HIGHLIGHTS
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Excimer Lasers in High-T_c Superconductor Research

Only three years ago the scientific world was excited by the discovery of high-T_C superconductors. In the mean time, an estimated 50 000 scientists and engineers work in this field so that it is difficult to get an overview on the state of the art. Excimer lasers have become important tools in the production of superconducting thin films and in the analysis of the deposition process. This article, which is not necessarily comprehensive, is an attempt to report on recent progress in this special field.

Introduction

"At the extreme forefront of research in superconductivity is the empirical search for new materials", Karl Alexander Müller and Johannes Georg Bednorz began their Nobel Prize–honoured paper in 1986 [1], referring to M. Tinkham et al., who expressed the needs at that time at a workshop at Copper Mountain, Colorado, in August of 1983.

The "copper mountain" in superconductivity began to rise with Müller's and Bednorz' publication, and has apparently not yet reached its summit: *Fig. 1* [2] shows what happened with respect to the transition temperature of superconductors since 1911, when Kamerlingh–Onnes discovered superconductivity in mercury. Indeed, the compound Ba–La–Cu–O opened a new era; Cu–O was soon recognized to form a non–perovskite type phase of that compound responsible for superconductivity (as firstly communicated in a note added in proof in [1]).

Within a few months after the publication of [1], the transition temperature rose to 92 K, as achieved at the University of Houston (C.W. Chu and co–workers, 1987) by replacing lanthanum with the smaller yttrium ion. The importance of this result: the transition temperature was then raised to above 77 K, which is the temperature of liquid nitrogen at atmospheric pressure.

$YBa_2Cu_3O_{7-x}$ became the high-T_C compound mainly investigated until today, frequently called "one-two-three" for the stoichiometry of the first three atoms. "x" stands for a variable deficiency of oxygen.

In other laboratories in Japan and the US, bismuth and thallium cuprates have been found meanwhile to exhibit even higher transition temperatures, and, following the opinion of experts, a definite end of this development is not yet to be seen.

The role of lasers in the game is twofold. Laser evaporation is very effective, very reliable, and fairly simple in the deposition of thin films of said superconductors. Furthermore, laser induced fluorescence is a convenient means to analyze molecular composition and details of the deposition kinetics.

Why thin films?

It turned out soon that high-T_c superconductivity in the bulk material suffered from low current density: if the current in a sample is increased, a breakdown of superconductivity occurs. Furthermore, since the superconductivity effect is strongly anisotropic, in a poly-crystalline bulk an unfavorable averaging of the superconducting properties of all crystal orientations occurs. On the other hand, once crystal growth is epitaxial, the supercurrent density can be increased over that of poly–crystalline material. *Fig. 2* [3] shows schematically the material deposited in the favorable c–orientation on a $SrTiO_3$

750 W XeCl reached at Lambda Physik R & D

A few weeks ago* 750 W output were reached with the XeCl laser which had already set landmarks earlier (cf. HL 11, June 1988). Fig. 1 shows the new curve 'average power versus repetition rate' now valid. Comparing it with that in HL 11 it is seen that the 50% higher average power is achieved by an increase of the repetition rate up to 500 Hz (300 Hz earlier). The repetition rate improvement was brought about by adding electric power. However, to take advantage of the higher electric power installed, UV preionization of the discharge had to be improved. The concept used earlier, UV emitting spark electrodes behind the mesh electrode, was given up in favor of a proprietary improved UV preionization. Dr. Elmar Müller-Horsche, head of the research team,

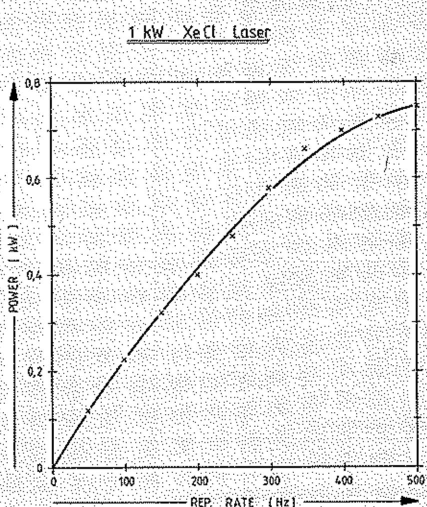

Fig. 1: Average power versus repetition rate

* First reported at the Eureka EU 205 meeting, October 9, 1989.

foresees further increase of average power of this type of laser using X-ray preionization. To reach 1 kW is the goal of the second phase of the Eureka EU 205 project which is to start in 1990.
Clearly, although under laboratory conditions, realizing average power in

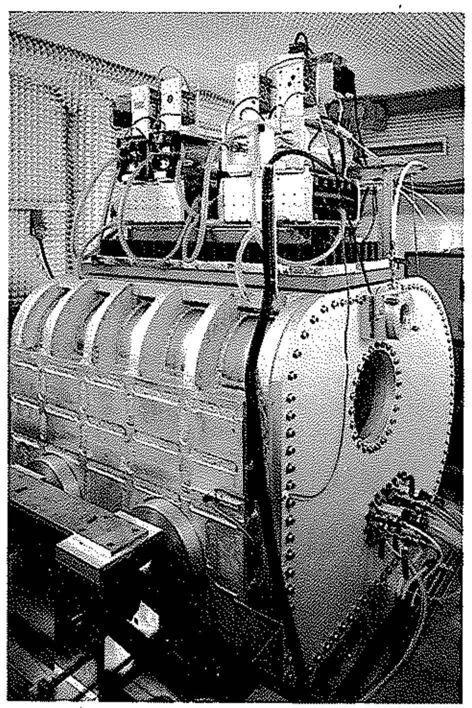

Fig. 2: 750 W XeCl laser at Lambda Physik

this order of magnitude provides a lot of experience for current product development, especially as the materials employed undergo rigorous testing. In addition, UV preionization, which is less costly than the X-ray technique, shows remarkable potential for medium to high-power lasers. Fig. 2 shows the laser in a view somewhat different from that in HL 8.

