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Review
Creep of ceramics
Part 1 *Mechanical characteristics*

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Many experiments have been undertaken to investigate the creep behaviour of ceramics. This review tabulates the available data in terms of the shapes of the creep curves and the dependence of the steady-state creep rate on stress, grain size and temperature. Numerous theoretical mechanisms are available for intragranular and intergranular deformation processes, and the predictions of these mechanisms are summarized for comparison with the experimental data.

1. Introduction
Considerable interest has developed in recent years in the slow deformation, or creep, which occurs in crystalline materials at elevated temperatures under the action of an applied stress. This interest has arisen because of the current need for a wide range of structural materials for various engineering applications at high temperatures. However, from an historical point of view, scientific interest in creep dates back to the early experiments of Phillips [1], conducted almost 80 years ago, on the "slow stretch" of India rubber, glass, and metal wires.

The creep of metals received much impetus from the classic (and still widely cited) work of Andrade [2, 3] early in this century. As a result, a considerable volume of creep data has been assembled for many metallic systems, and the development of these data has been especially rapid within the last 30 years. Similarly, the creep of rocks in the geological domain was stimulated by the classic experiments conducted by Griggs [4, 5] in the 1930s.

Surprisingly, there appears to be no single classic paper which marks the onset of detailed studies of the creep of those non-metallic materials of primary interest to ceramicists. Despite very early work on the orientation of preferred slip systems in some non-metallic single crystals (for example, the experiments of Reusch [6] and Mügge [7] on NaCl single crystals in the 19th century), the creep or high-temperature mechanical properties of ceramics started rather modestly with investigations in the mid-1950s by Wachtman and Maxwell [8] on Al_2O_3 single crystals, Stavrolakis and Norton [9] and Coble and Kingery [10] on polycrystalline Al_2O_3, and Christy [11, 12] on alkali halides. It is also surprising to note that, despite widespread reports throughout the 1950s of power-law creep with a stress exponent greater than 1 for a wide range of polycrystalline metals, similar observations were first reported for polycrystalline ceramic materials only within the last 15 years [13, 14].

The slow development of detailed investigations of creep in ceramics is directly attributable to a combination of two unfavourable physical properties, an inherent brittleness and a susceptibility to thermal shock, which suggested that ceramics would be of little use in structural applications at high temperatures. In recent years, however, this aversion has been partially overcome by the realization that many ceramic materials possess unique combinations of properties, such as a high

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strength and a resistance to oxidation. Thus, there has been a very rapid expansion in experimental studies of the creep of ceramics, so that there are now several hundreds of publications on ceramic creep in the scientific literature.

This review was motivated by the realization that the various reports of the creep of ceramics are scattered through a large number of publications and that no attempt has been made to take an overview of the available data. The overall scope of the review is discussed in detail in the following section.

2. Scope of the review

The objectives of this review are two-fold. First, to bring together and to tabulate the various reports of the creep of ceramics at present available in the scientific literature. Second, to analyse these data with respect to possible deformation mechanisms, to examine bodies of information on a single material for consistent trends, and to make a direct comparison with the very extensive data reported for metals.

For completeness, it should be noted that some limited reviews of the creep of ceramics are now available. Gittus [15] and Poirier [16] included chapters on the creep of non-metals in their books on high-temperature deformation, Burton [17] examined the role of ceramics in a book on diffusion creep, and there are sections on creep in the books on ceramics by Kingery *et al.* [18] and Davidge [19]. There are review articles, dealing primarily with the basic mechanical properties, by Evans and Langdon [20] and Wilshire [21]. There is also a detailed review by Bretheau *et al.* [22] dealing exclusively with binary and ternary oxides, a review of creep in SiC, Sialon and Si_3N_4 by Thümmler and Grathwohl [23], and an early review of the creep of ceramic nuclear fuels by Seltzer *et al.* [24]. Finally, a review of steady-state creep in single-phase crystalline materials by Takeuchi and Argon [25] includes some limited data on non-metallic systems although it is devoted primarily to metals, and Kirby and Raleigh [26] included several ceramics in their review of flow in the mantle.

In order to keep this review within tractable dimensions, it was necessary to divide it into two parts. In the present report (Part 1), there is a compilation in table form of the various creep data published to date and a brief discussion of the mechanisms of creep. In a subsequent report (Part 2), there is an analysis of the data for selected polycrystalline materials where several sets of results are available and a direct comparison with the general trends in metals.

3. Compilation of the creep data

The creep data are assembled in Tables AI to AIII of the Appendix; for convenience, the references associated with these tables are numbered separately from the references contained in the body of the paper.

Tables AI to AIII list the experimental reports of the creep of ceramic materials divided into the three separate sections of single crystals (Table AI), bicrystals (Table AII) and polycrystalline materials (Table AIII). The materials are listed alphabetically by chemical name within each table, except for graphite in Table AIII.

Some selectivity was necessary in order to decide on the materials included in the tabulation. In general, the tables incorporate all materials of interest in the ceramic scientific community, with the exception that no attempt was made to include creep details for the commercial refractory brick materials. Graphite is included in Table AIII: it was also included in the review by Gittus [15]. However, non-metallic materials of interest primarily to geologists were specifically excluded (e.g. calcite, olivine, quartz and the orthopyroxenes): these materials are contained in the reviews by Carter [27] and Nicolas and Poirier [28].*

Within each table, the references are listed chronologically under each material. In Table AI, the second column shows the total metallic impurity or dopant (in ppm), the third column gives the orientation of the single crystals with respect to the stress axis, the fourth and fifth columns give the testing temperature and applied stress, and the sixth and seventh columns give the test technique and atmosphere. For the testing technique, creep tests are designated by the letters B (bending), C (compression) and T (tension): many tests have been conducted also at high temperatures using a constant strain rate (CSR), and this procedure is so designated. There are also occasional references in the tables to other procedures such as a constant loading rate (CLR), an indentation technique and stress relaxation. The three columns on the right in Table AI give details of the experimental results. Specifically,

*The latter two reviews also cover the creep of halite (NaCl).

they list the type of creep curve (or stress–strain curve), the stress exponent, n, and the activation energy for the flow process, Q: the characteristics of the creep (or stress–strain) curves are discussed in detail in the following section. Tables AII and AIII are essentially similar to Table AI, except that they provide alternative information such as boundary misorientations for bi-crystals (Table AII), and the density (as a percentage of theoretical), grain size and grain size exponent, p, for polycrystalline materials (Table AIII).

