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Low-Temperature Synthesis of Thin Films with Tailored Grain Size, Texture, and Phase Composition

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Background

Metallic films have a broad range of applications in electronics, optoelectronics, plasmonics, catalysis, and MEMS sensors and actuators. In many of these applications it is highly desirable to control the microstructure (size and spatial distribution of grains, texture, and phase composition) of the films since the microstructure largely governs their mechanical and physical properties. For instance, large grain sizes are desired in electronic interconnects to reduce electrical resistivity and electromigration. In shape memory thin films like NiTi, a particular phase (austenite or martensite) may be required depending on the application.

It is also often necessary to reduce the processing temperature (deposition or post-deposition annealing) of the metallic films to make them compatible with the fabrication methods of the devices into which they are incorporated. For example, when NiTi films are employed for MEMS sensor/actuator applications, their deposition/annealing temperatures need to be kept low to maintain compatibility with MEMS device production. Similarly, when NiTi films are deposited on polymeric substrates, the processing temperatures are limited because the structure and properties of polymers degrade at elevated temperatures. Thus, a method that enables precise control of the microstructures of thin films while reducing processing temperatures could be immensely beneficial.

Invention Description

Researchers at Arizona State University have developed a method to synthesize thin films with highly controlled grain size, texture and phase composition using physical vapor deposition. The method alloys precise tailoring of thin film microstructures to systematically tune their mechanical and physical properties. The method is applicable to a wide range of materials including metallic alloys, ceramics, and semiconductors. The synthesis process comprises the following steps:

1. An amorphous layer of the material is deposited by physical vapor deposition at room temperature (RT).

2. An appropriate seed layer that has a crystalline structure at RT is deposited. The seed layer is very thin (< 5 nm thick) and has a high interfacial energy with the amorphous layer so that it forms crystalline islands (seeds) on the amorphous layer.

3. The seed layer is encapsulated by depositing another amorphous layer.

4. Steps 2 and 3 are repeated until the desired film thickness is reached.

5. Finally, the film is crystallized by annealing at elevated temperature.

Potential Applications

Synthesis of thin films for use in:

- Photovoltaics
- MEMS sensors and actuators
- Thermal barrier systems
- Wear- and corrosion-resistant coatings
- Diffusion barriers/insulators in electronics
- Optical coatings

Benefits and Advantages

- Applicable to a broad range of materials including metallic alloys (e.g., ordered intermetallics, high-entropy alloys), semiconductors and ceramics (e.g., oxides, nitrides)
- Low processing temperatures: Less than half the melting temperature of the thin film material
- Provides precise control of key microstructural parameters (e.g., grain size and size distribution, orientation, and phase composition) and allows microstructural parameters to be spatially varied as desired

Research Homepage of Professor Jagannathan Rajagopalan