... Superconductors

crystal, supercurrents supposedly flowing in the Cu-O planes which extend parallel to the substrate.
In addition, from a practical point of view, thin films are the usual approach to designing advanced electronic circuits. This holds even more so as the production of superconducting wires raises problems, since the material is very brittle.
However, thin films need convenient substrates. To achieve epitaxial films, ideally the substrate should show a crystalline lattice favorable for the film

critical temperature, T_C	mean temperature at the transition from normal to superconductivity. The resistivity drop begins with the onset and ends with R=0 showing a narrow transition width.
critical current density	current density sufficiently high to destroy superconductivity
as-deposited	film properties (e.g. superconductivity) usable without any post-deposition processing
in situ	meaning here the same as as-deposited'
annealing	heating followed by slow cooling so that the crystal structure is modified
epitaxial	crystalline growth of material deposited on a substrate crystal
sputtering	sputtering of material yielding the atoms of the sputtered compound using the impact of energetic ions on the material; magnetron sputtering means the generation of sputtering ions in a magnetron-driven discharge.
isentropic expansion	is an adiabatic expansion keeping entropy constant. Practically, for the expansion of a molecular beam into high vacuum, this means rapid cooling by removal of the energy contained in the transverse, rotational and vibrational degrees of freedom of the beam molecules; simultaneously, an acceleration of the molecules up to supersonic speed (Mach numbers >1) occurs with drastic narrowing of the velocity distribution.

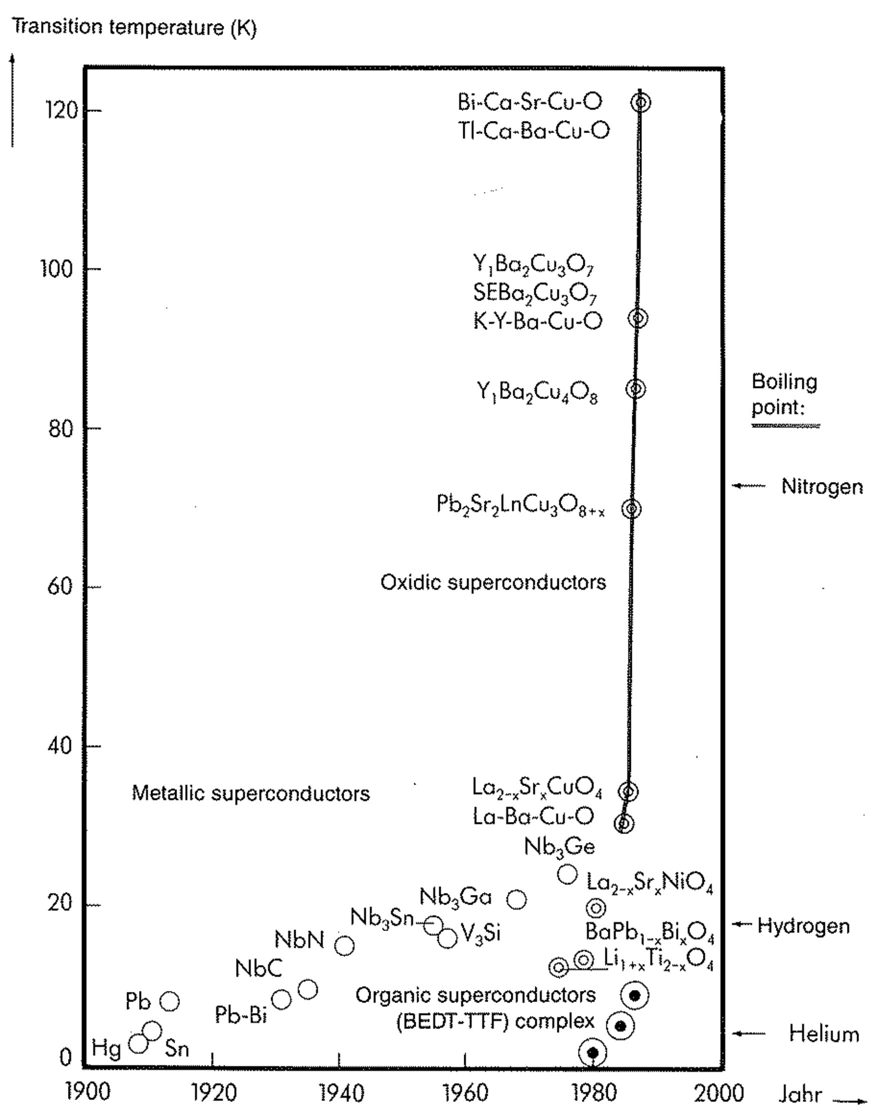

Fig. 1 History of superconductivity: the transition temperature is plotted versus time. On the right scale the boiling points of helium, hydrogen, and nitrogen are marked [2].

