Skysong Innovations
Advancing the Arizona State University Knowledge Enterprise

1475 N. Scottsdale Road, Suite 200
Scottsdale, AZ 85287-3538
Phone: 480 884 1996 Fax: 480 884 1984

Case ID:M20-134P
Published: 1/11/2021

Low-Temperature Synthesis of Single-Crystal Films on Amorphous Substrates

Inventors

Jagannathan Rajagopalan

Contact

Shen Yan
shen.yan@skysonginnovations.com

Background

Single-crystal metallic films, which have applications in electronics, optics, thermal barrier coatings and microelectromechanical systems (MEMS), can be synthesized by epitaxial or heteroepitaxial growth on single-crystal substrates that have a high degree of lattice matching with the film. This technique, however, suffers from drawbacks, including the limited number of usable substrates and the stringent conditions that need to be satisfied for epitaxial growth, which severely restricts the choice of materials. In many applications, metallic films need to be deposited on amorphous or polycrystalline substrates, which preclude the use of epitaxial or heteroepitaxial growth. While single-crystal and very large-grained Au and Ag films have been synthesized on amorphous substrates by liquid phase epitaxy and oxygen-induced grain growth, respectively, these processes typically require very high temperatures (exceeding the melting temperature Tm of the metal) or involve incorporation of impurities that may compromise the properties of the film. Thus, a general approach to synthesizing a broad range of single-crystal metallic films on amorphous substrates at low temperatures (e.g., below 0.5 Tm) is needed.

Invention Description

Research at Arizona State University has led to a process for synthesizing single-crystal films (tens to thousands of nanometers thick) over large areas (several square millimeters or even square centimeters) on amorphous substrates.

The synthesis process includes growing amorphous metallic alloy layer(s) of desired thickness by physical vapor deposition (e.g., by magnetron sputtering). A single seed crystal is formed by depositing the seed material at an appropriate temperature and rate through a patterned mask with a nanometer-sized hole. The seed crystal can be encapsulated by the substrate and an amorphous alloy layer or by two amorphous alloy layers. It can also be deposited on top of an amorphous alloy layer. The seed crystal along with the amorphous layer(s) comprise the precursor film. The precursor film is then crystallized by annealing to obtain the single-crystal film. This seeding technique allows nucleation of a single grain in the precursor film, which grows to consume the film and form a single crystal in a solid-to-solid (amorphous to crystalline) transformation, which typically requires much lower temperatures than liquid-to-solid transformation processes. The processing temperatures are relatively low (0.4-0.6 times the Tm of the metallic alloy or lower). Moreover, unlike epitaxial or heteroepitaxial growth methods, special single-crystal substrates are not required.

Potential Applications

- Electronics and optoelectronics
- MEMS
- Photovoltaics (transparent conducting oxide films)
- Protective coatings for high-temperature alloys (TiAl and NiAl films)
- Solid state thermal energy storage (NiTi films)

Benefits and Advantages

- Applicable to a broad range of materials including metallic alloys (e.g., ordered intermetallics, high-entropy alloys), semiconductors, and ceramics
- Can be used to grow single-crystal films on any amorphous surface and a majority of polycrystalline and monocrystalline substrates
- Low processing temperatures

Research Homepage of Professor Jagannathan Rajagopalan