It should be noted also that the ranges of stress, temperature and grain size quoted in Tables AI to AIII serve only as a guide to the testing conditions, and they do not mean necessarily that experiments were conducted over the entire ranges for each variable: the original references should be consulted to obtain the exact combinations of the various experimental parameters.

It is necessary to point out that, although creep testing generally refers to experimental conditions of constant stress or load, tests at constant strain rate were included in the tabulation *provided* they were conducted at creep temperatures of the order of $\sim 0.5T_m$ or above, where T_m is the absolute melting point of the material. Thus, the criterion for creep was based on the test temperature rather than the mode of testing, and the very extensive experiments performed on many non-metallic materials at low homologous temperatures are therefore necessarily excluded from Tables AI to AIII.

4. The shape of the creep or stress–strain curves

The nature of the creep or stress–strain curves is indicated in Tables AI and AIII according to the schematic illustrations given in Fig. 1. Four creep curves are shown as A to D, plotting strain, ϵ, against time, t, at constant stress, σ (or constant load). Curve A shows the normal three-stage curve usually observed in metals, consisting of an

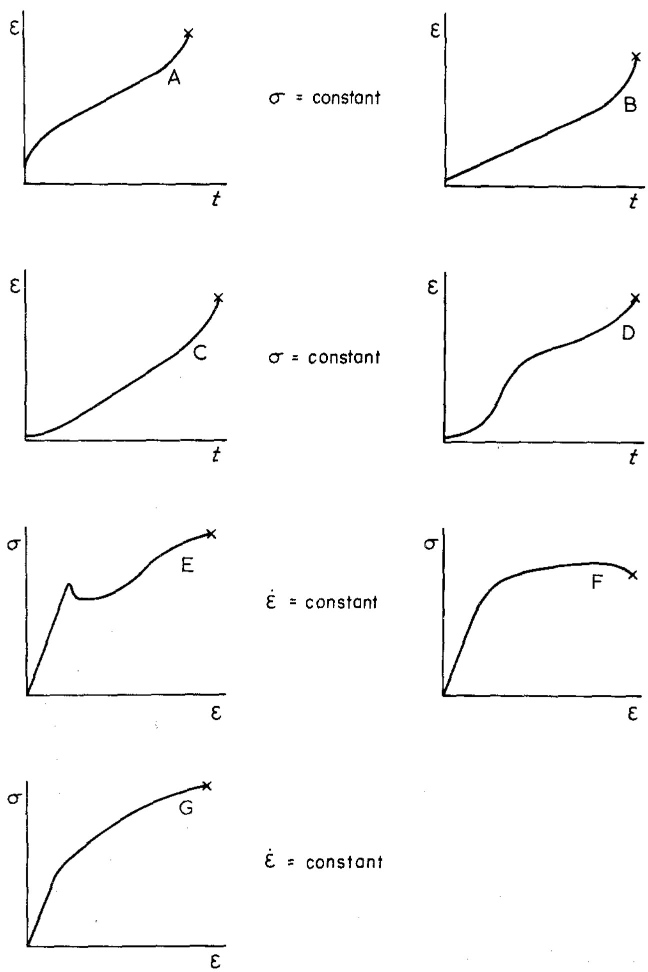

Figure 1 Schematic illustrations of the various curves arising from tests conducted under constant stress (A to D) and constant strain rate (E to G). The experimental curves are designated according to these types in Tables AI to AIII.

instantaneous strain, a primary stage in which the creep rate decreases with time, a steady-state or secondary stage of constant strain rate, and a tertiary stage of increasing creep rate to the point of fracture. Curve B lacks the primary stage and shows only two-stage behaviour, and curve C contains an inverted primary stage. Curve D contains a sigmoidal primary before steady-state flow: this type of creep curve is often observed in single crystals containing a very low dislocation density, and the initial primary is then due to the multiplication of dislocations. Three stress–strain curves are shown as E to G, where the instantaneous stress, σ, is plotted against the total strain, ϵ, for tests conducted at true (or nominal) constant strain rate, $\dot{\epsilon}$. Curve E shows the presence of a yield drop and subsequent hardening, curve F shows little or no hardening after the yield point, and curve G shows extensive hardening after yield.

Some difficulty was occasionally experienced in attempting to match the various experimental curves with those depicted schematically in Fig. 1. In general, there tended to be more variations in the appearance of the stress–strain curves at constant strain rate so that, although the general features in each set of experiments match the designations given in Tables AI and AIII, the precise shapes of the curves may differ considerably between different materials and testing conditions. For the creep tests, an apparent primary stage may occasionally result from concurrent grain growth, or the steady-state condition may not be fully achieved. Nevertheless, the creep curves were classified, according to the available information, in terms of types A, B, C or D in Fig. 1. In addition, some tests were conducted at a constant loading rate, where the stress increases linearly with time: where possible, these tests were characterized in terms of curves E to G.

Although it is difficult to correlate directly the curves for constant stress and constant strain rate shown in Fig. 1, some basic features may arise from similar mechanisms. Thus, the primary stage of curve A is due to the hardening arising from substructure development, and the hardening in curves E and G also relate to substructural changes. The early stages of curves C and D, where the primary is inverted, is due to dislocation multiplication; similarly, the upper yield point in curve E may, in some crystals, arise from a multiplication process. In general, constant strain rate tests are easier (and quicker) to perform, but detailed creep studies strictly require tests at constant stress (or load).