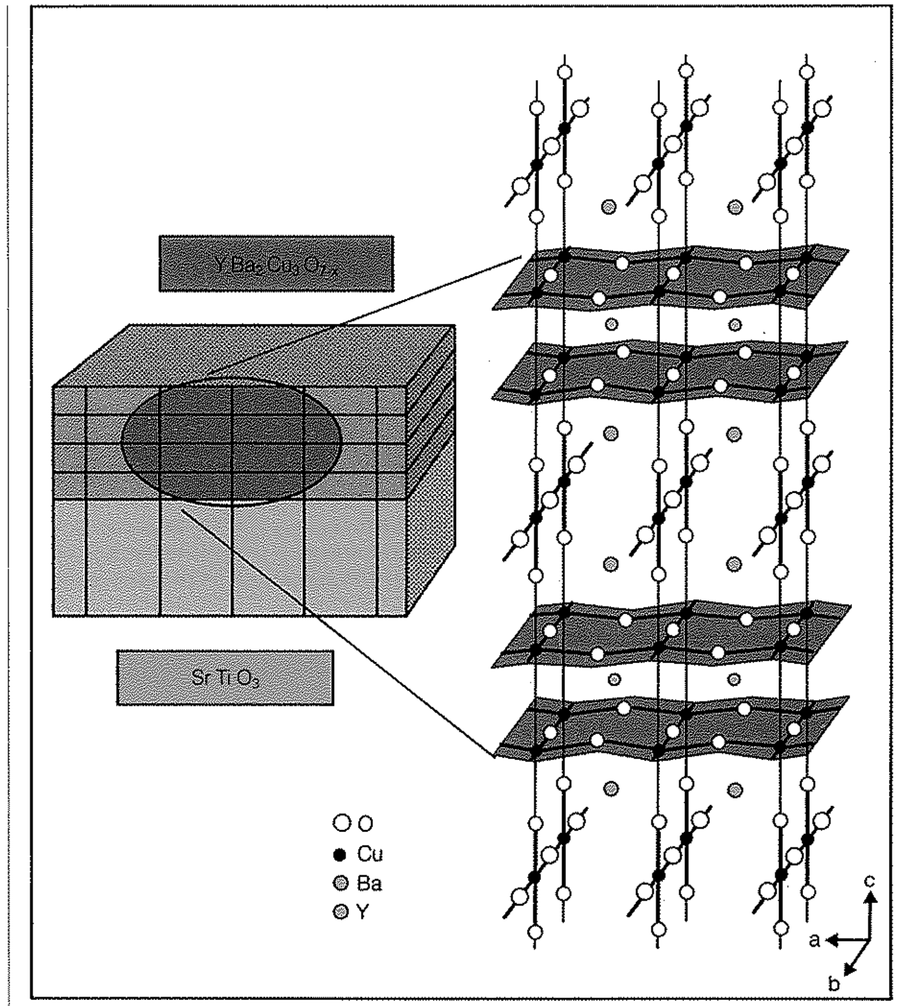

Fig. 2 Scheme of a $YBa_2Cu_3O_{7-x}$ film deposited with the c–axis normal to the substrate surface [3]

atoms to arrange. This is the reason that $SrTiO_3$ is frequently chosen as the substrate for experimental investigation. However, for any practical application in electronics circuits, Si would be much more convenient as the substrate.

Depositing thin films

Producing thin films of multi–element composition can be performed by simultaneous vapor or molecular beam deposition using e.g. three different ovens in an oxygen atmosphere at low pressure. Also metal–organic vapor deposition is used. These procedures are difficult to control and costly.
Therefore, the superconducting compounds are mixed in advance in an almost correct stoichiometric ratio. Targets prepared in this way are then sputtered onto a substrate. Also, flash-evaporation of the premixed material was tried. The difficulty is maintaining the stoichiometric ratio during evaporation.
Another well-proven deposition technique is magnetron sputtering.

The aim of any deposition technique for high–T_C films is to obtain the required stoichiometry in the film including the oxygen content, to achieve almost unidirectional growth in the required crystalline structure, and to avoid impurities. Frequently, these goals cannot be achieved simultaneously so that an annealing process of the as–deposited film in oxygen may be necessary.

Depositing high-T_C layers: annealing or not?

Excimer laser ablation was firstly used at Bellcore by Venkatesan et al., as *Highlights* reported in its October 1987 issue (HL 7). Generally, pulsed laser radiation can be applied in a well-controllable way to the target. Pulsed UV radiation is very effective in the ablation of non-volatile and ceramic material. As a consequence, in the film, almost the same stoichiometry as in the bulk can be ascertained. However, as reported in HL 7,1987, in these early experiments annealing in oxygen at 900 °C and cooling down over several hours was still necessary. Heating of the substrate during deposition was required providing thermal energy for the deposited atoms and molecules to migrate on the surface and to arrange themselves in the energetically favored lattice. Post-deposition annealing is not only time-consuming for any practical application. Also, high-temperature annealing favors interdiffusion from the target to the superconductor, thus spoiling the superconducting properties of the film. Due to a careful control of the deposition process this situation has now changed dramatically, as will be described below.
A recent magnetron sputtering experiment should be mentioned [4]: it allowed a moderate temperature (645 °C) at the substrate, and did not require annealing, but a careful cooling-down at a rate of 30 K/min. Critical current density was 2 x 10^5 A/cm² at 77 K which is not as high as that reached by the laser techniques.

UV wavelengths are favorable

Infrared lasers have also been investigated for laser evaporation. Recently, films close to the stoichiometry of the target were obtained [5] using a long–pulse (about 1 ms) 50 J Nd:glass laser, providing a fast deposition rate (100 nm/pulse); however, 850 °C-annealing was still necessary. Deposition by frequency-doubled short-pulse (10 ns) Nd:YAG laser radiation, 532 nm, required 725 °C at the substrate [6]; the same group reports that frequency-tripled radiation (355 nm) produces much smoother films [6]. A similar result is reported in [12].
Obviously, Nd:YAG laser users recognized that short wavelengths are more favorable. In principle, this would not be surprising, considering the background of excellent ceramics material processing capabilities demonstrated in many laboratories for excimer lasers. However, very recently, this trend has been questioned again by a paper published by the same IBM group [7], who reports that in-situ layers epitaxially grown on $LiNbO_3$ do not show superconducting properties different when deposited using Nd:YAG fundamental, frequency-doubled or tripled radiation.

Excimer-laser deposition: defining the process parameters

Avoiding post-deposition annealing

First results in producing excimer laser-deposited 1-2-3 layers in-situ without annealing ("one-step process") were soon reported by the Bellcore group in 1988 [8]:

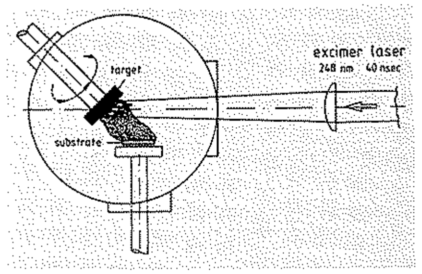

Fig. 3 Typical excimer laser deposition scheme [10]

they improved their technique by applying an oxygen jet directly to the substrate and observed chemiluminescence when the plume of laser-ablated atoms appeared: apparently, oxidizing of metal atoms occurred already in the gas phase. In this way, in-situ films of about 2000 Å thickness on $SrTiO_3$ and Al_2O_3, superconducting as-deposited, could be achieved, needing fairly low substrate temperatures of 650 °C and 580 °C. Cooling down at 250 Torr oxygen pressure took about 1 h. A short time later, a Siemens group also succeeded in circumventing annealing. However, the substrate temperature was still high (750 °C) and, again, cooling-down as long as 1 h was necessary [9].

