

PRESS Project – Fabrication and Characterization of $\text{YBa}_2\text{Cu}_3\text{O}_7$ Superconducting Thin Film using Pulsed Laser Deposition (PLD)

Chan Yuk Hei ^a, Dr. K.H.Wong ^b

^a Sha Tin Methodist College

^b Department of Applied Physics, The Hong Kong Polytechnic University

Introduction

The emergence of high temperature superconductor based on conducting oxides such as YBCO has tremendous impact on the field of superconductor research. These types of superconductors have transition temperature of 90 K or above, which can be cooled using the liquid nitrogen (78K b.p.). This is important because liquid nitrogen is cheaper and easier to obtain, thus lower the cost of the applications that superconductor plays a role and make them possible. Some applications of high temperature superconductors include the inter-connects in ULSI (Ultra Large Scale Integrated Chips) and ultra-sensitive magnetic field detectors called SQUID.

In order for the superconductors to be used in microelectronics, their integration with Si semiconductors is a prior requirement. High quality YBCO film cannot be grown on Si substrate due to the large lattice mismatch and detrimental chemical diffusion across the interface. Instead, buffer layers of some appropriate materials inserted between the superconductor and Si have shown to be a good solution. Integrated YBCO films on Si have been fabricated in this way with various degrees of successes.

Objectives

1. Use pulsed laser deposition (PLD) method to fabricate heteroepitaxial YBCO high temperature superconducting thin films.
2. Familiarize with structural characterization techniques such as scanning electron microscopy (SEM) and X-ray diffractometry (XRD).
3. Learn to use the four-point-probe method and cryogenic equipment for measuring the R-T profiles of the YBCO films.

Fabrication of YBCO films using PLD



KrF Excimer Laser used in PLD



Photo of TiN plated Si wafer

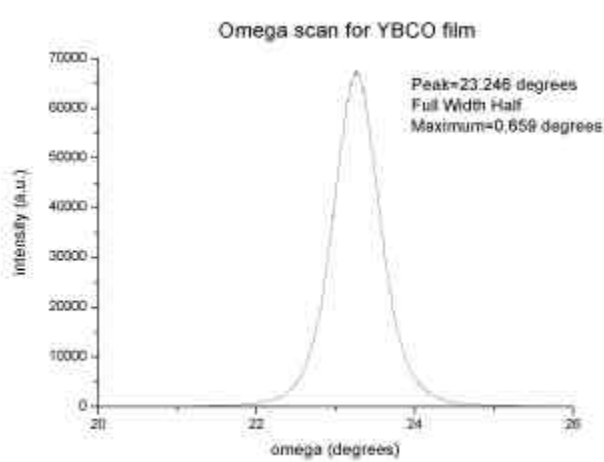
Pulsed Laser Deposition, PLD, is a technique to “coat” some material (called “target”) onto substrate. PLD has several advantages. Targets are heated to their evaporation temperature and the stoichiometric ratio is preserved. Also, the power is intense so the target will not be heated up. The most important thing is the substrate need not to be heated to a high temperature, so the semiconductor and the integrated circuit will not suffer from thermal degradation. But it also has some disadvantages like small area and it will have some damage to the substrate.

The bulk sample of YBCO and the substrate is placed inside a chamber, which most air is pumped out and oxygen is kept flowing to reduce the loss of oxygen during PLD. The pressure inside is 400 mTorr (1atm = 760 Torr). The substrate is heated. The laser beam is focussed on the surface of target, rapidly rise the temperature of the surface and ablate it into solid-density plasma. The plasma YBCO expand away from the target and is collected on the surface of substrate. A slow cooling of the substrate allows the YBCO to grow well. Different substrates will be used, such as TiN (Titanium Nitride)/Si, LAO (Lanthanum Aluminium Oxide) and MgO. The surface will then be investigated using scanning electron microscopy (SEM).

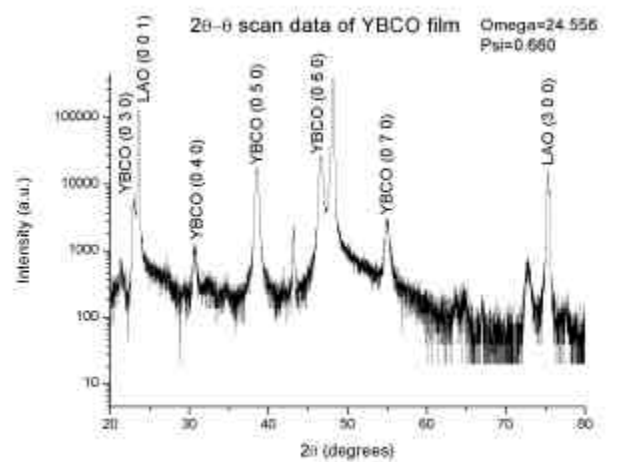
X-ray diffractometry for structural characterization