5. The dependence of steady-state creep rate on stress, temperature and grain size

Most mechanisms of high-temperature creep predict a steady-state creep rate, $\dot{\epsilon}$, which is given by

$$\dot{\epsilon} = \frac{ADGb}{kT}\left(\frac{b}{d}\right)^p\left(\frac{\sigma}{G}\right)^n \qquad (1)$$

where D is the appropriate diffusion coefficient, G is the shear modulus, $\boldsymbol{b}$ is the Burger's vector, k is Boltzmann's constant, T is the absolute temperature, d is the grain size, p is the exponent of the inverse grain size, n is the stress exponent, and A is a dimensionless constant. The diffusion coefficient, D, is given by

$$D = D_o \exp(-Q/RT), \qquad (2)$$

where D_o is a frequency factor, Q is the activation energy for the diffusion process, and R is the gas constant (8.31 J mol^{-1} K^{-1}).

It follows from Equations 1 and 2 that each creep mechanism is uniquely specified by the values of the three constants, A, p and n, and by the activation energy, Q. In general, however, the experimental values of A depend rather critically on the precise values of p, n and Q, so that the dimensionless constant A is usually of little value in determining the precise deformation mechanism. Accordingly, Table AI shows the values obtained experimentally for n and Q in the tests on single crystals, and Table AIII shows the values obtained for n, p and Q in the tests on polycrystals. The significance of these various values is discussed in more detail in the following section.

A word of caution is necessary concerning the experimental values of the activation energy, Q, shown in Tables AI and AIII. In most experiments, Q was determined from the slope $(= -Q/2.3R)$ of a plot of logarithmic $\dot{\epsilon}$ against $1/T$. In practice, this represents the *apparent* activation energy because it fails to include either the variation in shear modulus with temperature or the term $1/kT$ contained in Equation 1. The *true* activation energy is obtained from a plot of logarithmic $\dot{\epsilon}G^{n-1}T$ against $1/T$, and this is significantly lower than the apparent activation energy when n is large. The difference between the true and apparent activation energies tends to be rather minor when $n \simeq 1$ to 2.

6. Interpretation of the creep data

6.1. General observations

Inspection of Tables AI and AIII shows that the body of literature describing the creep behaviour of single crystals is significantly smaller than the available data for polycrystals. This difference arises because single crystal studies have tended to concentrate primarily either on a determination of the critical resolved shear stress as a function of temperature for a selected slip system or on a detailed investigation of the dislocation configurations and interactions. Only a small portion of the published data on single crystals includes details of the variation of deformation with time, stress and/or temperature: it is the latter studies which are included in Table AI.

In addition, it is often difficult to interpret the creep data for single crystals in terms of the mechanisms developed for polycrystals because much of the single crystal deformation takes place by unrestricted glide on the primary slip system. A more direct correlation with polycrystalline behaviour may be obtained by orienting the single crystals so that slip occurs on systems experiencing a high Peierls force: for example, experiments on sapphire single crystals oriented perpendicular to the basal plane with an [0001] stress axis [29].

Most of the bicrystal studies have been directed towards an examination of grain boundary sliding. It is clear from these tests that the situation is complex, and both the total misorientation across the boundary and the impingement of lattice dislocations on to the boundary appear to be important factors in determining the magnitude of the sliding offsets. The precise relationship between sliding on the long unconstrained boundary of a bicrystal and sliding on the relatively shorter boundaries contained in a polycrystalline matrix remains an unresolved problem.

The rate-controlling creep mechanism in a polycrystal is usually determined by reference to the experimental values of n, p and Q. If the dominant mechanism is intragranular, there is no dependence on the presence of grain boundaries so that $p = 0$; whereas if the deformation process involves the grain boundaries, the value of p is in the range from 1 to 3. These two types of process, termed lattice and boundary mechanisms [30], respectively, are considered in the following sections.

6.2. Lattice mechanisms of creep

Lattice mechanisms are based on the intragranular motion of dislocations and, by definition, they require $p = 0$.

Many theoretical mechanisms have been developed for intragranular deformation and these are summarized in Table I in terms of the predicted values for n and Q, where Q_l, Q_{ci} and Q_p are the activation energies for lattice self-diffusion, chemical interdiffusion of solute atoms and pipe diffusion along the dislocation cores, respectively. A detailed description of the principles of these various mechanisms is beyond the scope of this paper, but several of the mechanisms were outlined in an earlier review [20] and a complete description of each model is given in the various references cited in Table I.*

Unfortunately, inspection of Table I shows that many of the theoretical models lead to identical predictions in terms of n and Q. In general, the predicted value of n is within the rather limited range from 3 to 4.5 when the activation energy is equal to the value for lattice self-diffusion, Q_l, although it is possible to obtain higher values of n at lower temperatures by invoking pipe diffusion with an activation energy of Q_p ($\simeq 0.6 Q_l$). It should be noted also that, with the exception only of the model of Chang [35] based on transmission electron microscope observations of MgO, all of the theories were developed originally for metals. However, Evans and Knowles [48] specifically tested the predictions of their theory for climb of dislocation links [46] with experimental data from four ceramics (Al_2O_3, LiF, MgO and UO_2).

A review of the polycrystalline data in Table AIII shows that many of the results lead to stress exponents close to 1 and there is a relatively small proportion of the data giving $n \simeq 3$–5. This contrasts with metals where Newtonian viscous flow (with $n = 1$) is a rather limited phenomenon and most investigations give high values of n (see, for example, the detailed review of creep of metals by Bird *et al.* [49]). An important reason for this difference is that ceramics are often tested at lower normalized stresses to avoid problems of cracking.

Close inspection of the tabulated data shows that many of the results with $n > 2$ tend to group around either $n \simeq 3$ or $n \simeq 5$. This, too, is similar to the metals data, although in metallic systems

*Some models which do not lead to singular and well-defined values of n are not included in Table I: for example, the theory of Poirier [47] for the unblocking of dislocation loops by climb and cross-slip.