It was soon recognized that lengthy post-deposition annealing could be avoided by using moderate substrate temperatures only, with appropriate oxygen admission, or by switching off the heater as early as possible after deposition:

A typical set-up for laser deposition is shown in *fig. 3* as realized by B. Stritzker and co-workers at KFA Jülich, FRG [10]. They use a 248 nm excimer laser (LPX), slightly focussing the beam. As will be described below, only a few J/cm² are necessary to obtain good results. As reported also by other groups, the repetition rate has to be in the range of 5 to 10 Hz, otherwise the films do not grow in the required crystalline structure. Due to the short wavelength, sputtered material as well as ambient gas is excited to fluorescence or chemiluminescence (*fig. 4*) (compare also HL 7). In a recent experiment [11], Fröhlingsdorf, Zander, and Stritzker achieved 500 Å thick films within 5 min (including heating, ventilation, and removal from the stage) which showed a T_c of 92 K (R=0) and a critical current density of 1.5 x 10^6 A/cm². In this experiment the substrate (single-crystalline $SrTiO_3$ or random–ZrO_2 as well as YSC–ceramics) was kept at an elevated temperature (optimum at 780 °C for $SrTiO_3$) during deposition, the heating switched off immediately after deposition, and oxygen used for ventilation during the cooling-down period. No further annealing was necessary.

The deposition temperature

In this experiment, the deposition temperature was found to be fairly critical: *Figs. 5a, 5b* show the optimal transition to superconductivity (a) achieved in this experiment, and (b) a plot demonstrating the importance of a careful choice of the substrate temperature in order to achieve a narrow transition width: the T_c onset (R=100%) temperature is plotted against substrate temperature as well as temperatures belonging to fractional resistivities including R=0. Clearly, at 780 °C the curves most nearly approach each other, showing that the transition from ohmic resistance (100%) to superconductivity (R=0) is very steep when this temperature at the substrate had been chosen. The transition width (defined as the 10%-90% resistance interval) was 1K only.

It should be mentioned here that the resistance curves are generally measured with the standard four-probe technique, the critical current densities up to which superconductivity survives are obtained by applying increasing current through a well defined bridge in the film (suitably prepared by excimer laser ablation) and measuring the voltage/current characteristics until ohmic behaviour appears.

Congruent evaporation: dependence on fluence

The dependence of the film composition on laser pulse fluence for a given 1-2-3 target was systematically investigated by Roas, Schultz, and Endres [12] of Siemens, Erlangen, using a 308 nm laser. *Fig. 6* shows a triangular at-% composition diagram for Y-Ba-Cu. To use this diagram, start at a given point within the triangle, projecting a line parallel to the Ba axis onto the Cu axis to find the copper percentage. Then rotate counterclockwise until parallel to the Y axis in order to find the Ba %, then parallel to the Cu axis to find the Y %. The ideal 1-2-3 stoichiometry is given by the intersection of the three lines (verify the 50 : 33,2 : 16,6 percentage ratio). The experimental points, for different fluences, refer to the compositions found on the film (on the substrate) and, correspondingly, on the target at the spot after laser evaporation. Clearly, the circles (4.5 J/cm²) and the triangles concentrate both for target (full circles) and film (open) close to 1-2-3 stoichiometry indicating the most congruent evaporation at this fluence. Fortunately, fluences in this order of magnitude are easily achieved by current excimer lasers.

The layers obtained in this way were found to have grown epitaxially (on $SrTiO_3$) with excellent superconducting properties: critical current was measured to be 5.2 x 10^6 A/cm² at 77 K, at 2 Tesla still being 3 x 10^6 A/cm². Also, at 4.2 K, where classical superconductors work, superconductivity up to a current density of 10^7 A/cm² was found, about an order of magnitude higher than that in commercial Nb_3Sn wires, the authors report.

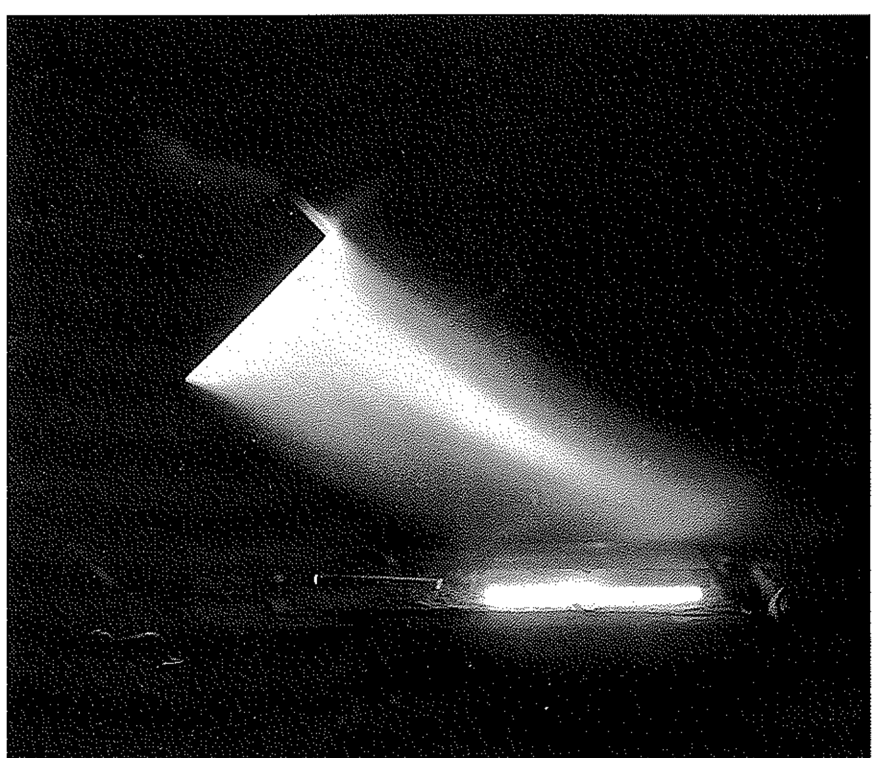

Fig. 4 Light emitting plume due to excimer laser ablation [3]. The deposition geometry is that of fig. 3.

