Formation and annealing behavior of unetched fission tracks: Apatite *vs.* zircon

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Fission tracks (FTs), damage trails caused by the spontaneous fission of ^{238}U in minerals, are extensively used to determine the thermal history of rocks from the upper part of Earth's crust. In the absence of actual observations of the atomic-scale process of latent, unetched FTs, FT thermochornology is essentially based on purely empirical fits to annealing data of FTs revealed by chemical etching. As a result, the track-annealing kinetics in apatite and zircon, the minerals most often used for FT thermochronology, has been considered to control by the same mechanism, essentially epitaxial recrystallization. In this work, we studied both randomly orientated neutron-induced FTs and parallel ion tracks created by the irradiations of GeV ions (e.g., 2.2 GeV Au ions) or fission fragments (e.g., 80 MeV Xe ions) by using transmission electron microscopy (TEM). The very different thermal annealing behavior of unetched FTs in zircon and apatite, as directly observed by *in situ* TEM,[1] is a direct result of differences in the internal structure of the track — the amorphous domain in zircon *vs.* the low atomic density void in apatite.[2] We also used a novel microtome-cutting sample-preparation technique that allows the investigation of the entire length of unetched FTs in apatite by TEM.[3] High-resolution analysis was performed to show how crystallographic orientation affects track shape as well as radius at the atomic-scale.[4]

[1].W. Li, L. Wang, M. Lang, C. Trautmann, and R. Ewing, *Earth Planet. Sci. Lett.*, **302**, 227-235 (2011). [2].W. Li, L. M. Wang, K. Sun, M. Lang, C. Trautmann, and R.C. Ewing, *Phys. Rev. B*, **82**, 144109 (2010). [3].W. Li, M. Lang, A. Gleadow, M. Zdorovets, and R. Ewing, *Earth Planet. Sci. Lett.*, **321–322**, 121-127, (2012). [4].W. Li, P. Kluth, D. Schauries, M. Lang, F. Zhang, M. Zdorovets, C. Trautmann, and R. C. Ewing, *Am. Mineral.* (accepted), http://dx.doi.org/10.2138/am.2014.4669, (2014).