TABLE I Values of n and Q for lattice mechanisms with $p = 0$

Mechanism	n	Q	Reference
Dislocation glide and climb, controlled by climb	4.5	Q_l	Weertman [31–33]
Dislocation glide and climb, controlled by glide	3	Q_{ci}	Weertman [34]
Dissolution of dislocation loops	4	Q_l	Chang [35]
Dislocation climb from Bardeen–Herring sources	3 5	Q_l * Q_p	Nabarro [36]
Non-conservative motion of jogged screw dislocations	3†	Q_l	Barrett and Nix [38]
Nabarro–Herring creep at subgrain boundaries	3	Q_l	Friedel [39]
Climb of dislocations in two-dimensional subgrain boundaries	3	Q_l	Ivanov and Yanushkevich [40]
Climb of dislocations in subgrain boundaries of finite width	4	Q_l	Blum [41]
Recovery creep assuming slip distance is independent of mesh size	4	Q_l	Lagneborg [42, 43]
Recovery creep including distribution of dislocation link lengths	3	Q_l	Öström and Lagneborg [44]
Network coarsening by jog-controlled climb	3	Q_l	Gittus [45]
Climb of dislocation links within a three-dimensional network:			
(i) Average slip distance equals mesh spacing of network	3 5	Q_l * Q_p	Evans and Knowles [46]
(ii) Slip distance is independent of mesh size	4 6	Q_l * Q_p	Evans and Knowles [46]

*These theories lead to a stress exponent of n and an activation energy for lattice self-diffusion, Q_l, at high temperatures, and a stress exponent of $(n + 2)$ and an activation energy for pipe diffusion, Q_p, at low temperatures. A similar transition to $(n + 2)$ and Q_p is also believed to occur in dislocation glide and climb controlled by climb [37].
†The original theory of Barrett and Nix [38] gives $n = 4$ by putting the density of mobile screw dislocations, ρ_{ms}, proportional to σ^3. The value of $n = 3$ is obtained by making the more reasonable assumption that ρ_{ms} is proportional to σ^2.

it is now reasonably established that $n \simeq 5$ is the typical behaviour of a wide range of pure metals and $n \simeq 3$ is associated with some solid solution alloying: these two types of behaviour are termed class M (Metal type) and class A (Alloy type), respectively [50]. The situation is less well-defined in ceramics where a larger proportion of materials exhibit $n \simeq 3$ and there are often problems in interpreting the precise role of impurities. A detailed evaluation of the creep behaviour of several selected polycrystalline ceramics is given in Part 2.

6.3. Boundary mechanisms of creep

Boundary mechanisms are based on deformation processes associated with the presence of grain boundaries so that, by definition, $p \geqslant 1$.

Table II lists several boundary mechanisms in terms of the predicted values for n, p and Q, where Q_{ph} is the activation energy associated with the presence of a grain boundary liquid phase.

A consequence of all boundary mechanisms is that adjacent grains become displaced with respect to each other, with the displacement occurring at, or close to, the grain boundary plane. It is convenient to make a distinction between those boundary mechanisms in which the displacement, or grain boundary sliding, occurs in association with grain elongation in the tensile direction and those mechanisms in which the displacement is not associated with an elongation of the grains [62]: these two processes are generally termed Lifshitz [63] sliding and Rachlinger [64] sliding, respectively.

Lifshitz sliding requires full accommodation by either vacancy flow [63] or intragranular flow extending completely across the grains [65]. For the former accommodation, vacancies diffuse between grain boundaries where the vacancy concentration is either higher or lower than the equilibrium concentration, respectively, and, as indicated in Table II, this process gives $n = 1$ but

TABLE II Values of n, p and Q for boundary mechanisms

Mechanism	n	p	Q	Reference
(i) *Lifshitz sliding*				
Sliding accommodated by diffusion:				
(a) Nabarro–Herring creep	1	2*	Q_l	Nabarro [51], Herring [52]
(b) Coble creep	1	3	Q_{gb}	Coble [56]
Sliding accommodated by intragranular flow across the grains	1	1	Q_{gb}	Crossman and Ashby [57]
(ii) *Rachinger sliding*				
With a continuous glassy phase at the boundary	1	1	Q_{ph}	Orowan [58]
Without a glassy phase:				
(a) sliding accommodated by formation of grain boundary cavities	2	1	Q_l	Langdon [59]
(b) sliding accommodated by formation of triple-point folds	3.5†	2	Q_l	Gifkins [60]

*These values may change to $n = 2$ and $p = 1$ if the grain boundaries are not perfect sources and sinks for vacancies [53–55].

†Gifkins [60] obtained a stress exponent of $n = 4.5$ and a direct proportionality between the rate of sliding and the subgrain size, λ. The exponent of $n = 3.5$ is obtained by putting $\lambda \propto \sigma^{-1}$ [61].

different values of p and Q depending on whether the vacancies diffuse through the lattice (Nabarro–Herring creep [51, 52]) or along the grain boundaries (Coble creep [56]); in practice, this process may be considered *either* in terms of grain elongation *or* in terms of the sliding displacement [67–69]. For the latter accommodation, plastic flow takes place between triple points on either side of the grains, giving $n = 1, p = 1$ and $Q = Q_{gb}$ [57].

Diffusion creep is well understood in simple metallic systems, but there is an additional complication in ceramics because of the presence of two ionic species. Since the cations and anions both participate in the diffusive process, it is necessary to consider ambipolar diffusion and mass transport along parallel diffusion paths [70–72]. The significance of this effect in terms of temperature and grain size is discussed in detail elsewhere [20].

Grain boundary sliding without concomitant grain elongation, termed Rachinger sliding, may arise in two distinct ways depending on whether there is a glassy phase at the boundary [58] or the crystalline nature of the lattice is continuous up to the boundary plane [59, 60]. The former situation is not generally important in metals, but it becomes important in ceramics such as Si_3N_4 where a thin glassy phase is often present at the majority of grain and interphase boundaries [73–75]. It is now clear that the presence of this phase has a marked influence on the mechanical properties observed at high temperatures [76, 77]. In the absence of a glassy phase, sliding may be accommodated locally by the opening up of grain boundary cavities [59] or by the formation of short folds at the triple points [60].

As indicated in Table AIII, many of the experimental results give $n \simeq 1.5$ to 2.5 at intermediate to high stress levels: an example is shown by the data for Sialon and Si_3N_4 where, typically, $n \simeq 2$. These results are significant because the presence of a glassy phase and the reports of intergranular cavitation and triple point cracking [78] suggest the occurrence of some form of Newtonian viscous sliding with $n = 1$. This apparent discrepancy probably arises because there is an additional component of strain due to the evolution of grain boundary cracks and cavities, and indeed a statistical model based on the elastic opening of cracks due to the presence of cavities leads to a stress exponent of $n = 2$ [79].

