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# Magnetic microdisks: production and internalization by skin cancer cells

**R. Zurbano[1], C. Redondo[1], C. Penas[2], M. D. Boyano[2,3], I. K.Schuller[4], and R. Morales.[5,6]**

1. Department of Physical-Chemistry, University of the Basque Country UPV/EHU, 48940 Leioa,Spain. 2. Department of Cell Biology and Histology, University of the Basque Country UPV/EHU, 48940 Leioa, Spain. 3. Biocruces Health Research Institute,48903 Barakaldo, Spain. 4. Center for Advanced Nanoscience and Department of Physics, University of California San Diego, La Jolla, California 92093, United States. 5. Department of Physical-Chemistry & BCMaterials, University of the Basque Country UPV/EHU, 48940 Leioa, Spain. 6. IKERBASQUE, Basque Foundation for Science, 48011 Bilbao, Spain.

## INTRODUCTION

Disk-shaped magnetic elements in vortex state are promising particles for novel biomedical applications. A vortex spin configuration yields zero remanence in magnetization curves, which make these particles suitable to avoid agglomerations [1,2].

In this work, we fabricate microdisks as large as 3.4 microns in diameter still in a vortex configuration. They present a large magnetic moment to interact with external magnetic fields. The internalization process of these particles was investigated *in vitro* assays with melanoma cells and macrophages. Scanning electron and confocal microscopy reveal the internalization of microdisks for incubation periods of 24 h.

## MICRODISKS MANUFACTURING

**1. Photoresist spin coating** onto an Al sacrificial layer on a Si wafer.

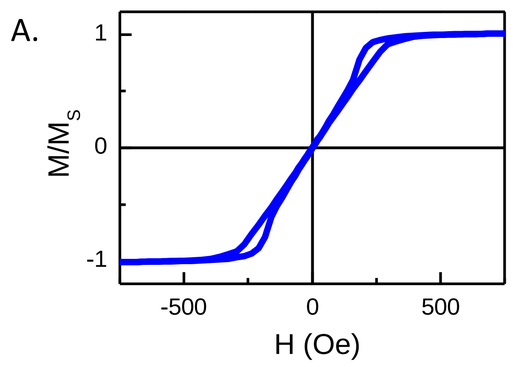
**2. Optical Litography**
Templates are patterned by Direct Laser Writing over the whole Si wafer.

**3. Material deposition.**
Two protective layers of Ti and a magnetic layer of Permalloy (NiFe) wre deposited by electron beam evaporation.

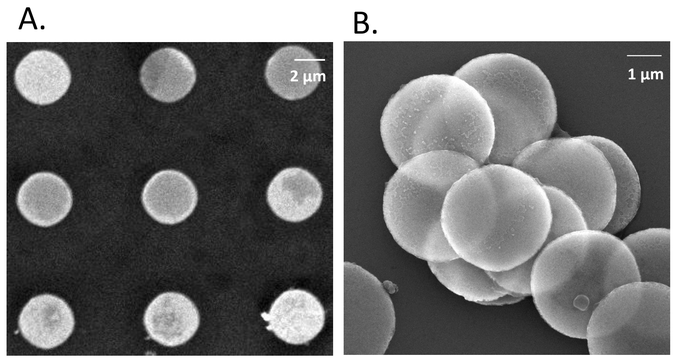
**4. Lift-off**
The photoresist is chemically removed and microdisks remain on the Al layer.

