

## THIN FILMS OF YBaCuO BY E-BEAM EVAPORATION

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We have fabricated thin films of YBaCuO by evaporation of the metals under application of an oxygen beam. An oxygen annealing step is required to obtain superconductivity with onsets of 90K. Various substrates have been used. The interaction with sapphire substrates has been studied.

We fabricate films of YBaCuO by simultaneous evaporation of the metals in a Balzers UHV system<sup>1,2</sup>. The copper and yttrium are evaporated from electron beam guns, the barium from an effusion cell. The rates are controlled with a cross-beam quadrupole mass spectrometer which is used in a three-channel multiplexed mode. For each of the metals the nominal concentration for 1-2-3 material can reliably be obtained to within 5% of the desired value. During evaporation oxygen is sprayed onto the substrate through five outlets at several cm distance. The growth rate of the film is varied between 0.2 and 1 nm/s. The substrate temperature is between room temperature and 400 °C.

After evaporation our films are smooth, dark brown and unstable when exposed to wet air. X-ray analysis indicates that they are amorphous or very strongly disordered with two diffuse rings showing. The composition as determined from EPMA is typically  $Y_1Ba_2Cu_3O_6$ . It is possible to obtain an oxygen contents corresponding to  $Y_1Ba_2Cu_3O_7$ , but such films turn out to be even more unstable. We attribute this behaviour to formation of peroxides of barium. When substrate temperatures of 600 °C or higher are used, we find precipitates of pure copper in our films.

Our analysis seems to indicate that it not possible to oxidize the copper under the attainable conditions. When pure copper was evaporated under similar conditions in the presence of oxygen no oxidation was found to occur. The equilibrium diagrams of Cu with  $CuO_2$  and  $CuO$  indicate that it is necessary to use higher pressures than  $10^{-2}$  Pa, as present in our system.

Superconductivity in our films is obtained by annealing in pure oxygen. With different substrates and different bake-out procedures widely different results are obtained. Both 'metallic' and 'semiconducting' temperature dependence of the resistivity are observed on cooling from room temperature. The superconducting onset temperature is about 90 K.

On sapphire substrates the best results are obtained when

the oxygen anneal step consists of an increase to 800°C in several hours, followed by a slow cool-down. The resultant films show a broad resistive transition, starting with a sharp drop of resistance at 80 to 90 K, followed by a slow tail ending with zero resistance at about 40 K. X-ray diffraction shows considerably broadened lines, consistent with orthorhombic or tetragonal structure with a high degree of disorder. The material is not single phase. Chemical reactions take place between substrate and film. We find a transparent layer of about 30 nm at the bottom of the film which is not conducting.

In the top part of the film no aluminium is detected. We observe a grain-like structure with dimensions of about 4  $\mu m$ , much larger than the grain size that is determined from X-ray diffraction. That grain-like structure is best observed with backscattered electrons in the SEM. In the 'grain' boundaries Si is detected of unknown origin. When we fabricate narrow lines by etching, lines narrower than 5  $\mu m$  show a strongly increased resistance. Analysis by different techniques (scanning tunneling microscope<sup>3</sup>, optical and electron spectroscopy<sup>4</sup>) show that the material within the grains has good superconducting properties.

On strontium titanate substrates the resistive transition is much sharper.

### References

1. A.J.G. Schellingerhout, R.H.M. van de Leur, D. van der Marel, H.S.J. van der Zant, B.J. van Wees, L.J. Geerligs, D. Schalkoord, J.E. Mooij and group. Proceedings Conference of the European Materials Research Society, Strasbourg 1987
2. A.J.G. Schellingerhout, R.H.M. van de Leur, D. van der Marel and J.E. Mooij. Zeitschrift für Physik B, to be published.
3. H.F.C. Hoervers, P.J.M. van Bentum, L.E.C. van de Leemput and H. van Kempen, A.J.G. Schellingerhout and D. van der Marel. Physica C, to be published.
4. D. van der Marel, J. van Elp, G.A. Sawatzky and D. Heitmann. Phys.Rev.B, to be published.

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