Finally, it should be noted that some possible boundary mechanisms are not included in Table II because the models require further development: for example, the viscous or diffusive growth of intergranular cavities [79], the role of a solution-precipitation process through the intergranular glassy phase [80] and elastic or compliance creep arising from cavity formation [81] and crack growth [82].

7. Discussion

This paper tabulates the available creep data for ceramic materials and summarizes the theoretical deformation mechanisms in terms of the dependence of steady-state creep rate on stress, grain size and temperature.

Some general indications of the rate-controlling process may be obtained from a comparison of the experimental data in Tables AI and AIII and the predictions of the theoretical models in Table I or, for polycrystalline materials, Tables I and II. However, the experimental studies often include additional information, such as observations on subgrain formation or dislocation configurations and direct measurements of the boundary displacements due to sliding. These additional microstructural observations, and the significance of the mechanical data for specific materials, are considered in Part 2.

8. Conclusions

Part 1 may be summarized briefly as follows:

(1) The creep data available at present for ceramic materials are tabulated in terms of the shapes of the creep curves and the dependence of the steady-state creep rate on stress, grain size and temperature;

(2) Numerous theoretical mechanisms are available for intragranular and intergranular deformation processes, and the significant predictions of these mechanisms are reviewed.

The detailed microstructural evidence and the relationships between ceramic creep and metallic creep are considered in Part 2 of this review.

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Appendix

The creep data are summarized in three tables: Table AI for single crystals, Table AII for bicrystals and Table AIII for polycrystalline materials. The creep testing techniques are indicated by B (bending), C (compression) or T (tension): tests conducted at high temperatures under a constant strain rate are designated CSR. The shapes of the creep or stress–strain curves are indicated by the letters A to G using the types illustrated schematically in Fig. 1. The references in Tables AI to AIII are numbered separately from those contained in the text.

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TABLE AI High temperature mechanical properties of ceramic single crystals

Reference	Experimental conditions						Experimental results		
	Total metallic impurity or dopant (ppm)	Orientation of stress axis	Test temperature (° C)	Applied stress (MPa)	Test technique	Atmosphere	Type of creep curve	Stress exponent, n	Activation energy, Q (kJ mol^{-1})
AgBr									
Christy [1]	300	⟨100⟩, ⟨111⟩	300–410	0.12–1.2	C	Air	C, D	–	290
Christy [2]	–	⟨100⟩	–	–	–	–	–	–	340
AgCl									
Pontikis and Poirier [3]	> 40	⟨100⟩	270–440	0.15–0.98	C	Ar	–	3	155
Pontikis and Poirier [4]	–	⟨100⟩	308	0.2–0.7	C	–	A	5.3	–
Pontikis [5]	–	⟨100⟩	308	–	C	Air	A	6.1	–
Al_2O_3									
Wachtman and Maxwell [6]	–	~ 30° to [0001]	1000–1300	29–147	T	Air	D	–	–
Wachtman and Maxwell [7]	–	Various	900–1400	7–90	T, B	Air	D	–	–
Chang [8]	"pure" to 20 000 Cr_2O_3	For basal slip	1550–1925	5–20	T	–	A	4.5–5	755
Rogers et al. [9]	–	–	1000–1200	–	B	–	C	~ 6	–
Kronberg [10]	–	60° to [0001]	1200–1700	14–140	CSR	Air	E	–	355–390
Conrad et al. [11]	–	60°–70° to [0001]	1200–1500	5–50	CSR	Air	E	5.2	460
Klassen-Neklyudova et al. [12]	700	60° and 90° to [0001]	1500–2000	20–180	CSR	Vac.	–	2.1–4.1	310–1340
Radford and Pratt [13]	300–4500	Various	1200–1650	–	CSR	Air, H_2, Ar	–	–	–
Heuer et al. [14]	–	[0001]	1600–1800	86–114	T	Air	B	3	375–490
Bertolotti and Scott [15]	–	45° to [0001]	1400–1700	10–45	C	Vac.	–	–	420–545
Shahinian [16]	–	[0001]	1700–1900	172–220	T	Vac.	D	–	–

TABLE AI Continued

Reference	Experimental conditions						Experimental results		
	Total metallic impurity or dopant (ppm)	Orientation of stress axis	Test temperature (° C)	Applied stress (MPa)	Test technique	Atmosphere	Type of creep curve	Stress exponent, n	Activation energy, Q (kJ mol^{-1})
Govorkov *et al.* [17]	"pure", 700	0°, 60°, and 90° to [0001]	1750–2000	319–28	CSR	Vac.	–	3.9	480–510
Govorkov *et al.* [18]	–	various	300–1900	–	Identation	–	–	–	–
Gooch and Groves [19]	–	$\frac{1}{2}$°–6° to [0001]	1600–1800	65–180	T	Air	C, D	6–7	840–1300
Gooch and Groves [20]	"pure", 240–770	0°, 8°, 10°, 90° to [0001]	1200–1750	–	CSR	Air	E, F	4.2–19	590–920
Nehring and Jones [21]	–	–	1300	32	B	Air	A	–	–
Firestone and Heuer [22]	–	60° to [0001]	1460–1500	–	CSR	Air	E	–	–
Aksel'rod *et al.* [23]	–	–	1650–1970	30–300	B	Vac.	–	4.2	820
Michael and Tressler [24]	–	[0001]	1800–1850	225–254	CSR	Air	–	6.2–6.6	530
Pletka *et al.* [25]	–	0°, 60° to [0001]	1200–1500	30–60	CSR	Air	E	–	–
Tressler and Barber [26]	–	[0001]	1760–1875	32–36	CSR	Air	–	8.5–12.4	670–1260
Tressler and Michael [27]	< 50, 2400–7700 Ti^{3+}	[0001]	1760–1875	–	CSR	–	E	6–12	480–710
Firestone and Heuer [28]	–	[0001]	1600–1900	75–120	T	Vac.	C	2.7–3.4	–
Pletka *et al.* [29]	–	For basal slip	1400–1700	8.8–64	CSR	–	E	–	–
Pletka *et al.* [30]	–	60° to *c*-axis, 30° to ⟨11$\bar{2}$0⟩	1400–1720	10–70	CSR	Air, Vac.	E	–	–
Cadoz *et al.* [31]	–	For prismatic slip	1400–1800	–	CSR	Air	E	–	–
Cadoz *et al.* [32]	–	For prismatic slip	1450	–	CSR	–	–	–	–

