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New fabrication techniques for PASS

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Abstract

The Planar Array of Superheated Superconductors was introduced by the UBC group in 1990. It is a regular array of micron-sized spheres of indium or tin that acts as a detector of radiation or particles in a similar fashion to the Superheated Superconducting Granule Detector. Over the years, it was demonstrated that this device exhibited good energy sensitivity, a narrow spread of individual transition temperatures, position sensitivity, and, using line geometry, partial avalanche effects. The great difficulty, however, was to produce a detector of sufficient size. We discuss three possible approaches to this problem. The first method is to fabricate the array photolithographically in much the same way as before, but on a much larger scale. The second way is to emboss squares in a metal film with an ultrafine cutting tool before melting. The third technique involves depositing the metal on to a structured surface then melting. Some experimental tests are described.

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1. Introduction

The Superheated Superconducting Granule Detector (SSGD) [1,2] is an ensemble of spherical, type I superconducting microspheres ("granules") that, by adjusting the temperature and applied magnetic field, can be put in the superheated superconducting state very close to the line separating that phase from the normal one. Energy deposition in a granule by a particle or radiation then nucleates the transition and "flips" it into the normal state. The resulting change in the magnetic flux distribution associated with the flip is sensed by a read-out system based on a SQUID or an inductive pick-up.

The original SSGD was a "colloidal" suspension of spherical granules in a suitable medium, e.g. paraffin wax or epoxy. The best such SSGDs use commercially produced granules with good sphericity and a variation in granule diameters of about 20%. Although the "colloidal" detector has been used very successfully in various applications, it does have a relatively wide spread in the superheated superconducting-to–normal transition temperatures of the individual granules, ΔT_{SH}, and this can degrade the efficiency of the detector. This difficulty was overcome by the invention by our group of a new fabrication procedure described in Section 2 that uses photolithography to produce a

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regular array of superconducting spheres [3]. The granules in this "Planar Array of Superheated Superconductors" (PASS) have excellent uniformity in shape, size and position, and ΔT_{SH}, is an order of magnitude less than that for a colloidal SSGD. The drawback is that our fabrication technique can only produce arrays of relatively small size.

We have demonstrated that the PASS detector has both good energy [4] and position sensitivity [5], and can detect neutrons [6]. Further, a partial avalanche occurs in a line of granules thereby enhancing the magnetic signal [7], allowing, in principle, the use of very small granules to improve the energy sensitivity.

2. "Old" fabrication method

The first step in the fabrication of the PASS is the fabrication by evaporation and photolithography of uniform squares, circles or ovals of a suitable type I superconductor on an appropriate substrate, and we have fabricated indium/mylar and tin/kapton arrays. The usual array is square, but we have also made other geometries including sets of squares and sets of lines. The array is then carefully heated through the melting point of the metal in the presence of a wetting agent (a flux such as abietic acid). On melting, the squares (or other shapes) form into spheres, and, on cooling, an array of spherical granules has been produced.

Various arrays have been fabricated with granule diameters ranging from 4 to 50 μm and sizes ranging up to 250×250. The uniformity is such that deviations in position and size are less than 4%.

3. New large scale fabrication

One approach to increase the size of the PASS is to use large scale photolithography on a silicon wafer. In fact, IMEC at Leuven has fabricated, for quite different reasons, arrays of indium hemispheres on 5 cm diameter circular wafers. We tested a small section of one of these arrays, and found that the sample array did go superconducting, but no hysteresis was observed, presumably due to the geometry of the granules. It should be possible to produce granules with a much smaller base, i.e. closer to a spherical shape, and these should exhibit superheating and supercooling. Also it should be relatively easy to produce PASS arrays on, for example, 15 cm diameter wafer.

The 3 M Company has developed a process in which shapes are imprinted into a metal film with an embossing tool that achieves very fine and precise diamond machining. This method can produce a planar array of squares that can then be made into a PASS by a melting process similar to the one developed at UBC. The important improvement is that, in principle, the tool can produce very large arrays. Figs. 1 and 2 show the embossed surface prior to and after melting respectively.

