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 $-k \frac{\partial T}{\partial r} (a,t) = \epsilon\sigma T^4(a,t)$. Here a is the
radius of the body, k is its thermal conductivity, ϵ is its emissivity and σ
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, $\psi_c (r,R)$. 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 $dn = 4\pi r^2 \psi_c(r,R) dr dR$. 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 $\psi_c(r,R)$ employed measured (2, 3, e.g.) value
of the crystal growth rate as a function of temperature, $u(T)$. A number of
functions $I_v(T)$ were used to represent the rate of crystal nucleation per
unit volume. Included in these were the special case of homogeneous nucle-
ation as well as a variety of assumed distributions of nucleating hetero-
geneities 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.

CRYSTAL DISTRIBUTIONS

Hopper, R. W. et al.

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

(1) HOPPER, R. W., SCHERER, G., and UHLMANN, D. R. (1974) "Crystallization Statistics, Thermal History and Glass Formation", accepted for publication, J. Non-Cryst. Solids.
(2) SCHERER, G., HOPPER, R. W., and UHLMANN, D. R. (1972) Geochim. et Cosmochim. Acta, Suppl. 3. Vol. 3, 2627.
(3) CUKIERMAN, M., KLEIN, L., SCHERER, G., HOPPER, R. W., and UHLMANN, D. R. (1973) Geochim. et Cosmochim. Acta, Suppl. 4, Vol. 3, 2685.