

Elastic Properties of Iron Nanoparticle Monolayer

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Abstract

Through a drop drying technique, we can deposit free standing membranes of nanoparticles onto micrometer size circular holes. We use force microscopy to probe their remarkable elastic properties. Through electron microscopy, we study their monolayer crystal structure.

Introduction

There are many types and forms of membranes. They have many useful applications ranging from filtration to high sensitivity sensors. Nanoparticle membrane, a single layer of nanoparticle, is an ultimate limit. Many studies have shown that nanoparticles of two different materials often form crystal structure with interesting properties.ⁱⁱⁱ

Iron nanoparticle membranes are of particular interest; Iron particles can respond to magnetic signals, making them promising candidates for a wide range of applications. Our nanoparticle system consists of closed packed inorganic particles, Iron, and organic polymers functioning as spacers. Nanoparticle monolayers can be created using a simple drop drying technique. These ultrathin membranes can be stretched across micrometer-size holes. A similar system of 6 nm gold nanoparticle arrays, stretched across 5 - 2.2 μm holes, shows remarkable strength with a Young's modulus on the order of GPa.ⁱⁱⁱ Iron nanoparticle membranes are more stable, covering up to 10 μm holes of silicon nitride.

Atomic force microscopy can be used to perform force curve analysis. Through Begley and Mackin's elastic theory for free-standing membranes with considerable pre strain over a circular boundary^{iv}, the Young's modulus can be determined. Transmission electron microscopy enables us to identify monolayer structure and study its crystal arrangement.

Outline

SEM: identify AFM Cantilever spring constant

AFM: surface image, perform force curve analysis

TEM: to study its crystal arrangement

Compare data with theories and identify elastic properties.

Conclusion

Expect to see Young's Modulus on the order of GPa.

Know the crystal structure.

ⁱ E. V. Shevchenko, D. V. Talapin, N. A. Kotov, S. O'Brien, C. B. Murray, "Structural Diversity in Binary Nanoparticle Superlattices", *Nature* 439, 55 – 59 (2006).

ⁱⁱ J. J. Urban, D. V. Talapin, E. V. Shevchenko, C. R. Kagan, C. B. Murray, "Synergistic Effects in Binary Nanocrystal Superlattices: Enhanced p-type Conductivity in Self-Assembled", *Nature Materials* 6, 115-121 (2007).

ⁱⁱⁱ Klara E. Mueggenburg, Xiao-Min Lin, Rodney H. Goldsmith, and Heinrich M. Jaeger, "Elastic membranes of close-packed nanoparticle arrays", *Nature Materials* 6, 656 - 660 (2007).

^{iv} M. R. Begley, T. J. Mackin, "Spherical indentation of freestanding circular thin films in the membrane regime", *J. Mech. and Phys. Solids*. 52, 2005 (2004).