CORDIERITE Glass-ceramics based on the hexagonal form of cordierite are strong, have excellent dielectric properties, good thermal stability, and thermal shock resistance. The commercial composition given in Table 5 is the standard glass-ceramic used for missile nose cones. It is a multiphase material nucleated with titania, but the major constituent is cordierite ($Mg_2Al_4Si_5O_{18}$) with some solid solution toward "Mg-beryl" (i.e. $Mg^{2+} + Si^{4+} \rightarrow 2Al^{3+}$). This phase is mixed with cristobalite, rutile, magnesium dititanate, and minor glass, which is isolated at grain-boundary

Table 5 Commercial cordierite glass-ceramic (Corning 9606)

Composition		wt%	mol%	Phases
SiO_2	xl	56.1	58.1	
Al_2O_3		19.8	12.1	Cordierite
MgO		14.7	22.6	Cristobalite
				Rutile
CaO		0.1	0.1	Mg-dititanate
TiO_2	n	8.9	6.9	
As_2O_3	f	0.3	0.1	
Fe_2O_3		0.1	0.1	
		Use: Radomes		

nodes. The mechanical properties of these glass-ceramics have been studied extensively (9). A Weibull plot of flexural strength data on transverse-ground bars hewn from a slab of this commercial composition is shown in Figure 3, which illustrates the narrow range and predictability of strength. Other important properties include coefficient of thermal expansion (0–700°C) $45 \times 10^{-7}/°C$; fracture toughness (K_{IC}) 2.2 MPa $m^{1/2}$; thermal conductivity 0.09 cal/s·cm·°C; Knoop hardness 700; dielectric constant; and loss tangent at 8.6 GHz: 5.5 and 0.0003, respectively.

The choice of composition in this case was based primarily on glass-forming considerations. If thermal stability and shock resistance were the only important factors, a stoichiometric cordierite base would have been chosen. However, to optimize viscosity at the liquidus, the lowest ternary eutectic in the refractory system, $MgO\text{-}Al_2O_3\text{-}SiO_2$, was approached. This ternary eutectic, cordierite-enstatite-cristobalite, has an equilibrium temperature of 1355°C. The addition of 9% TiO_2, which is required for internal nucleation, further decreases the liquidus to 1330°C, where sufficient viscosity is achieved for centrifugal casting or spinning (see curve C, Figure 2).

One result of the choice of the eutectic composition is that significant cristobalite had to be incorporated into the glass-ceramic, which had the adverse effect of raising its thermal expansion. This free silica incorporation, however, allows a post-ceram surface leaching treatment with hot caustic to produce a porous skin that tends to prevent initiation of flaws and further enhances strength.

OTHER ALUMINOSILICATE SYSTEMS There are several other aluminosilicate glass-ceramics which, although they are not yet produced commercially, have potentially useful properties. Mullite glass-ceramics can be produced