TABLE AI Continued

Reference	Experimental conditions						Experimental results		
	Total metallic impurity or dopant (ppm)	Orientation of stress axis	Test temperature (° C)	Applied stress (MPa)	Test technique	Atmosphere	Type of creep curve	Stress exponent, *n*	Activation energy, *Q* ($kJ\,mol^{-1}$)
Rivière *et al.* [33]	–	For prismatic slip	1450	–	CSR	–	–	–	–
Cadoz *et al.* [34]	–	For prismatic slip	1450	–	CSR	–	–	–	–
Kotchick and Tressler [35]	< 1000, 0.13% SiO_2	⟨1 1 $\bar{2}$ 0⟩	1550–1850	–	CSR	Vac.	G	4–20	210–630
Cadoz *et al.* [36]	–	Perpendicular to [0001]	1400–1800	–	CSR	Air	E, G	–	770–960
Castaing *et al.* [37]	–	Perpendicular to [0001]	25–1800	–	CSR	–	–	–	–
Al_2O_3–MgO									
Palmour [38]	–	⟨100⟩, ⟨110⟩, ⟨111⟩	1550–1850	–	CSR	–	F	1.76–4.5	305–805
Lewis [39]	< 1000	⟨100⟩, ⟨110⟩, ⟨111⟩	1300–1520	–	CSR	–	–	–	–
Doukhan *et al.* [40]	20	⟨110⟩	1300–1450	90–110	C	Air	A	3.9	510
Hwang *et al.* [41]	–	45° to (111) and ($\bar{1}$01)	1790–1895	–	CSR	Ar	F	–	–
Mitchell *et al.* [42]	–	–	1790–1895	–	CSR	–	F	3.9	870
Doukhan *et al.* [43]	"pure"	[001]	1550–1740	40–90	C	Air	A	4.5	580
Duclos *et al.* [44]	Low	[001]	1575–1730	88–118	C	Air	B, D	4	550
Duclos [45]	–	[001], [110], [111]	1220–1250	120–160	C	Air	D	–	290–340
Duclos and Crampon [46]	–	[001]	1350–1650	30–140	CSR	–	E	3.9	500
Duclos [47]	–	⟨111⟩	1420–1630	60–250	CSR	Air	E	3.7	560
Al_2O_3–SiO_2									
Dokko *et al.* [48]	various	3 to 6% off *c* axis	1400–1500	–	CSR	Air	–	–	–
Menard *et al.* [49]	–	–	70–600	4–12	CSR	Air	F	–	–

TABLE AI Continued

Reference	Experimental conditions						Experimental results		
	Total metallic impurity or dopant (ppm)	Orientation of stress axis	Test temperature (°C)	Applied stress (MPa)	Test technique	Atmosphere	Type of creep curve	Stress exponent, n	Activation energy, Q (kJ mol^{-1})
CaF_2									
Phillips [50]	"pure",	⟨100⟩, ⟨111⟩	25–1000	–	CSR	Air	G	–	–
Urusovskaya and Govorkov [51]	doped with Sm and Nd	⟨110⟩	200–1120	–	CSR	Ar	G	–	–
Feltham and Ghosh [52]	10	⟨100⟩	950–1100	6.9–31	C	Air	A	4.1–5.0	280
CdTe									
Hall and Vander Sande [53]	10	–	25–500	–	CSR	Air	F, G	–	–
CoO									
Clauer *et al.* [54]	< 1000	⟨100⟩	1000–1200	6–12	C	Ar, P_{O_2} varied	D	6.8	435–365
Clauer *et al.* [55]	< 1000	⟨100⟩	1000–1240	6–12	C	P_{O_2} varied	D	7.1	–
Krishnamachari and Jones [56]	10–5000	⟨100⟩	950–1100	7–31	C	Air, Vac.	A	3–5	170–280
Krishnamachari [57]	10	⟨100⟩	1000–1100	13.8	C	Air	A	–	300
Krishnamachari *et al.* [58]	–	[001]	1000	14	C	–	–	–	–
Nehring *et al.* [59]	1500	[100]	1000–1290	7.6–14	C	Air	–	5.0	210
Nehring and Smyth [60]	–	–	1100	8.2	C	–	D	–	–
Castaing *et al.* [61]	–	⟨001⟩	–196 to 1123	–	CSR	Air	E	–	–
Routbort [62]	–	⟨100⟩	1000	–	CSR	P_{O_2} varied	E	–	–
Dominguez-Rodriguez *et al.* [63]	–	[001]	1100–1400	5–25	C	P_{O_2} varied	–	6.3–8.5	500

