# IV characteristics of YBCO thin films with a periodic array of Ni dots

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**Abstract**

Enhancing the pinning force in cuprates can be achieved by externally introduced magnetic dots. We have used a novel nanochannel glass technique to create metal replica masks with submicron-size holes that have a triangular lattice pattern. With this replica mask, magnetic dots with a periodic array were deposited onto the surface of YBCO thin films by a simple deposition. The IV characteristics of an YBCO thin film strip with a uniform Ni dots have been measured. They were compared with that of a bare YBCO strip without any magnetic dots. The results show that as the magnetic field strength increases the critical current value of the strip with the magnetic dots reduces with a much slower pace in comparison with the values obtained from the bare sample.

*Key words:* external pinning, periodic array, cuprate

## 1. Introduction

To increase the pinning strength has been the subject of much interest in high-$T_c$ and low-$T_c$ superconductors. The influence of artificial pinning centers such as regular arrays of holes [1] and arrays of magnetic dots [2] for low-$T_c$ superconductors has been studied. In those studies, the standard e-beam lithography method was used to create sub-micrometer sized magnetic dots, and then the Nb thin films were deposited on top of the magnetic dots. This approach can not be used for high-$T_c$ superconducting thin films. The fabrication of high-$T_c$ superconducting thin films always involves high temperature deposition in an oxygen environment. The magnetic dots can not survive in this harsh condition. On the other hand, to deposit magnetic dots onto high-$T_c$ superconducting thin films by e-beam lithography may damage high-$T_c$ thin films because there are many steps in e-beam lithography. In this paper, we will describe a novel technique to deposit uniform hexagonal arrays of nano-sized magnetic dots onto high-$T_c$ thin films by a single deposition. The order and size of the magnetic dots are obtained by fabrication methods using metallic replica masks [3] that are fabricated using nanochannel glass technology [4].

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## 2. Experimental Procedure and Results

Our fabrication technique is based on a special material, nanochannel glass (NCG), which is a glass matrix containing extremely uniform arrays of hollow channels. The hollow channels are arranged in a hexagonal close packed pattern. The channel diameter can be as small as 20 nm. The channel diameter of the NCG material used in this experiment was about 450 nm. The fabrication procedure of NCG was reported in reference 4.

NCG replica masks are thin films of metal having uniform, patterned voids that duplicate the pattern of the underlying NCG on which they are grown. The fabrication procedure of metal replica masks was reported previously[3]. A regular array of magnetic dots with a hexagonal pattern was obtained on the surface of the YBCO thin film by sputtering magnetic materials through the mask. After this, optical lithography

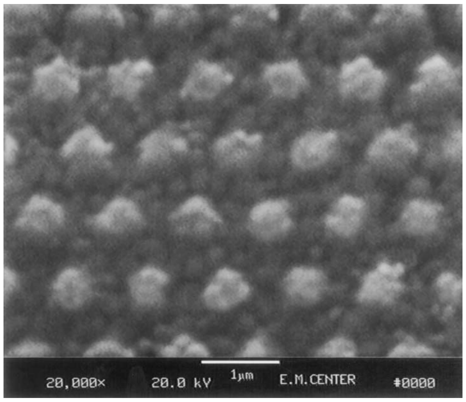


Fig. 1. SEM image of Ni dots 450 nm in size and 60 nm in thickness on the YBCO thin film.

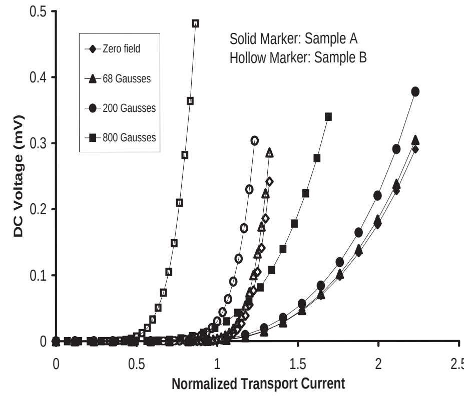


Fig. 2. IV characteristics of the sample A and B at various magnetic fields obtained at T = 83.5 K.

and wet etching were used to define a 0.1 mm wide and 0.3 mm long YBCO strip as the sample A for transport measurements. The whole strip was covered by the Ni dots. In this work, magnetic dots approximately 450 nm in diameter, 60 nm in thickness and 1 $\mu$m in pitch were prepared. The matching field for this sample was about 23 G. Fig. 1 shows the SEM picture of the Ni dots. For the purpose of comparison, another bare YBCO strip without magnetic dots having the same dimension as the sample A was fabricated as the sample B. Both of the YBCO thin films were fabricated by magnetron sputtering under the similar conditions. The transition temperatures of the samples were about 89 K and the thicknesses of them were 100 nm.

The IV characteristics of the samples were measured in a nitrogen cryostat with a 1.0 KG solenoid magnet. The magnetic field was always applied perpendicular to the transport current. We measured the IV characteristics of both samples at various magnetic fields and temperatures. Fig. 2 shows the results obtained at T = 83.5 K at various magnetic fields for both samples. In the figure, the transport current was normalized by the critical current of each sample at the zero field. The figure shows that as the strength of the field increased the critical current reduced for both samples, so that the IV curves shifted to the left. However, the rate of the shift for the sample A (with dots) was slower than that of the sample B (no dots). To make quantitative comparison, we found the normalized transport currents at V = 0.2 mV for all IV curves. Then for each sample the percentage shift for a specific magnetic field was calculated using the value at zero field as 100%. Those values are shown in the table.

| Magnetic field (G) | 68 | 200 | 800 |
|---|---|---|---|
| Sample A | 1.0% | 4.9% | 25.9% |
| Sample B | 1.5% | 9.9% | 42.0% |

The results show that the shifts of IV curves of the sample A were smaller than that of sample B at all fields. As the field increased the difference in shift increased. We also found that as the temperature reduced, the difference in shift increased too. Please note that 800 G is about 35 times stranger than the matching field. This could be explained by the fact that the magnetic dots in the sample A serve as additional pinning centers. Because the dot size is much larger than the vortex size, the dot works as a large pinning center. Each dot can pin multiple vortices. So at fields many times stronger than the matching field, there is still strong pinning effect from the dots.

In conclusion, we have developed a new way to introduce sub-micron magnetic dots on high-$T_c$ thin films. The experimental results indicate that large magnetic dots can work as effective pinning centers at magnetic fields much stronger than the matching field.

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