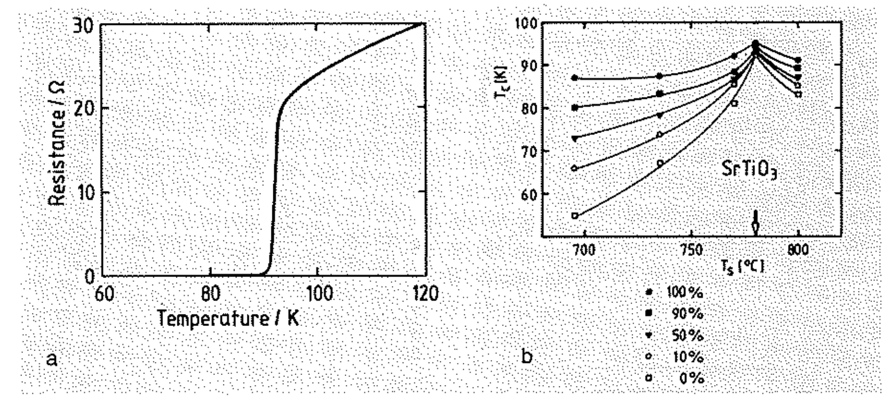

Fig. 5a Optimum transition to superconductivity achieved in [11] with 780°C at the $SrTiO_3$ substrate showing a 10-90% width of 1 K. R=0 is reached at about 92 K.

Fig. 5b Plot showing the transition widths of $YBa_2Cu_3O_{7-x}$ films on $SrTiO_3$ prepared at various substrate temperatures: R(T_c onset)=100%, 90%, 50%, 10%, and 0% (R=0) [11]. At 780°C the steepest transition is obtained (cf. fig. 5a).

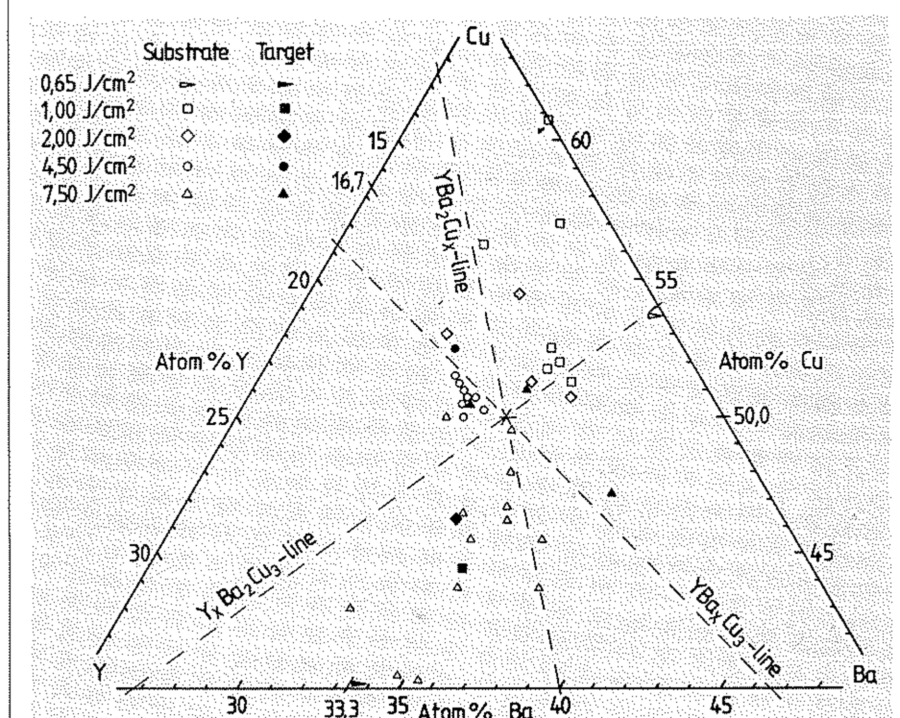

Fig. 6 Composition of deposited films and target beam spots after laser evaporation for various laser beam fluences [12]. See text for further explanation of this diagram.

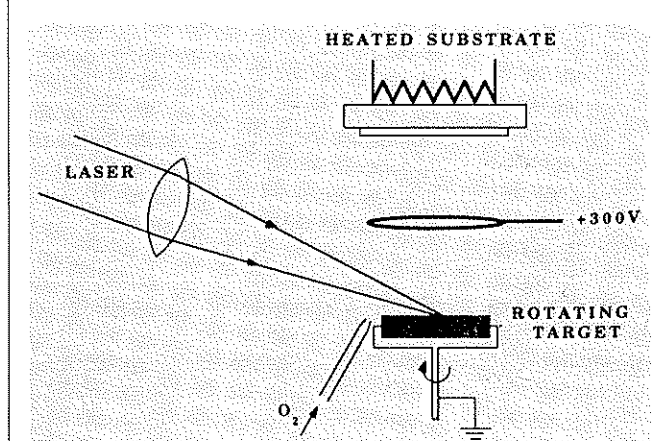

Fig. 7 Scheme of the plasma-laser deposition according to [14]

Oxygen admission: the key for high quality films

As already mentioned above, an extremely important process parameter is the oxygen partial pressure during deposition and cooling down. Since Cu-O areas are believed to be essential for high-T_C superconductivity, the control of the oxygen admission is crucial. This holds the more as the oxygen atom sticking coefficient is less than that of the metal atoms, and oxygen may be ejected.

