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Epitaxial Growth of NiTi Films on Single-Crystal Silicon Substrates Using Seed Layers

Background Nitinol (NiTi) is a nickel titanium alloy that has shape memory features, and can recover its initial shape after deformation upon heating. NiTi has a large recoverable strain and high work output, making NiTi films an ideal choice for sensors and actuators in MEMS devices. However, the thermal shape memory effect in NiTi is suppressed when the grain size is below 50 nm. As a result, ultra-thin NiTi films, which typically have very fine grain sizes, are unviable for MEMS applications.

Even when the grain size is increased sufficiently through annealing to restore the shape memory effect, polycrystalline NiTi films still have two other main limitations. First, the incompatible transformation strains between neighboring grains in NiTi films can lead to stress concentrations near grain boundaries, and can result in plastic deformation and incomplete strain recovery. Second, the stress concentrations can induce fatigue cracks during thermal or mechanical cycling, which can ultimately lead to failure. These problems can be circumvented if the NiTi film can be made monocrystalline rather than polycrystalline. These single-crystal NiTi films could also have higher recoverable strain compared to previous versions. Invention Description Researchers at Arizona State University have developed a novel method for fabricating single-crystal NiTi films on single-crystal silicon (Si) wafers. This process involves selecting one or more seed layers that have progressively better lattice matching with NiTi, which enables NiTi to grow epitaxially on the topmost seed layer. These films can be made extremely thin (<100 nm) which can enable high frequency operation of MEMS sensors and actuators. These films can also be processed at relatively low temperatures, which removes the need for annealing at high temperatures to restore the shape memory effect. Potential Applications • Micro-electromechanical systems (MEMS) • Biomedical applications (including orthopedic implants and orthodontic devices) • Electrical devices (including sensors and actuators) Research Homepage of Professor Jagannathan Rajagopalan