Application Note: 3D-Printed Titanium

Overview

The Young's modulus and hardness of 3D-printed titanium were measured by standard nanoindentation (N = 32) as:

- E = 120.5 ± 12.3 GPa
- H = 2.67 ± 0.22 GPa
- HV = 252 ± 20 kg/mm^2

ANM offers nanoindentation testing using instruments that undergo quarterly verification and daily checks for assured accuracy.

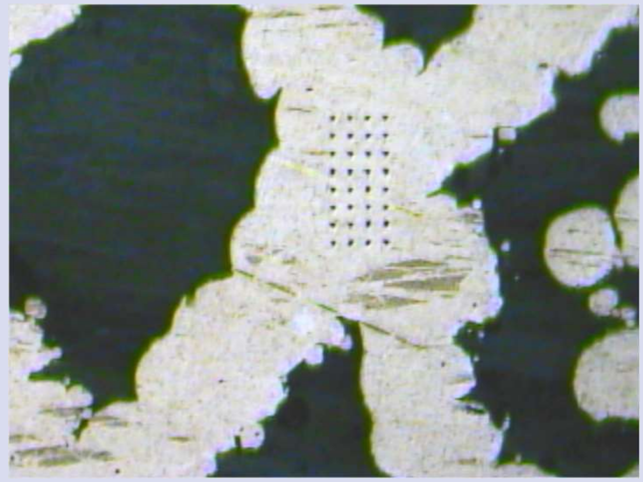

Figure 1. Microscopic view of testing surface; light areas are titanium; dark areas are epoxy

Procedure & Analysis

A scaffold of pure titanium was manufactured by 3D printing. The sample was prepared for nanoindentation by mounting in an epoxy disk (1.25" diameter) and polishing to expose a smooth cross-section of the scaffold.

Thirty-two (32) indentations were performed to a peak load of 50mN in accordance with ISO 14577-1. The testing load of 50mN caused an indentation depth of about 850nm. Individual indentations were separated by 30um.

The Oliver-Pharr calculation for contact depth ($h_c = h - 3P/4S$) was not used, because the surface outside the contact zone does not "sink-in" for soft metals. Instead, the contact depth was calculated as equal to the total depth ($h_c = h$) to achieve an accurate determination of contact area from the load-depth data.

Per ISO 14577-1, Vickers hardness (HV) was estimated as a constant multiple of the nanoindentation hardness ($HV = 94.5*H_{IT}$).

Significance

The value of 120.5GPa for Young's modulus is reassuring, because this is typical for pure titanium. As a true material property, Young's modulus is independent of material volume.

For metals, hardness depends on material volume, because the volume constrains the growth of crystalline grains.

Moreover, hardness is proportional to yield stress, with a constant of proportionality of about 3 ($H = 3\sigma_y$). The mechanical response of this scaffold could be modeled by finite-element analysis with constitutive properties of E = 120.5 GPa, σ_y = 0.89 GPa, and a hardening exponent of 0.1.

Getting started

To discuss nanoindentation testing of your materials, contact Jennifer Hay at Applied Nanometrix at 865-804-9721 or Jennifer@appliednanometrix.net.