Single Crystal High-Temperature Shape-Memory

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Purpose

The objective of the Phase I was to first develop and then validate a new single crystal growth capability, specifically tailored for growing single crystals of shape memory alloys (SMAs), and then to develop and optimize single crystal SMAs with high temperature capability. This effort was not to replace our existing efforts on polycrystalline SMA development, but to leverage that knowledge by providing a method for producing materials with even greater shape memory and superelastic properties. Studies of single crystals are frequently used to explore fundamental materials behavior, but are also commercially relevant, as for example in the electronics industry as well as superalloy turbine blades.

Background

A major challenge in producing single crystal SMAs is that NiTi-based alloys are difficult to melt, primarily because the high Ti content in the alloys is very reactive with ceramic and graphite crucibles employed in conventional single crystal growth processes. A single crystal, which was previously studied, was grown in Russia by the Bridgman technique using a graphite crucible. Therefore, although it possessed exceptional properties, it also contained large carbides, which would diminish actuator performance and impact fracture and fatigue behavior. Due to this carbon contamination, the preferred solidification techniques should be restricted to containerless or cold-hearth processes such as were used in the Czochralski (CZ) single crystal growth furnace in the Ceramics Branch at NASA GRC. Using the Czochralski method, the SMA material was melted in a water-cooled copper crucible under a high purity argon atmosphere. The melting was achieved via arc melting with three tungsten electrodes, which allows for uniform heating and homogeneous melt composition during the process. The crystals were then produced by dipping the end of a tungsten or NiTiHf pull rod in the melt and withdrawing it at a controlled rate to allow a crystal to nucleate and grow from the melt. This method allowed us to grow high purity single crystals and thus avoid the detrimental effects of additional carbon and oxygen contamination. The knowledge and materials being developed in this Seedling Fund project will allow shape- memory alloys to be used in more demanding and varied applications, due to the improvements in work output available in the single crystal materials.