Observing dust-forming refractory oxides AlO, TiO, and TiO_2 in circumstellar gas around evolved stars

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The refractory oxides of aluminum and titanium (AlO, TiO and TiO_2) are expected to play a major role in initiating dust formation in oxygen-rich envelopes of cool stars. Formed at temperatures above 2000 K, they are thought to provide molecular clusters (or "seeds") on which dust condensation occurs in cooler parts of the envelope. Until recently, these species have been only rarely observed in stellar spectra, almost exclusively at optical wavelengths, which hampered detailed studies of their formation and depletion in circumstellar envelopes. Here we present and describe the first *(sub-)millimeter* observations of pure rotational transitions of AlO, TiO, and TiO_2 in the circumstellar envelopes of the peculiar red supergiant, VY CMa, and two mira stars, Mira itself (*o* Ceti) and IK Tau. The location of the emitting gas was derived from the (sub)-millimeter spectra and from comparing these with the optical electronic bands of the rare species. We conclude that we are probably observing shocked material that is strongly influenced by non-equilibrium chemistry and complex excitation conditions. Our first (sub-)millimeter observations, to be followed-up with ALMA at a higher angular resolution, will provide strong constraints on the formation, processing, and destruction of dust in oxygen-rich circumstellar envelopes.