Combinatorial Methods Used to Identify New Compositions of Ferromagnetic Shape-Memory Alloys

Combinatorial materials science is used to systematically study materials properties as a function of composition using a number of small samples differing slightly in composition. In a study published in the March issue of *Nature Materials*, I. Takeuchi and colleagues from the University of Maryland, Rowan University, and Neocera, Inc. have used thin-film composition spreads of multiferroic Ni-Mn-Ga alloys, of which the so-called Heusler composition, Ni_2MnGa, is a well-known shape-memory alloy, to study both the mechanical behavior and ferromagnetic properties of the alloys.

Multiferroic alloys exhibit the ability to switch between two conditions, such as ferromagnetic and paramagnetic, in more than one combination of conditions. The Ni-Mn-Ga alloys are ferromagnetic and are also shape-memory alloys, so, in addition to exhibiting martensitic transitions due to temperature change, shape-memory effects can, in many cases, be induced by an applied field, leading to a number of potential applications. The objective of the study was to determine which compositions of the ternary Ni-Mn-Ga system other than the Heusler composition exhibit ferromagnetic shape-memory effects. This required the development of techniques to measure both mechanical and magnetic properties of a series of compositions of the alloy system.

For measuring magnetization, the researchers used a spread of patterned combinatorial array of 2 mm × 2 mm square grids and a scanning superconducting quantum interference device (SQUID) microscope. For detecting structural martensitic phase transition, a spread of compositions was deposited as thin films on a series of silicon cantilevers. When the cantilevers are heated causing a phase transformation, they bend, which is detected during visual inspection of the image of the cantilever arrays as a change in reflection resulting from a changing radius of curvature.

Results showed that the strongest magnetization and the highest phase-transition temperatures were observed in regions away from the traditional Heusler composition. However, higher magnetization was coupled with a lower transition temperature. Thus there is a tradeoff between the two properties in the system. It was found that in a ternary system, the Heusler composition does not necessarily yield optimized functionality.

More importantly, this study demonstrates the use of combinatorial methods in conjunction with unique characterization techniques to systematically study an alloy system.

GOPAL RAO

Rupture of Rhodamine-Labeled DNA Studied by Simultaneous, Spatially Coincident Optical Trapping and Single-Molecule Fluorescence

Heretofore, optical trapping and single-molecule fluorescence, two important techniques in single-molecule research, have not been successfully combined in a single experiment because the light emitted by a single fluorophore is 10 orders of magnitude lower than the light intensity of an optical trap. (Optical traps, also known as optical tweezers, use photon momentum transfer to grasp and manipulate microscopic dielectric particles, such as microspheres, cells, and cellular organelles.) In previous attempts, either the optical trap was separated from the fluorescence region by several millimeters or the two techniques were employed sequentially. Recently, a team of researchers from Stanford University's Biological Sciences, Applied Physics, and Physics departments demonstrated simultaneous, spatially coincident optical trapping and single-molecule fluorescence.

As reported in the February 24 issue of the *Journal of Biology*, Stanford researcher S.M. Block and co-workers observed changes in single-molecule fluorescence and force-induced strand separation in dye-labeled double-stranded DNA. The researchers attached one end of a 1,010 base-pair DNA duplex to a polystyrene bead with a diameter of 500 nm. The distal end of the DNA, designed with an overhanging segment on the 5′ end, was annealed to a complementary 15 base-pair oligonucleotide, which was anchored on its 5′ end to a cover glass surface (see figure). Tetramethylrhodamine (TAMRA) dyes conjugated to nucleotides were attached to complementary bases on the free end of the DNA, that is, on the 3′ end of the 15-mer and on the 5′ end of the long DNA duplex. In such close proximity, fluorescence of the dye molecules is self-quenched. The researchers note that the very short distances probed by TAMRA self-quenching (about 12 nm) is smaller, in most cases, than those probed by fluorescence-resonance energy transfer.

The instrument developed by the researchers incorporates a microscope, a laser for trapping (1064 nm), another to detect position (827 nm), and a third for fluorescence excitation (514 nm). By trapping the DNA-bead complex and moving the microscope stage at constant velocity, the researchers pulled the bead from the center of the trap and increased the load until rupture occurred, that is, until the 15 base-pair duplex "unzipped" into two single strands. Before rupture, the researchers observed low light levels, indicative of the quenched dye state, and a monotonic increase in the force. At rupture, the force abruptly decreased from 9 pN to 0 pN and the light level increased, indicating that the two fluorophores separated, thereby unquenching the dye bound to the 15-mer. Two control experiments with single dye molecules, in which TAMRA was bound either to the long DNA duplex or to the 15-mer, demonstrated that rupture corresponds to strand separation and not to breakage of the linkage holding the DNA to the cover slip.

The researchers believe that simultaneous optical trapping and single-molecule fluorescence will supply vital information about the sequence of molecular events. Furthermore, the researchers anticipate that "this technique will have broad appli-

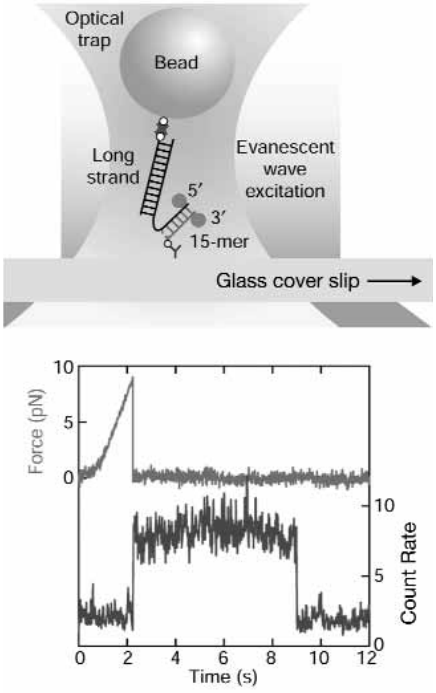

Figure. A combined optical trapping and fluorescence experiment to unzip DNA. (a) Schematic of the experimental geometry; (b) simultaneous measurements of the force required to rupture (top trace) and the fluorescence (bottom trace). The dye unquenched upon rupture and then later bleached. Courtesy Journal of Biology **2** *(6)(2003); http://jbiol.com/content/2/1/6.*

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