We have conducted tests that show that an embossed sample exhibits hysteresis demonstrating that the spheres superheat and that the array acts as a detector. This is shown in Fig. 3.

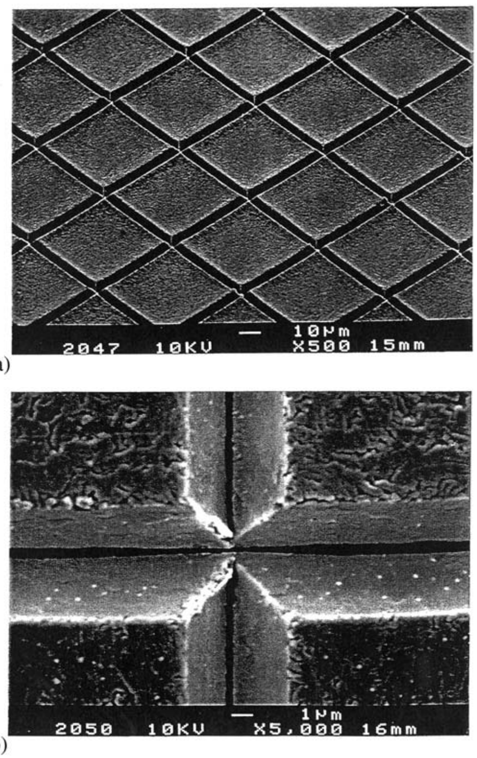

Fig. 1. (a) Embossed surface showing cuts by 3 M tool into the tin film prior to melting. (b) Magnified view.

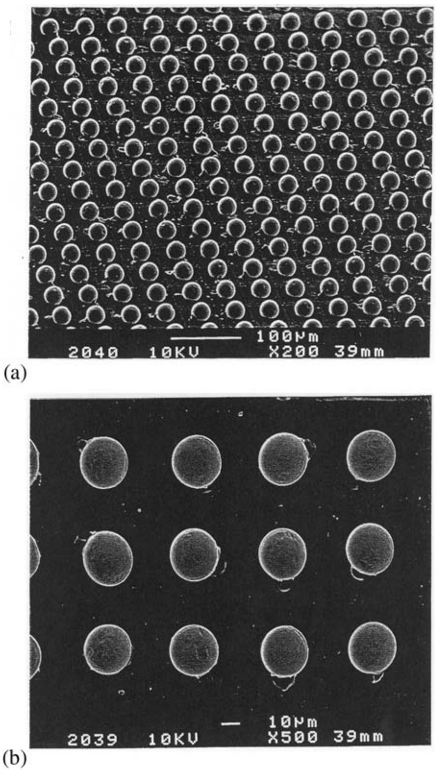

Fig. 2. 3 M sample after melting: (a) Scale 100 μm and (b) Scale 10 μm.

In a third method, a thin metal film is deposited on a structured substrate that has hollows in it. Wetting and melting then causes granules to form in the hollows. We have made a rudimentary array by this means, but because of the size of the indentations in our structured surface, the granules were too large (several hundreds of microns) for the sample to act as a PASS. However, the 3 M Company have produced arrays composed of smaller spheres [8]. Again, it would be relatively easy to make very large arrays using this technique.

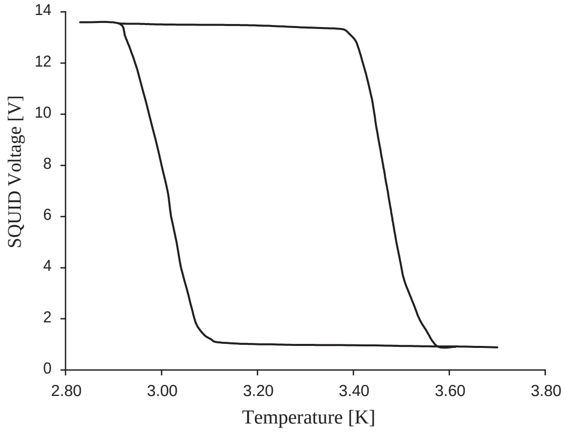

Fig. 3. Hysteresis curve showing superheating and supercooling of 3 M PASS sample.

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