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First single-shot image of the alpha->beta Phase Transformation in Pure Nanocyrstalline Ti with Nanosecond Resolution.

T. LaGrange

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DYNAMIC TRANSMISSION ELECTRON MICROSCOPE

First single-shot image of the $\alpha \rightarrow \beta$ Phase Transformation in Pure Nanocyrstalline Ti with Nanosecond Resolution.

JANUARY 2007

SCIENTIFIC IMPACT AREA

Nanoscale Science and Technology, Computational Material Science

ACCOMPLISHMENT

The first single-shot, 15ns, dynamic brightfield TEM images of a phase transformation in the DTEM have been acquired. The $\alpha \rightarrow \beta$ phase transformation in nanocrystalline Ti is not possible to study with standard in-situ TEM techniques due to the high growth rates associated with the martensitic phase transformation. However, with the DTEM, the ns time-resolved imaging clearly shows the morphology and grain size of the β phase that was captured as it transformed from α to β.

SIGNIFICANCE

The observed β-phase fraction at 1µs is consistent with the time-resolved diffraction data at 1700K. The lens shape of many of the β-grains is evidence that the transition occurs by a martensitic type mechanism. The average grain size, which is similar to the initial grain size, confirms prior estimates made of nuclei density and β-grain volume used in the kinetic modeling of the time-resolved electron diffraction data (T. LaGrange et al.)

ENABLING TECHNOLOGY

The acquisition of images were made possible by the enhancement of the photocathode laser stability and beam quality, optimization of laser and electron optics settings to produce higher yields of usable electrons, the implementation of a new TVIPS CCD camera with single electron sensitivity and signal to noise ratios >25. The planned arbitrary waveform generator laser system and condenser lens modifications will ensure that DTEM will produce time resolved images with quality comparable to conventional TEM.

FUTURE DIRECTIONS

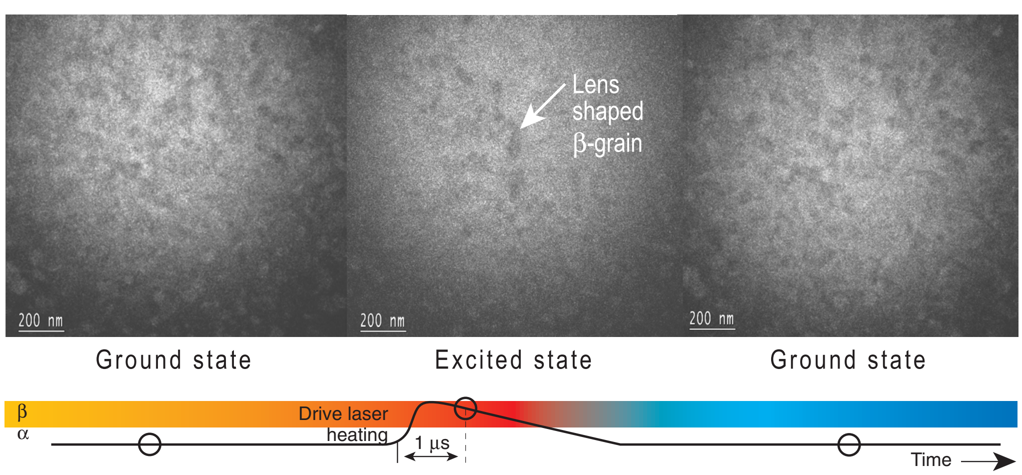
To enhance current theory and kinetic models of isothermal martensitic transformations, further trends in the evolution of the beta phase.

INVESTIGATOR

T. LaGrange

PUBLISHED

To be decided.



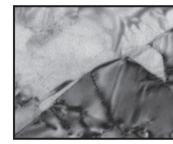
Series of single-shot bright-field, time-resolved (15ns pulsed electron beam) TEM images showing the change in grain morphologies induced by the $\alpha \rightarrow \beta$ phase transformation, left image is the ground state before laser strikes the film, the center image is taken 1µs after laser hits the film in the excited high temperature state (Estimated temperature rise ~1700 K.), and the right image is taken after the specimen cools to the ground state condition

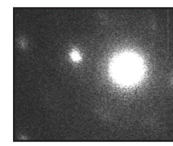
cmls Directorate

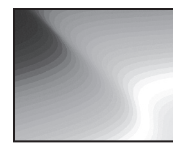
DTEM

DYNAMIC TRANSMISSION ELECTRON MICROSCOPE

Studying Nanoscale Transformation Kinetics.







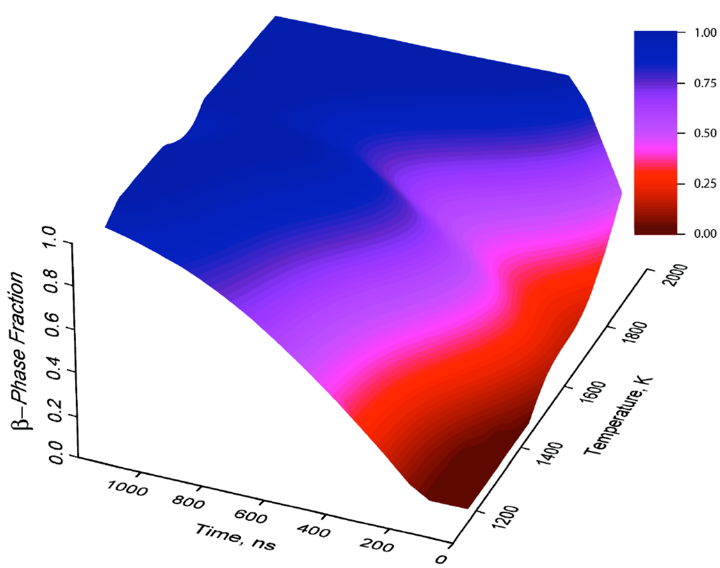
SCIENTIFIC IMPACT AREA

Nanoscale Science and Technology, Solid State Physics of Phase Transformation, Martensite Theory, Structural Materials Technology.

ACCOMPLISHMENT

Using the high time resolution capabilities of the dynamic transmission electron microscope, the evolution of the $\alpha \rightarrow \beta$ transformation at various temperatures was studied by taking single-shot electron diffraction patterns at different time delays. Using quantitative analysis techniques, the phase fractions were determine as function of time and temperature. The data were assembled to create the first ever reported isothermal diagram for Ti.

This is the first reported isothermal phase diagram for pure, nanocrystalline Ti, showing the rapid (nanosecond time scales) transformation rates occurring in these material. Studying the kinetics of the nanocrystalline Ti will give new insight into how the nanometric lengths affect the behavior of fundamental material process such as the martensitic transformation.



SIGNIFICANCE

Although Ti has been studied for many years, the kinetics of the transformation have not been well defined, i.e. no reports of the activation or detailed, quantitative analysis of transformation mechanism. In this study we report for the first time activation energies for the transformation and show that transformation behavior is similar to that of the isothermal martensitic transformation in Fe-Ni alloys.

ENABLING TECHNOLOGY

Experiments were enabled due to the nanosecond time resolution and single-shot capabilities of the dynamic transmission electron microscope. Single-shot capabilities are essential for these studies since the transformation is altered after one laser strike, and thus it cannot be studied using stroboscopic techniques.

FUTURE DIRECTIONS

To observe the effect of grain on the nucleation and transformation rates, similar experiments and diagrams will be performed and developed for single crystalline Ti. Data gathered from experiment and empirical models will be compared with CALPHAD and MD simulations.

WHO

T. LaGrange and G. H. Campbell

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