CRYSTAL DISTRIBUTIONS IN A PARTIALLY DEVITRIFIED GLASS COOLED BY RADIATION, R. W. Hopper, P. Onorato and D. R. Uhlmann, Dept. of Metallurgy and Materials Science, Center for Materials Science and Engineering, M.I.T., Cambridge, Mass. 02139

The devitrification of a spherical body of an opaque glass-forming material, cooled by radiation into a vacuum, has been studied theoretically. Calculations appropriate for a variety of lunar compositions containing sizable concentrations of iron have been completed.

The temperature at any location \( r \) within the body at any time \( t \), \( T(r, t) \), was obtained by numerically solving the heat flow equation subject to the nonlinear boundary condition

\[
-k \frac{\partial T}{\partial r} (r, t) = \varepsilon \sigma T^4(a, t).
\]

Here \( a \) is the radius of the body, \( k \) is its thermal conductivity, \( \varepsilon \) is its emissivity and \( \sigma \) is the Stephan-Boltzmann constant. The assumption of opacity, which justifies an approximation of a constant thermal conductivity, should be valid for the iron-rich lunar compositions at temperatures of perhaps 1500°C and below (1). The method employed in solving the heat flow problem involved iterating solutions which were obtained for linear boundary conditions by means of a finite difference method. The algorithm employs backward time differences and has proved relatively stable. No numerical difficulties were encountered. The problem was solved for a range of particle sizes from 0.01 cm to 100 cm and for a range of initial temperatures of the bodies.

The state of crystallinity in the bodies has been described by the recently-introduced (1) crystal distribution function, \( Q_c(r, R) \). This function is defined such that the number of crystals in the body located in the spherical shell between \( r \) and \( r + dr \) having radii between \( R \) and \( R + dR \) is

\[
dn = 4\pi r^2 Q_c(r, R) dr dR.
\]

It has been assumed in the analysis that the growth rate can be approximated as isotropic, and hence that the morphology of the crystals can be approximated as spherical. The number density of crystallites \( D_N(r) \) and the volume fraction transformed \( F_v(r) \) have also been calculated. The calculations of \( Q_c(r, R) \) employed measured (2, 3, e.g.) value of the crystal growth rate as a function of temperature, \( u(T) \). A number of functions \( I_N(T) \) were used to represent the rate of crystal nucleation per unit volume. Included in these were the special case of homogeneous nucleation as well as a variety of assumed distributions of nucleating heterogeneities of different potency. In obtaining these functions, use was also made of the measured variations of viscosity with temperature for the compositions considered (3, e.g.).

The results of the calculations permit an evaluation of the critical conditions for glass formation of various lunar compositions, and the dependence of these conditions on a number of important factors. Included among the factors whose inter-relations have been evaluated are the size and initial temperature of the body, its thermal properties, the distributions of nucleating heterogeneities in the body, the variation of the growth rate with temperature, the magnitude of the viscosity at the liquidus temperature, and the variation of viscosity with temperature.
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The results of the calculations will shortly be compared with observations of the distributions of crystals in partly-devitrified lunar samples to provide estimates of their original temperatures. Extensions of the work to include semi-transparent bodies, whose thermal conductivities vary with temperature as $k = A + BT^3$, are presently underway. Also in progress are direct inversions of the experimental observations of $\psi_c(r,R)$ for a number of lunar compositions to determine their thermal histories, $T(r,t)$. It is hoped that results in these areas will be available for inclusion in the verbal presentation.

REFERENCES