An investigation on the oxygen admission was recently performed by Ying, Kim, Shaw, and Kwok of New York State University, Buffalo [13] who used an 193 nm excimer laser (EMG) with a fluence of 4 J/cm² at 8 Hz. They examined, at 600 °C substrate temperature, the oxygen admission parameters leading to films superconducting as-deposited (with 5 mTorr oxygen), and the parameters required for producing films (0.5 mTorr oxygen) which showed superconductivity only after a subsequent 850 °C annealing procedure. To do this, they measured the resistivity during laser deposition and oxygen admission after deposition. At the deposition temperature at the substrate (ZrO_2 (100)) there is, of course, no superconductivity, but the resistivity results were strongly dependent on the amount of oxygen used during deposition. The resistivity in $Y_1Ba_2Cu_3O_{7-x}$ is known to depend strongly on the oxygen deficiency x which, at the same time, determines whether the tetragonal phase (non-superconducting) or the orthorhombic phase (O, superconducting) prevails.

The authors concluded that at higher substrate temperatures (as 600 °C), outward diffusion of oxygen leads to a tetragonal (T) phase instead of the orthorhombic (O) phase unless oxygen background pressure is not rather high (this method is used by the Jülich group [11]). The O phase is recognized to be responsibel for good high-T_C superconductivity. Therefore, the authors conclude, true in-situ superconducting films can be obtained only with substrate temperatures lower than 350 °C. However, in this case, the activation of the substrate surface which is needed for epitaxial film growth is critical.

To achieve this, Witanachchi, Kwok, Wang, and Shaw introduced plasma-assisted laser deposition for high-T_C layers [14]. *Fig. 7* shows the scheme of this technique: a low-pressure (10^{-4} T) O_2 discharge is sustained, generating oxygen atoms, ions, and molecular ions. The substrate was at floating potential. The authors report that only O_2^+ ions formed by electron impact ionization between the ring electrode and the substrate were effective in the improvement of the deposition (ion-assisted deposition). Also, O_2^+ ions are believed to enhance the oxygen content of the deposited film, thus improving its superconducting properties. Very recently, Bormann and Nölting [15] pointed out that favorable O_2 conditions are in accordance with the O_2 vapor pressure of the material in dependence of temperature.

Homogeneous velocity of atoms in supersonic beams

In a recent publication by the Buffalo group [16] the influence of the oxygen background on the velocity distribution of the target atoms released by the laser pulses was investigated in more detail. Using an optical time-of-flight method (TOF) (see *fig. 8*) to analyze the velocity distribution of individual species in the plasma plume at 10^{-5} Torr background pressure, the distributions of Cu, Y, and Ba atoms were measured (ascertaining that TOF spectra were independent of the atom's emission line monitored) at a distance of 7.2 cm from the target. The distributions, averaged from over 200 laser shots, could be fitted almost perfectly with a distribution to be obtained in an isentropic supersonic beam expansion. Thus, considerable energy and speed was transferred to the atoms:

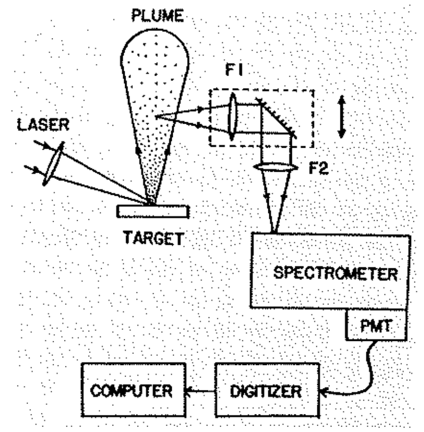

Fig. 8 Set-up for optical time-of-flight analysis of ablated species [16]

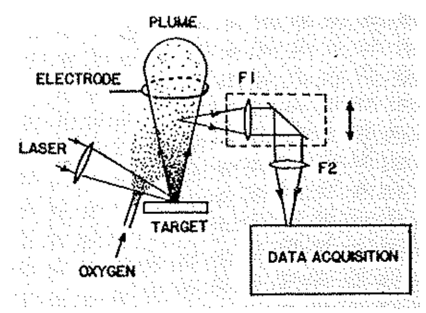

Fig. 9 Optical time-of-flight measurement of ablated species including oxygen admission [17]

Species number	Most probable speed (10^4 m/s)	Mean kinetic (eV) energy	Mach
Cu I	1.12	41.35	4.05
Y I	0.97	43.40	2.3
Ba I	0.82	47.92	1.2
Ba II	1.12	86.40	0 (Maxwellian)

Table 1: Supersonic expansion parameters obtained in ArF laser–generated ablation with 5.3 J/cm², focused to a spot of 0.5 x 1 mm [16]

The remarkable result is that a supersonic molecular beam is formed very similar to beams obtained in hydrodynamic expansion of a (fairly) high-pressure gas via a narrow nozzle. As a consequence, the most probable velocity values do not differ so much due to equalization in the isentropic expansion. In an accompanying paper [17], the influence of the oxygen flow onto the velocity distributions was studied (cf. *fig. 9*). Again, an EMG ArF laser was used to collimate the beam via the oxygen jet onto the target, providing a fluence of 5.3 J/cm² which was found most convenient for the generation of superconducting films. The oxygen jet was observed to emit a red glow indicating efficient interaction of the 193 nm radiation with O_2 molecules. A DC voltage applied downstream even enhanced radiation emission and changed its color. Oxygen admission was adjusted such as to provide as-deposited superconducting films. Under these conditions, the velocity distributions of the atoms Cu I, Y I, Ba I, Ba II, and O I were measured as a function of distance from the target. *Fig. 10* shows the result both for the Mach number and the mean velocity. Clearly, at a distance of about 7.2 cm, equalization has occurred including the Ba and oxygen atoms which have been accelerated. This distance was also found to be optimal for high-T_C as-deposited films under these experimental conditions!

