Sapphire mechanical characterisation according to its growth and its crystalline quality

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Abstract: Synthetic sapphire is known for its high strength. Indeed, only diamond is susceptible to scratch it. Therefore, colourless sapphires are used as scratch-resistant Swiss watch glasses. In order to minimize shard appearance on watches, RSA Le Rubis, French sapphire manufacturer, wishes to improve its product mechanical property knowledge. How fracture strength fluctuates according to elaboration conditions, and the part of structural defects in this.

Clockmaking sapphires are mainly grown at R.S.A. by historical Verneuil process or Edge-defined Fed-film Growth (EFG). Several growth conditions are studied in both processes, such as crystals size and position in the oven, or component ageing.

Further, two flexural tests have been designed and massively performed : four point bending and ball on three balls test. Both show a higher flexural strength for Verneuil crystals compared to EFG ones. Transition between elastic and plastic deformation was also studied through nano-indentation pop-in analysis.

X-ray characterisations at the European Synchrotron Radiation Facility (ESRF) helped mechanical results understanding by revealing structural defects in crystals. White beam topography and Rocking Curve Imaging were used, as they are complementary.

It appears that Verneuil crystals high flexural strength is due to higher dislocation densities, about one hundredth more than in EFG crystals. Dislocation formation results from temperature gradient variation during growth. Higher fluctuation in Verneuil process lead to higher dislocations density.