TABLE AI Continued

Reference	Experimental conditions						Experimental results		
	Total metallic impurity or dopant (ppm)	Orientation of stress axis	Test temperature (° C)	Applied stress (MPa)	Test technique	Atmosphere	Type of creep curve	Stress exponent, n	Activation energy, Q (kJ mol^{-1})
CoO–NiO									
Griffin and Smyth [64]	–	[001]	1000–1300	–	C	–	D	–	–
Cu_2O									
Schmidt-Whitley [65]	~ 1	⟨110⟩	900	~ 4.7	C	Ar/O_2	A	–	–
Fries *et al.* [66]	10	[001]	800	10	C	Ar/O_2	–	–	–
Martinez-Clemente *et al.* [67]	10	⟨001⟩, ⟨1$\bar{1}$0⟩	RT-800	3–10	CSR	P_{O_2} varied	F	–	–
Bretheau *et al.* [68]	–	⟨100⟩, ⟨110⟩	700–1000	2–24	C	Ar/O_2	A	5.1–6.0	190–740
Bretheau and Dolin [69]	–	[110], [100]	800–830	3–17	C	Air	–	–	–
Torres-Villaseñor *et al.* [70]	–	⟨051⟩, ⟨122⟩	RT-600	215–353	CSR	Castor oil	E, G	–	–
Fries *et al.* [71]	–	[001], [110]	800	1.5–10	C	–	–	–	–
Sieber *et al.* [72]	–	⟨001⟩, ⟨011⟩	250, 450	–	CSR	Ar, Air	–	–	–
Bretheau *et al.* [73]	–	⟨001⟩, ⟨011⟩ ⟨111⟩	700–1000	2–24	C	P_{O_2} varied	A, D	5.1	170
FeO									
Reppich [74]	–	⟨100⟩	–	–	CSR	P_{O_2} varied	E, F	4.4	355
InP									
Brown *et al.* [75]	–	⟨001⟩, ⟨123⟩	480–730	3–20	CSR	Air	E, G	–	–
KBr									
Montemayor *et al.* [76]	15	⟨100⟩	377–667	0.8–1.4	C	Air	A	5.3	84–140
Yavari and Langdon [77]	< 350	⟨100⟩	240–660	0.2–10	C	Air	A	4.3–6.7	106–183

TABLE AI Continued

Reference	Experimental conditions						Experimental results		
	Total metallic impurity or dopant (ppm)	Orientation of stress axis	Test temperature (° C)	Applied stress (MPa)	Test technique	Atmosphere	Type of creep curve	Stress exponent, n	Activation energy, Q (kJ mol^{-1})
KCl									
Geguzin *et al.* [78]	"pure"	–	700–750	0.0098–0.98	T	Air	E, G	24	–
LiF									
Gilman [79]	–	⟨100⟩, ⟨110⟩	–196–600	–	CSR	Air	–	–	–
Phillips [80]	–	⟨100⟩	25–800	–	CSR	Air	F	–	–
Phillips [81]	60 ppm Mg	⟨100⟩	–203–600	–	CSR	–	–	–	–
Budworth and Pask [82]	65	⟨100⟩, ⟨111⟩	24–700	–	CSR	Air	–	–	–
Day and Johnston [83]	–	⟨100⟩	300–700	–	CSR	–	F, G	–	–
Fotedar and Stoebe [84]	3–800 Mg	⟨100⟩	24–360	–	CSR	–	F	–	–
Brown *et al.* [85]	< 2	⟨100⟩	600–700	0.8	C	–	–	–	140
Reppich [86]	< 1	⟨100⟩	375–800	0.6–35	C	–	A	–	–
Coghlan *et al.* [87]	< 1	⟨100⟩	500–671	0.6–3	C	–	D	9.8	380
Menezes and Nix [88]	~ 1	⟨100⟩	530–620	1–2	C	–	D	–	–
Narayan Rao and Ruoff [89]	< 25	⟨100⟩	650–750	1.3–2.4	C	Ar	A	3.7–5.1	200
Reppich [90]	1–1300 Mg	⟨100⟩	RT-800	–	CSR	–	–	–	–
Reppich [91]	"pure", 1300-Mg	⟨100⟩	20–700	–	CSR	–	F, G	–	–
Streb and Reppich [92]	0.7–690 MgO	⟨100⟩	250–800	1–100	C	–	A	–	–
Reppich and Streb [93]	0.7–690 MgO	⟨100⟩	250–800	1–100	C	–	A	4	220
Brown *et al.* [94]	11–100	⟨100⟩	250–700	–	CSR	–	–	–	–
Menezes and Nix [95]	40–80	⟨100⟩	–	–	–	–	–	3.5–7	–
Cropper and Pask [96]	300	⟨100⟩, ⟨111⟩	650–750	7–35	C	Air	A	3.1–4.1	220

TABLE AI Continued

Reference	Experimental conditions						Experimental results		
	Total metallic impurity or dopant (ppm)	Orientation of stress axis	Test temperature (° C)	Applied stress (MPa)	Test technique	Atmosphere	Type of creep curve	Stress exponent, n	Activation energy, Q (kJ mol^{-1})
Ruoff and Narayan Rao [97]	< 25–1700 MgO	⟨100⟩	650–750	1–2	C	Ar	A	3.6–5	200–250
Yu and Li [98]	< 50	⟨100⟩	600–750	4–30	Impression loading	Air	A	4.5	210–225
MgO									
Hulse and Pask [99]	6000	⟨100⟩	− 196–1200	–	CLR	Air	F	–	–
Cummerow [100]	–	⟨100⟩	1450–1700	15–75	B	Ar	A	4–7	335–670
Neiman and Rothwell [101]	–	⟨100⟩	1000	50	B	Vac.	A	6.3	–
Hulse *et al.* [102]	6000	⟨110⟩, ⟨111⟩	26–1250	–	CLR	Air	F	–	–
Stokes and Li [103]	–	⟨100⟩	RT–1850	–	CSR	–	–	–	–
Day and Stokes [104]	–	⟨100⟩	1000–2000	–	CSR	Ar	F, G	–	–
Copley and Pask [105]	200–1000	⟨100⟩, ⟨111⟩	1000–1600	–	CLR	Air	F	–	–
Rothwell and Neiman [106]	–	⟨100⟩	1000–1630	14–69	B	Vac.	A	3–5.2	140–565
Atkins *et al.* [107]	–	–	1060–1727	–	Indentation	Vac.	–	–	420
Atkins and Tabor [108]	–	–	700–1700	–	Indentation	Vac.	–	–	460
Day and Stokes [109]	–	⟨110⟩	1400–1700	–	CSR	Ar	F	–	–
Atkins and Tabor [110]	–	–	600–1700	–	Indentation	–	–	–	460
Day and Stokes [111]	~ 1250 + 3000 NiO	⟨100⟩	1200–1800	–	CSR	Ar	F, G	–	–