The authors conclude that, for as-deposited superconducting films, it is important that the atoms travel at the same speed so as to impinge on the substrate at the same rate. In addition, the energetic oxygen atomic beam with a velocity of 6 km/s is believed

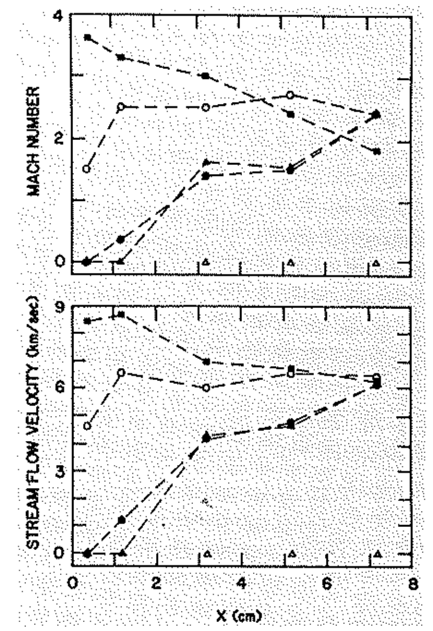

Fig. 10 Dependence of the Mach number and v_o on distance from the target for various species: (■) Cu I, (○) Y I, (▲) Ba I, (●) O I, (△) Ba II.

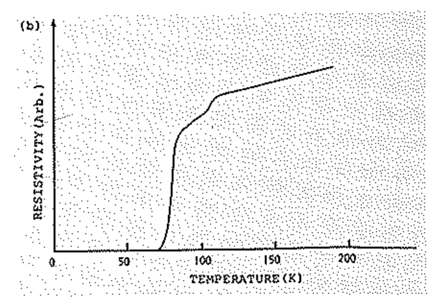

Fig. 11 Resistivity versus temperature of a Bi-Sr-Ca-Cu-O film on MgO(100) annealed at 885 °C in air for 1 minute, showing decrease of resistivity in two steps [21]

to allow the low temperature at which as-deposited superconducting films can be formed.

Using an EMG KrF laser (248 nm) at a fluence of 4 J/cm² and time-resolved spectroscopy, C. Girault, D. Damiani, J, Aubreton, and A. Catherinot of Faculté des Sciences, Limoges, France [18] found similarly energetic atomic beams, mean velocity components perpendicular to the target being almost higher than 10^4 m/s with rather narrow distribution which also is valid for the diatomic molecules CuO, BaO, YO. The authors attribute their result to the ablative nature of the decomposition.

Oxide formation in the plume

Metal oxides in the plume were spectroscopically studied by T. Venkatesan, E.W. Chase, C.C. Chang of Bellcore and coworkers of different institutions [19], in correlation with the oxygen partial pressure. It was shown that the formation of oxides already in the plume, enhanced by a high oxygen partial pressure, is essential for the production of higher-quality superconducting films.

"Tailored" films of Bi-Sr-Ca-Cu-oxides by excimer laser ablation: Higher T_C by lattice engineering?

As already mentioned at the beginning of this article, higher T_c values were observed, e.g. in Bi-Sr-Ca-Cu-oxides (BSCCO) [20] which appeared to contain two superconducting phases with T_C's at 85 K and 105-115 K (*fig. 11* [21]). Clearly, to analyze the site of superconducting phases and the influence of the constituents on the film is a major challenge. Investigations focussed to this aspect are being done at Osaka University, Japan, by the group of Professor Kawai using an EMG ArF excimer laser [22]. In order to control the deposition of multi-element films, the researchers used several targets ("multitarget") exposing them sequentially in a N_2O gas atmosphere as the oxidizer. Targets were sintered disks of $Bi_2Pb_3O_y$, $Sr_1Cu_1O_y$, $Ca_1Cu_1O_y$, $Ba_1Cu_1O_y$, and $Y_1Cu_1O_y$. Irradiation was performed in different sequences in repeated operation as to form 300Å-films of different compositions in which Sr atoms were partially replaced by Ba in a BSCCO fim, and Ba, Sr or Y atoms were substituted for Ca layered in BSCCO. Post-deposition annealing at 800 °C in air was applied for 30 min. *Fig. 12* shows schematically the modification of the crystal lattice due to the substitutions. The authors used X-ray diffraction for crystal analysis. In this figure, the pyramids mean the cuprates.

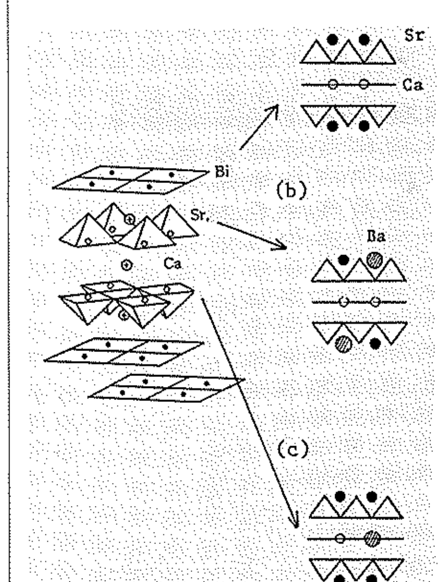

Fig. 12 Partial substitution of Ba at the Sr and Ca site. (a) BSCCO film without substitution, (b) partial substitution for Sr, 30-40%, (c) partial substitution for Ca, 30-40% [21]

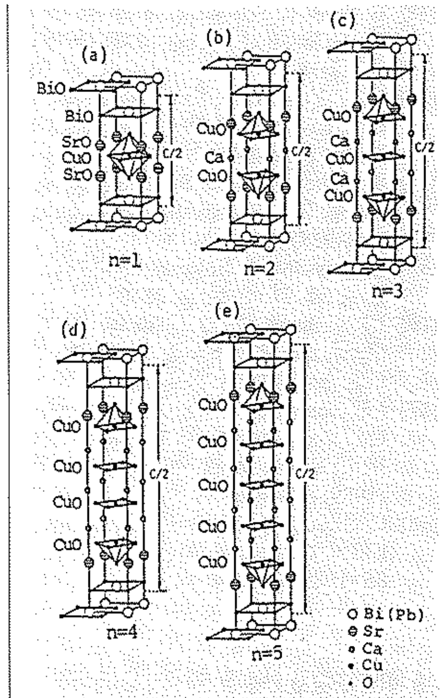

Fig. 13 "Tailored" layers of $(Bi(Pb)O)_2Sr_2Ca_{n-1}Cu_nO_{2n+2}$ in which n is 1-5 representing the number of CuO_2 layers between adjacent $Bi(Pb)_2O_2$ layers [23]

With such "lattice engineering", the c-axis length can be changed and correlated to the superconducting (or non-superconducting) properties. E.g. *fig. 13* shows lattices with different numbers of Cu-O layers between the BiO layers [23] which were obtained at low substrate temperature and reaction with N_2O.

