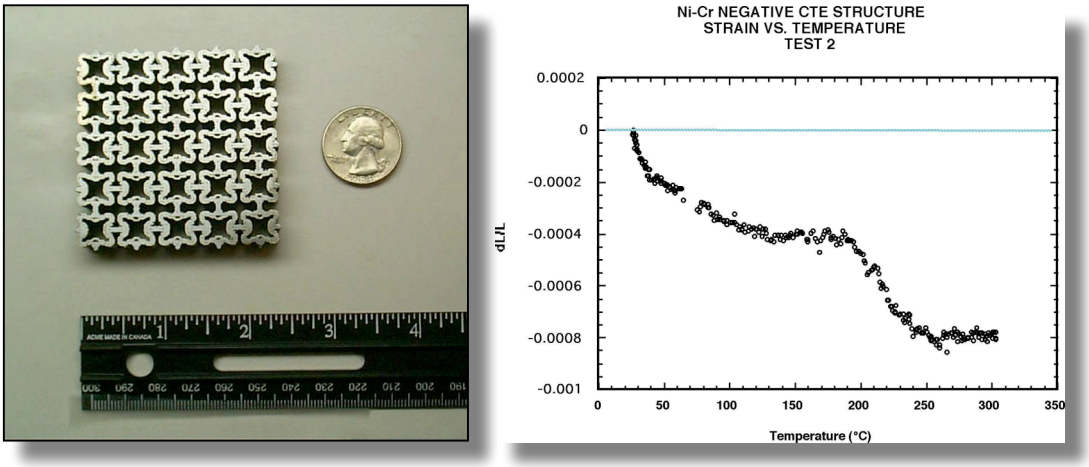
Performance Based Designed Materials Realized by Direct Metal Deposition

Direct Metal Deposition (DMD) technique has the capability to make fine fabrication resolution from pixel to pixel as well as fabricating multiple materials simultaneously. This advance opens the area of creating the new class of optimally designed material structures such as negative coefficient of thermal expansion structure created by topology optimization methodology and micro-electro-mechanical system (MEMS). DMD technology makes it possible to fabricate three-dimensional structure with complex geometry and functional graded materials. The manufacturing of such designed material microstructures and MEMS, which are usually featured at micron level, requires greater accuracy and material flexibility. These designed material micro- or macro-structures are normally composed of multiple materials which have different physical and chemical properties and may or may not have good miscibility under normal equilibrium state. Due to the non-equilibrium nature of laser cladding process, extended solubility of mixed materials can be obtained. To accurately control the local material concentration in solidified clad is still challenging the application of DMD technique in designed material fabrication.

Specific tasks including:

1. **Develop physics based models for characterizing laser based deposition, solidification, thermal stress and microstructure in single and multiple material DMD.**
2. **Scale down and adapt the current DMD system to manufacture metallic structures precisely at micro-level.**



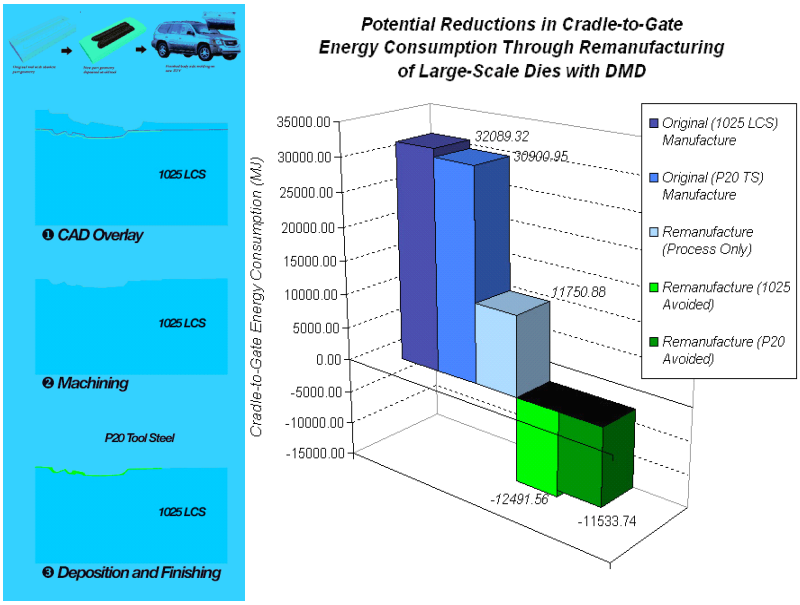
Left: Negative coefficient of thermal expansion (NCTE) specimen made with Nickel and Chromium by DMD process; Right: Behavior of negative strains of the NCTE structure in y-direction from a heating test in a precise controlled furnace.

Environmentally Conscious Tooling via Laser Aided Direct Metal Deposition

The environmental impact of traditional manufacturing operations is massive, arising from the consumption of inherently dilute and limited resources, as well as the release of environmental toxins and CO_2. In fact, traditional manufacturing holds a number of dubious environmental distinctions, including the leading producer of solid waste and the most toxic polluter of water. Such problems can be addressed by the utilization of DMD in place of traditional operations in the tooling industry. This program will develop supporting technology and knowledge to facilitate the diffusion of Closed Loop Direct Metal Deposition (DMD) technology as an energy, cost, performance, and environmentally improved alternative to traditional manufacturing processes, thus restoring the competitiveness of the U.S. tooling industry.

Specific tasks are described below.

1. **Develop physics based models for characterizing laser based deposition, solidification, thermal stress and microstructure in single and multiple material DMD.**
2. **Apply physics based models and control system to optimize DMD manufacturing performance in tooling fabrication and micro-scale fabrication.**
3. **Enabling Remanufacturing of "End of Life" (EoL) Tooling via DMD**



Energy reduction associated with DMD remanufacturing of large tooling in auto industry.