**5. Disk removal**
Microdisks are released by a chemical etching of the Al layer with KOH.

## CHARACTERIZATION



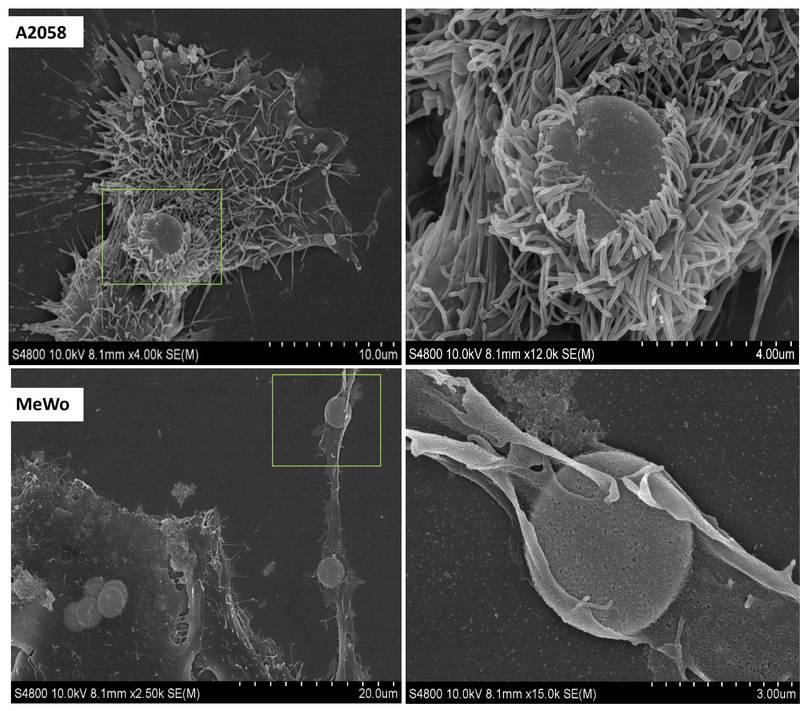

Magnetic characterization: (A) SQUID hysteresis loop of microdisks (diameter 3.4 mm and thickness 100 nm) attached to the substrate (step 4). (B) Representative illustration of the vortex state at zero field.



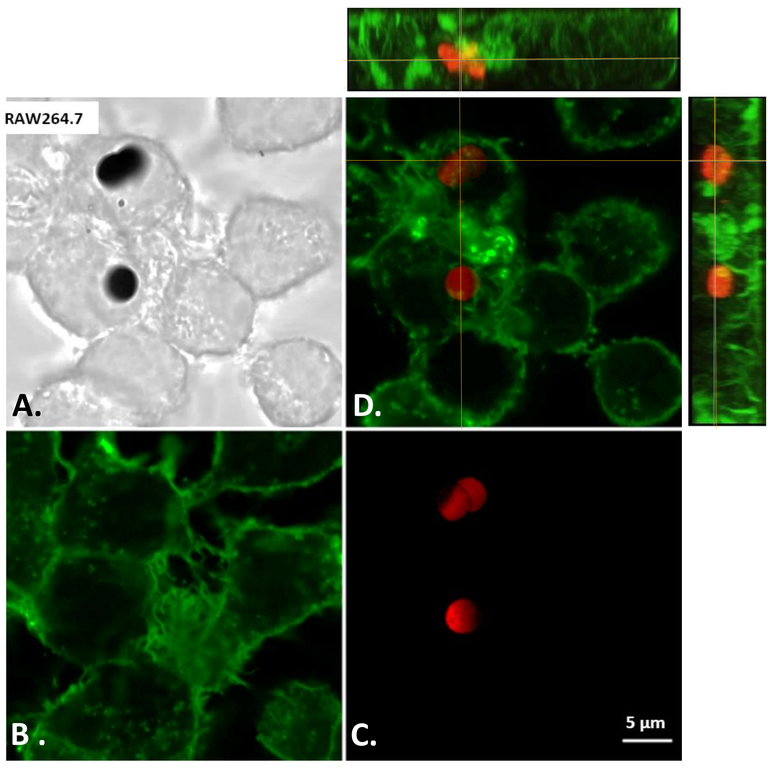

SEM images, (A) microdisks adhered to Si substrate, step 4 and (B) microdisks released in suspension, step 5.

## RESULTS OF *IN VITRO* ASSAYS

Using three cell lines, two of human metastatic melanoma (A2058, MeWo) and one of mouse macrophages (RAW 264.7), the location has been studied after 24 hours of essay. A location analysis was performed using scanning electron microscopy (SEM) and confocal microscopy.




In the SEM images, cell extensions are observed surrounding the microdisks, which could indicate the phagocytosis process for its internalization.




Confocal microscopy images: (A) clear field, (B) fluorescence of the actin filaments, (C) reflection of the metallic disks and (D) combined image of the three channels.

In addition, thanks to orthogonal views along yellow lines (rectangular pictures in (D)), magnetic disks can be located inside the cells.

## CONCLUSIONS

- **This manufacturing process allows to obtain magnetic microstructures with zero remanence in the absence of field, high magnetic moments, and biocompatible, in an efficient and economical way.**
- ***In vitro* tests shows that in 24-hour periods, the structures are internalized almost completely in RAW 264.7 (macrophages) and partially in MeWo and A2058 (metastatic melanoma lines).**

## FUTURE WORK

The possible cytotoxicity caused by the internalization of the structures will be ruled out and external magnetic fields will be applied to investigate magneto-mechanical effects on cells with internalized microdisks.

## CONTACT PERSON

Raquel Zurbano Tejada
raquel.zurbano@ehu.eus
eman ta zabal zazu
Universidad del País Vasco
Euskal Herriko Unibertsitatea

## REFERENCES

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[2] B. Mora et al. ACS Appl. Mater. Interfaces 10 (2018) 8165.

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