Surely, these investigations are in an early stage. However, even if no industrial application would emerge – due to complexity of the process or other restrictions – the merits obtained for an understanding of the high-T_C phenomenon are most important.

Resumé: High-tech pushes high-tech

This short survey of the work going on with $Y_1Ba_2Cu_3O_{7-x}$ and other compounds is by no means complete. Tremendous efforts are being made around the world to define the processing parameters and to correlate them with good results for high-T_C films. Obviously, most parameters are interdependent so that comparisons are somewhat difficult. However, considering all the results as a whole, a preliminary view arises:

- *Stoichiometry is most critical especially with respect to the oxygen content.*
- *Epitaxially grown films in single phase are most important.*
- *Reproducible production is to be achieved.*
- *Long-term stability has to be guaranteed.*
- *Lattice structures leading to higher T_C should be explored.*

All the different experimental attempts discussed here have these goals in mind. Whichever technique will prove best is presently open. This is certainly also true for techniques competing with laser deposition methods.

Furthermore, for a technical application in electronic circuits, deposition of high-T_C films on Si or other semiconducting materials as well as the combination with metallic conductors will be most important. In this respect research is at the early beginning. First results of in-situ preparation of c-axis oriented Y-Ba-Cu-O and Bi-Sr-Ca-Cu-O films on Si were presented by Krebs and Kehlenbeck [24]; using an LPX 110i they produced films showing superconductivity by applying oxygen in a narrow pressure range in agreement with [15].

In this young field, experimental physics is in the exciting stage of being far ahead of a theoretical understanding of the phenomena. Therefore, techniques which allow researchers to vary parameters almost independently are welcome. With respect to magnetron sputtering and other techniques, laser deposition has an immediate advantage due to its flexibility in varying experimental parameters, hence precise interaction control, and quick response. Thus, new high technology gets its best support from established high-tech!

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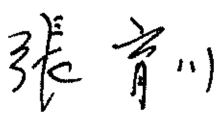
Chinese Scientist guest at Lambda Physik R & D



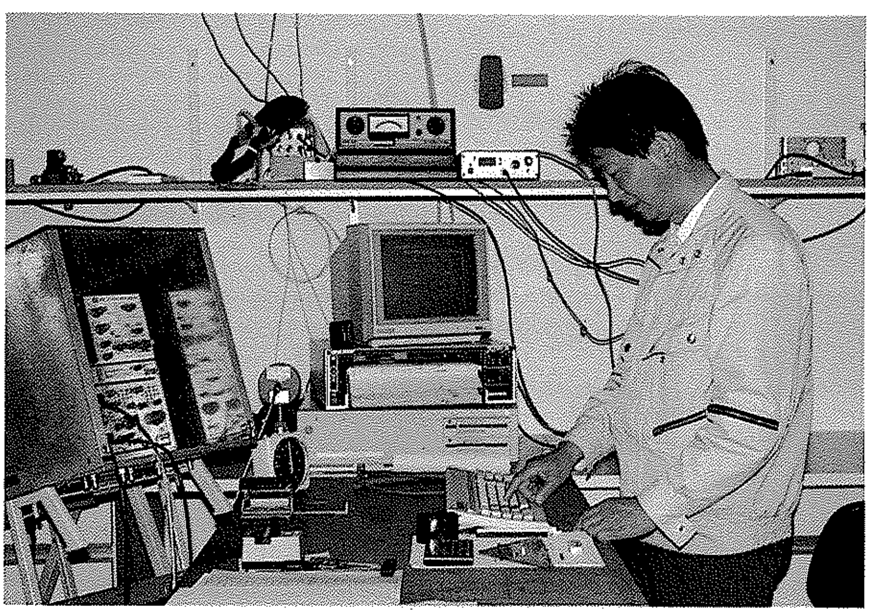
Zhang Yuchuan, Senior Engineer and Deputy Director at the Beijing Institute of Opto-Electronic Technology, Beijing, Peoples Republic of China, was at Lambda Physik for 11 months, working at the R & D division in Göttingen. His stay was a good example for the fruitful cooperation possible across borders which, until recently, were believed to be unsurmountable for a long time. At his Institute he mostly fulfilled management functions, so he enjoyed laboratory work, having sufficient time to do practical things. For example, using a laboratory set-up, he investigated the excimer laser beam pattern under various conditions, extending the analysis to the farfield pattern. Such time-consuming measurements are important for laser application and instrument improvement.

In 1977 Zhang Yuchuan first took notice of Lambda Physik, still in the "nitrogen laser era", when he investigated at his university a nitrogen laser he had built himself. At that time, Dirk Basting visited that laboratory so that the personal contact came about.

Yuchuan took advantage of his Stay travelling through different parts of Germany. When asked what he liked the most he appreciated very much Göttingen, "the city is so quiet – in comparison to the densely-populated big Chinese cities". In this respect, Munich seemed to him more comparable to Shanghai!

He noted a high efficiency in the daiöy work, and he was especially impressed by the skill of the technicians working at Lambda Physik. On coming home, he intends to apply his new experiences, as much as possible, to his work at the Institute.

However, first of all, he looked forward to seeing his family again.



Zhang Yuchuan

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