Red as Blood: Development of a Low-Temperature Synthesis for Alpha-Aluminium Oxide-Based Gemstones

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Chemically, rubies and sapphires are doped α-Al2O3 crystals, that means in this case that a certain percentage of aluminium cations is replaced by chromium(III) (ruby) or iron(II), iron(III) and titanium(IV) (sapphire) within the crystal lattice, causing their specific colors. Any chemical synthesis of these materials must include a liquid phase since the doping has to be statistically distributed among the lattice sites. Today, this is for rubies industrially performed by melting the components in a hydrogen flame and dropping the melt onto an existing singe crystal. However, this so-called Verneuil process consumes large amounts of energy and therefore we decided to develop an alternative synthesis method which works at lower temperatures. In order to synthesize ruby and sapphire powders, we have adopted a sol-gel process, starting with a solution containing the metal nitrates as well as ethylene glycole and citric acid. That has been chemically converted into the doped α-Al2O3 at a temperature of approximately 1100 °C. For the synthesis of macroscopic α-Al2O3 crystals we have used the eutectic system between aluminium oxide and cryolite. The procedure is straightforward: Al2O3, Cr2O3 and Na3AlF6 are weighed to match the desired doping level and to have a suitable melting point. The batch is then thoroughly mixed, heated to 1100 °C until all components are molten and then carefully cooled to room temperature. We have conducted various analysis on our results, most notably X-ray powder diffraction and EDX, proving that our synthesis methods yield the desired α-Al2O3 crystals.