Growth and characterization of SrCuO$_2$ thin films

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Transition metal oxides (TMOs) exhibit a rich variety of novel properties, which can be exploited for a wide range of applications including ultra-high-density magnetic data storage, spintronics, quantum computing and more recently thermal management applications. Thin films of TMOs offer enormous opportunities to explore intriguing physics and also practical applications. The discovery of high T_c superconductivity in cuprates has increased in recent years the interest for low-dimensional Heisenberg magnetic systems. Among these, the compound SrCu0$_2$ (SCO) has drawn much attention. SCO in the orthorhombic structure, consisting of zigzag chains of Cu^{2+} ions, has been recently shown to exhibit sizeable magnetic heat transport; while SCO in the tetragonal structure exhibits the simplest structure with superconducting CuO$_2$ planes (so called infinite layer compound). Depending on the phase and the orientation, SCO can then be used for different applications. While it has been possible to obtain bulk SCO only in the orthorhombic structure, in the thin film form this compound has only been stabilized in the tetragonal structure.

We work on the growth of SCO thin films by pulsed laser deposition (PLD), which is very appropriate for multi-component oxides, using an KrF excimer laser (wavelength, =248 nm; pulse duration, = 25 ns) and a HV chamber which was evacuated by a turbo molecular pump to a base pressure of typically 10^{-6} mbar before deposition. The deposition was carried out using oxygen as processing gas with pressures P_{O2}= 0.01- 1 mbar, substrate temperature T_S = 500-800°C and laser fluence = 0.2 - 2 J/cm^2.

SrCuO$_2$ (SCO) thin films were grown on (100) SrTiO$_3$ and (100) MgO substrates. SrTiO$_3$ substrates were treated with BHF etching to obtain a clean surface with TiO$_2$ termination layer.

We have observed that upon changing the substrate temperature a structural phase transition occurs from the tetragonal structure (infinite layer compound) to the orthorhombic structure. Preliminary X-ray diffraction studies indicate that highly oriented thin films are obtained in both phases (Fig.1, Fig.2).
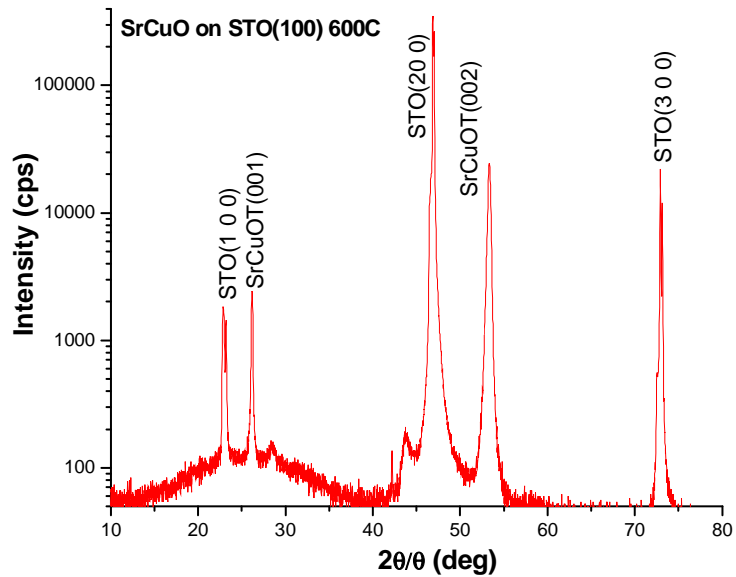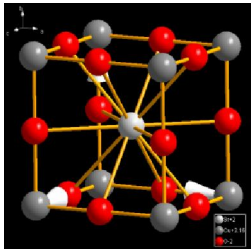
Tetragonal Structure

Figure 1 *XRD profile of SrCuO film deposited on (1 0 0) SrTiO₃ at 600°C*
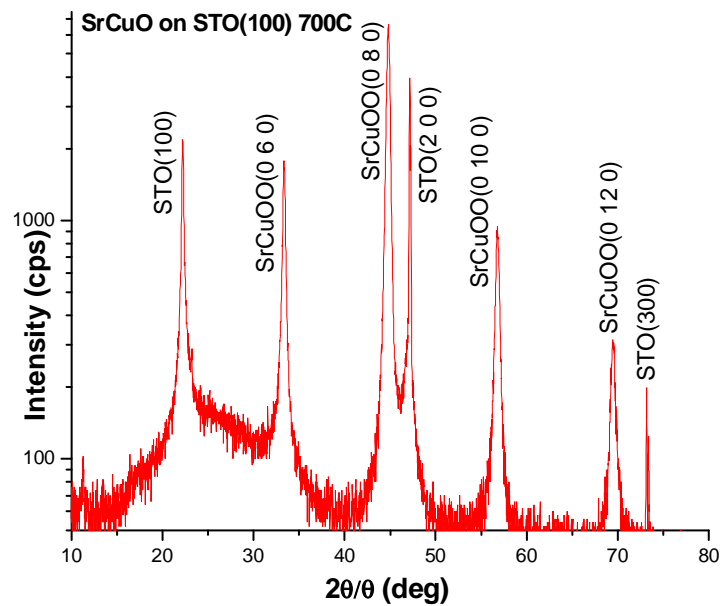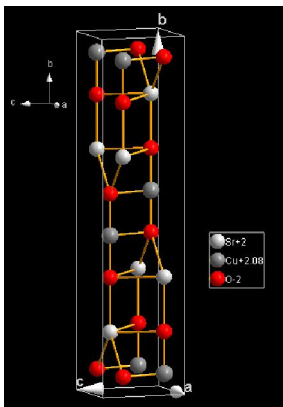
Orthorhombic Structure