Structural characterization by high-resolution X-ray diffractometry is essential for the evaluation of the quality of the homo- and hetero-epitaxial films. Crystalline phase and orientation will be identified by the standard 2θ - θ scan in the Bragg-Brentano configuration. The average crystalline size of the deposited films can be obtained by evaluating the full width half maximum (FWHM) of the diffraction peaks. The

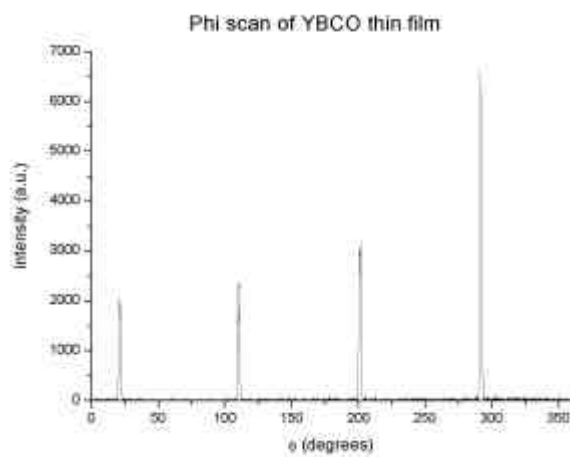
in-plane and out-of-plane mosaicity of the heterostructure can be quantified by the ultra-high resolution rocking curve measurement.



Rocking curve showing crystallinity



2θ-θ scan of YBCO film grown on LAO substrate



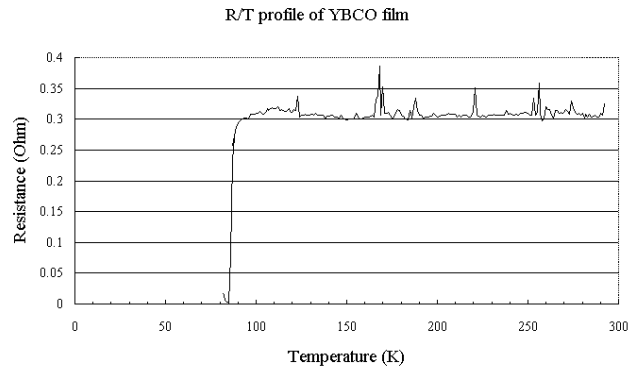
Phi scan showing the 4-fold symmetry of YBCO structure

4-point probe method for determining the T_c

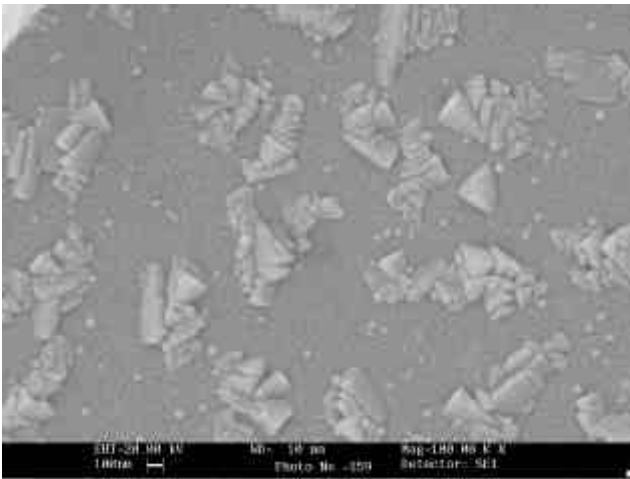
4-point probe is used to find out the resistance of the film against the temperature. The film coated with 4 platinum electrodes are connected to the set-up using the quick drying silver paint. The set-up consists of a constant current source connected to the two ends of the film, a voltmeter connected to the middle two point and a platinum thermometer measuring the temperature. By supplying a constant current, a p.d. is measured and the resistance is given by $R=V/I$. A graph of resistance against temperature is plotted.



The 4 point probe set-up with a piece of YBCO, to be immersed in liquid nitrogen for testing



R/T profile of YBCO film deposited on LAO, at a substrate temperature of 750 °C, with a quite sharp drop of resistance at around 85K



SEM photo of YBCO film deposited at 700 °C. The photo shows this is not a good temperature for depositing YBCO film as outgrowth are found.

Further work to be done

A further analyzing of the deposited films using SEM will be done.