Dynamic strain measurements after shock impact in minerals and ceramics

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Engineering ceramics frequently suffer shock impacts in applications ranging from thermal barrier coatings to fuel cell membranes and solid-state battery anodes. Such materials are often structurally related to naturally occurring rocks and minerals, which in turn may be subjected to shock impacts during episodes of seismic activity.

Powder x-ray diffraction is very sensitive to strain as it distorts the crystal lattice and affects atomic distances. While uniform residual strain in a specimen will result in Bragg peak shifts, a dynamic strain wave travelling through the specimen results in peak broadening since different parts of the sample are distorted to a different extent at the moment the scattering event occurs.

We have used beamline I11 at Diamond Light Source and its position-sensitive detector to record powder diffractograms at 1ms time resolution following laser impact, either from a 125W CO_2 laser heating a small part of the specimen away from the probe site or from a nanosecond-pulsed Nd:YAG laser from the EPSRC loan pool without any thermal load on the sample. By varying the displacement between impact and probe site, we were able to trace the spreading of the shock wave through the sample, most likely along grain contact points.

Our results show that there are lattice parameter oscillations as the *dynamic* strain in the specimen builds up and then releases periodically as grain contacts fail. The baseline of these oscillations increases over time, suggesting that the *residual* strain in the sample increases as damage from successive impacts is accumulated. However, this increase is on a significantly smaller scale than the oscillations of the dynamic strain.

The implication of these results is that the granular structure of a material determines its resilience to dynamic strain. Damage is kept within limits as long as sacrificial grain contacts are available to take up the impact.

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