Figure 2 *XRD profile of SrCuO film deposited on (1 0 0) SrTiO₃ at 700°C*

However, it was found that all the films, independently of phase, were highly unstable even though they were kept in a desiccator under vacuum and were disintegrated shortly after fabrication. The chemical stoichiometry of the grown films is very important and must be made using a reliable technique such as Rutherford Backscattering Spectrometry (RBS) or non-Rutherford Backscattering Spectrometry (NRBS).

Rutherford backscattering spectrometry with light ions, typically 1–2 MeV ^{1}H or ^{4}He ions, is a often used technique for depth profiling of elements concentrations. Furthermore, under channeling conditions, the technique may be exploited to give information about the sample structure and lattice locations of impurities. Channeling is a powerful technique which is widely used for ordered samples characterization.

In the extensive use of elastic backscattering for materials characterization purposes, ^{4}He particles up to several MeV have been for long considered as most convenient projectile. This often gives sufficient mass and depth resolution. However, the case of more complex film structures, with compound materials, have put higher demands on both the mass and the depth resolution in the analysis.

The RBS technique has also its limitations. Mass resolution for heavy elements and sensitivity for light elements are poor, and, except for the surface, mass determination is not unambiguously possible. The analysis of light elements in a heavier matrix is often impossible, because of the energy overlap of the beam ions scattered by light surface atoms and by heavier bulk atoms deeper in the sample. Furthermore, small amounts of light elements are difficult to analyze, because of the Z^2 dependence of the Rutherford cross section.

It is well known that the mass and depth resolution, as well as the sensitivity may be improved by using heavier and more energetic ions. In particular, mass separation for medium and heavy elements is improved significantly by heavy ions RBS. The expression for the energy separation as a function of the projectile mass M_1, the projectile energy E_0 and the target mass M_2 can be written as:

$$\Delta E \cong \frac{2M_1 E_0}{M_2^2}\left(1-\cos\theta\right) \qquad (1)$$

where is the backscattering angle. This is valid for $M_1/M_2 << 1$. The expression suggests the use of higher mass projectiles and higher bombarding energies. There are, however, some drawbacks, because the resolution of the silicon detector is worsened and, due to $1/E_0^2$ dependency of the cross section, the counting rate reduces. Subsequently, longer analyzing time has to be used if higher energies are needed. In order to avoid the worsened resolution of silicon detectors for heavy ions the measurement of backscattered ions energy using a time of flight spectrometer can be used.

A severe disadvantage of conventional RBS is low sensitivity for light elements. The Rutherford scattering cross section is proportional to the square of the nuclear charge of the target nucleus. Therefore, the scattering peaks from light elements such as C, N and O are

superimposed on a relatively high background due to backscattering from heavy elements in the sample. In recent years, high energy ^{1}H and [4]H backscattering has been utilized to overcome this difficulty and to quantify the stoichiometry or to profile the light elements in the heavy bulk samples. In the high energy backscattering experiments, ^{1}H and [4]He ions of *3–9 MeV* (or even more) are used as incident projectiles. The elastic scattering cross section for light elements becomes a nuclear rather than a Rutherford interaction, called non–Rutherford backscattering or nuclear resonance elastic scattering. The non–Rutherford backscattering can be used to enhance the sensitivity for light elements. For example, at [4]He energies of *3.045*, *4.265* and *3.72 MeV* the elastic backscattering cross sections for O, C and N are 25, 150 and 6 times larger than their corresponding Rutherford cross sections, respectively.

We intend to use RBS and NRA techniques to characterize the thin layers of the above mentioned material. Both RBS and NRBS with 10 MeV ^{12}C and 4.5 MeV [4]He wil be used. The measurements will be performed using a dedicated target chamber. The experiments will be performed at our Tandem using a standard backscattering setup. The energy of the [4]He beam used for measuremens will be calibrated. The method adopted for calibration of the analysing magnet fields of the Bucharest FN tandem accelerator consists simply of comparing the energies of alpha particles from a radioactive source with the energies of [4]He projectiles back-scattered into an silicon detector by thin carbon and gold layers.

The ions scattered at 167^0 will be detected by a Si detector having 17 keV resolution.

We need 3 days (9 shifts).

References

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