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Influence of grain boundaries on elastic and plastic properties of nanocrystalline diamond films

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Hot filament chemical vapor deposition is an easy and cost-efficient way to deposit nanocrystalline diamond films on large area substrates. The grain size and grain boundary structure can be tailored by variation of the growth conditions. The large grain boundary volume of nanocrystalline materials results in a strong influence of the grain boundaries structures on the overall material behavior. This allows adjustment of material properties for each application.

We found that under certain growth conditions, not only Young's modulus decreases, but also the Poisson's ratio of the nanocrystalline film is increased, compared to single-crystalline diamond. We rationalize the increased Poisson's ratio as a decreased ratio of shear to bulk modulus. This shows that (elastic) shape change of the material becomes easier and suggests a less brittle material behavior. Nonetheless, only elastic deformation until brittle fracture was observed at room temperature.

In contrast to that, in high temperature deformation experiments such films showed plastic deformation at forces much smaller than expected for poly- or single-crystalline diamond. Therefore, we hypothesis that this plasticity is due to grain boundary mediated processes, rather than crystal plasticity. The plastic deformation behavior at high temperature was transient, such that the rate of deformation decreased over time.