NanoSIMS U-Pb Dating of Shocked Zircons

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Introduction: U-Pb ages of shocked zircons have been used to constrain the ages of impacts recorded in both terrestrial and lunar samples [e.g. 1-4]. However, many shock features are too small to resolve with conventional SIMS or SHRIMP techniques making interpretation of complex samples difficult [e.g. 4-6]. At Lawrence Livermore National Laboratory (LLNL), we have increased the spatial resolution of U-Pb and Pb-Pb analyses to ~ 2 µm using the NanoSIMS 50. Analyses of two shocked zircons were undertaken to test the age resolution of NanoSIMS analyses and to investigate Pb disturbance associated with the formation of shock microtwins.

Samples: Two shocked zircons were chosen for NanoSIMS analyses. The first is from the VD-ILN drill core near the geographic center of the Vrederfort impact structure in South Africa [7]. This zircon had previously been characterized by conventional SIMS at the University of California Los Angeles allowing for direct comparison between the two techniques [8]. The ims1270 data are consistent with crystallization age ~ 410 Ma and show no evidence of the 2.02 Ga impact event. The second samples is a shocked Apollo 14 zircon (14305 Z34) that contains large, spherical shock twins that are ~5 – 6 µm thick [9, 10].

Methods: Initial characterization by electron beam imaging, including electron backscatter diffraction, for unknown samples were performed at the Zircon and Accessory Phase Laboratory (ZAPLab) at the University of Western Ontario.

U-Pb analyses were performed at LLNL using the Cameca NanoSIMS 50. The NanoSIMS 50 at LLNL is equipped with the Hyperion II ion source, which has ~2.5 times higher spatial resolution per unit current than the conventional duo plasmatron [11]. We achieved a <2 µm diameter spot size using a 600 pA ^16O^ primary beam and a mass resolving power of ~ 4000. A combination of multicollected and B-field stepping was used to measure ion intensities ranging from ^30Si^ to ^238U^ . For each analysis, the beam was rastered over a 13 x 13 µm square and data was collected only for an inner 10 x 10 µm area to avoid potential edge effects. Instrumental mass fractionation of Pb relative to U was calibrated using the AS3 standard zircon. The average errors for NanoSIMS ^207Pb-206Pb^ ages and U-Pb ages are respectively a factor of 1.5 and 4.4 larger than for conventional SIMS. The later error is dominated by uncertainties in calibrating instrumental mass fractionation, which can be improved in future sessions.

Results:

VD-ILN. The NanoSIMS data for the shocked Vrederfort zircon reveal Pb-loss due to both the 2.02 Ga impact event and the ~1 Ga local intrusive event; the former was not identified in conventional SIMS analyses of the same zircon. One analysis appears to be solely affected by impact related Pb disturbance and is associated with a highly crystalline region near the rim of the zircon. This suggests that complex, shocked zircons many contain small (here ~ 4 µm) age domains that are averaged over in the larger ~ 20-30 µm analysis spots of conventional SIMS [8].

14305 Z34. The spherical shell twins were located in the NanoSIMS rasters using the position of impact melt inclusions (spatially associated with the twins) in the Fe/Si maps. We observed no variation in U/Pb or ^207Pb/^206Pb across the Z34 zircon or across twin boundaries. This suggests either the twin forming mechanism is too rapid to cause significant disturbance of Pb, or the age of the impact event responsible for the twins cannot be resolved from the crystallization age within the errors of the NanoSIMS measurements. All analyses of Z34 are concordant and yield an average age of 4291 ± 14 Ma. The former scenario is favored based on previous Vrederfort analyses [5].

Conclusions: We achieved a spatial resolution of ~ 2 µm for U-Pb analyses of zircon with only a factor of ~ 2-4 decrease in age resolution compared to conventional SIMS. NanoSIMS U-Pb analyses are ideally suited for targeted investigations of complex grains or small zircons, such as those found in meteorite samples.

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