid body, act on decreasing in lattice faults, and removal the stress existence in connection regions between particles.
The Resistivity - Temperature \( \rho - T \) measurement obtained for Bi SrCaCuO films deposited on (n-type) Si, MgO substrates using four–probe technique at low temperature to determine the Tc for superconductor . The probe contacted to the surface of the samples using conductive silver paste. the two outer are for current and the two inner are for voltage. The sample was fixe under vacuum pressure of 10\(^{-2}\) m bar inside a cryostat and Joined also to a sensor thermomete and therom couple near the sample position. In order to evaluation Resistance R by using ohm equation the resistivity depend on sample length and cross section area give.[5] \( \rho = \frac{A}{L} \cdot \frac{V}{I} \) ……… ……… (1)

where A is area of film sample (\( A = \pi t^2 \) circular film deposited on MgO substrate), \( t \) is the thickness of the film (which equal to 184.2 nm) and L is length between two probe points (which equal to 29.272 \( \times 10^{-6}\)m). The current (I) pass through the film equal to 0.03mA.

so that, according to the value of variable in equation (1), the resistivity (\( \rho \)) becomes:

\[
\rho = \frac{3.14 \left(\frac{184.2 \times 10^{-7}}{2}\right)^2 \times 29.272 \times 10^{-6}}{417.176 \times 10^{-7} \frac{V}{I}} = 417.176 \times 10^{-7} \frac{V}{I} \] ……………(2)

We can use four probe method depend on passing electric current I through the film deposited on Si, and measured the voltage V between probes by keithley voltmeter, the dimension of the film, width \( b = 1 \) cm and the distance between the two probe points or length of the film \( L= 29.272 \times 10^{-6} \) m.

The final equation employing to measure resistivity for film deposited on Si:
\[ \rho = \frac{b t}{L} \cdot \frac{V}{I} = 1.258 \times 10^{-3} \frac{V}{I} \]

I is the current flow through the film which equal to 0.05 mA.

**Results and discussion:**

The \( \rho - T \) measurement by four probe and Tc for films of BiSr Ca CuO (2223) with different substrates of Si and MgO.

In general, it is observed that the Tc_{off} for film deposited on Si was 110 k but for film deposited on MgO substrate behaves as a superconductor behavior. Due to existence multi phases alternated between high and low, but low phases are higher, consequently make cutting super. Another feature could be observed from curve for MgO substrate, that the transition was not sharp and they have tail. The reason of this the hetroepitaxial for film deposited on MgO substrate which consists of unstrained structure includes misfit dislocation at the interface between the substrate and the film another reason the arrangement of atoms inside grains have short range order which make random in vector of move super pairs. But the film deposited on Si the strained system due to the constraint on the in-plane Lattice constant, the unit cell distorts by poisson's ratio for an epitaxial layer.

Can be observed from XRD Pattern for Mgo the Amorphous arrangement of atoms for film and crystalline arrangement for Si.
Conclusion:

From conclusion of this work there are two effects determine the shape of atoms.

Collection:- surface effect which make atoms layers spherical shape due to the atoms take solenoid path through transport from target to substrate, and lead to hetroepitaxial film, adsorption effect of base surface which make film surfacing and because two effects formation regions of stress, Strain in film and consequently influence on critical temperature $T_c$.

Evidently, the superconductivity of BiSrCaCuO film on Si substrate depends to a great extent on the prevention of Si diffusion to word film and MgO could be an effective diffusion barrier layer.

References :-

8- E.R-Canavan, B.L-James, T.P-Hait, The Astro H high temperature superconductor lead assemblies, 64 (2014) 194.
ρ – T for Si substrate

ρ – T for MgO substrate
XRD Pattern of Bi Pb Sr Ca Cu ZnO thin film deposited on Si

XRD Pattern of Bi Pb Sr Ca Cu ZnO thin film deposited on Mgo