TABLE AI Continued

Reference	Experimental conditions						Experimental results		
	Total metallic impurity or dopant (ppm)	Orientation of stress axis	Test temperature (° C)	Applied stress (MPa)	Test technique	Atmosphere	Type of creep curve	Stress exponent, n	Activation energy, Q (kJ mol^{-1})
Hulse [112]	6000	⟨111⟩	26–1530	–	CSR	Air	–	–	–
Day and Stokes [113]	–	⟨100⟩, ⟨110⟩	1800	–	CSR	Ar	F	–	–
Cropper and Pask [114]	5600	⟨100⟩	1125–1300	43–86	CLR	Air	A	–	–
Moon and Pratt [115]	200–400	⟨100⟩	25–1600	–	CSR	Air, Ar	F	–	–
Hüther and Reppich [116]	< 100	⟨100⟩	1347–1797	25–100	C	Ar	A	5–9	–
Birch and Wilshire [117]	500	⟨100⟩	1323	68	C	Air	A	–	450
Reppich and Hüther [118]	< 100	⟨100⟩	1347–1797	61–83	C	Ar	A	–	–
Ilschner and Reppich [119]	–	⟨100⟩	1400–1800	22–83	C	Ar	A	4–100	–
Birch and Wilshire [120]	500	⟨100⟩, ⟨111⟩	1323	68–155	C	Air	A	–	475
Birch and Wilshire [121]	500	⟨100⟩	1323	68	C	Air	A	4.1	450
Clauer and Wilcox [122]	500	⟨011⟩	1200–1500	29–86	T	Vac.	A	3.8–4.5	395
Clauer *et al.* [123]	500	⟨110⟩	1400	44	T	–	–	–	–
Dokko and Pask [124]	Various	⟨100⟩, ⟨111⟩	1200–1400	–	CSR	Air	E, F, G	–	–
Routbort [125]	Various	⟨100⟩, ⟨111⟩	1300–1800	3–40	CSR	He	F	4.2–8.4	–
Dixon-Stubbs and Wilshire [126]	Various	⟨100⟩, ⟨111⟩	1323	68–155	C	Air	A	3	–
Routbort [62]	–	Various	1100	–	CSR	Inert	G	–	–
NaBr									
Christy [2]	–	⟨100⟩	580–750	0.6–1	C	–	–	–	345

TABLE AI Continued

Reference	Experimental conditions						Experimental results		
	Total metallic impurity or dopant (ppm)	Orientation of stress axis	Test temperature (° C)	Applied stress (MPa)	Test technique	Atmosphere	Type of creep curve	Stress exponent, n	Activation energy, Q (kJ mol^{-1})
NaCl									
Christy [2]	–	–	600–750	–	C	–	A	3–4	285
Phillips [81]	20	⟨100⟩	–203–600	–	CSR	–	–	–	–
Ilschner and Reppich [127]	"pure"	⟨100⟩	500–750	0.24–0.74	C	–	D	6	255
Geguzin *et al.* [78]	"pure"	⟨100⟩	750–870	0.01–1	T	Various	A, D	4	240
Hesse [128]	< 2	Various	–173–630	–	CSR	Various	G	–	–
Blum and Ilschner [129]	> 1	–	550–800	0.4–3.5	C	Ar	A	4	245
Schuh *et al.* [130]	1300 Ca	⟨100⟩	260–780	0.15–19.6	C	Ar	A	4	150–335
Carter and Heard [131]	30	Various	25–500	–	Triaxial	CO_2	G	7	138
Messerschmidt [132]	"pure"	–	150–300	–	CSR	Vac.	–	–	–
Poirier [133]	460	⟨100⟩	480–795	1.0	C	Ar	A	4.2	240–250
Poirier [134]	–	⟨100⟩	480–795	0.1–1.0	C	Ar	–	–	–
Blum [135]	"pure", 1–12 Ca	–	150–801	6–41	C	Ar	A	4–30	–
Pontikis and Poirier [4]	–	⟨100⟩	308	0.3–0.5	C	–	A	6.3	–
Pontikis and Poirier [136]	–	⟨100⟩	308, 678	–	C	–	A	7.3	–
Pontikis [5]	–	[001]	679	0.2–0.4	C	Air	A	7.1	–
Guillopé and Poirier [137]	< 10–500	[001]	250–790	0.15–12	C	Ar	–	–	–
Eggeler and Blum [138]	3	⟨100⟩	923–1033	0.5–1.2	C	Air	A	4.5	–
NbC									
Williams [139]	–	⟨100⟩	800–1600	–	CSR	Vac.	–	–	–
Dement'yev *et al.* [140]	320 Si	⟨110⟩	1800–2700	12–68	C	Neutral	A, B	3.3–4.8	355–500

TABLE AI Continued

Reference	Experimental conditions						Experimental results		
	Total metallic impurity or dopant (ppm)	Orientation of stress axis	Test temperature (° C)	Applied stress (MPa)	Test technique	Atmosphere	Type of creep curve	Stress exponent, n	Activation energy, Q (kJ mol^{-1})
NiO									
Dominguez-Rodriguez and Castaing [141]	Various	–	–72–700	–	CSR	–	–	–	–
Dominguez-Rodriguez and Castaing [142]	1000	⟨100⟩	20–1200	–	CSR	Air	F	–	–
Dominguez-Rodriguez *et al.* [143]	Various	⟨001⟩	72–1300	40–100	CSR	Air	G	–	–
Cabrera-Caño *et al.* [144]	100	⟨100⟩	950–1200	50–120	C	–	A	11.6	480
Cabrera-Caño *et al.* [145]	100	⟨100⟩	1050–1200	25–120	C	Air	A, C	11.4	520
Routbort [62]	–	⟨100⟩	1100–1400	8–20	CSR	P_{O_2} varied	F	–	–
$Ni_{0.66}Fe_{2.34}O_4$									
Veyssière *et al.* [146]	–	⟨100⟩, ⟨110⟩	1100–1600	–	CSR	–	–	–	–
PbS									
Seltzer [147]	–	⟨110⟩, ⟨100⟩	575–750	1.2–2.9	C	H_2/H_2S	C	4–7	165–280
Seltzer [148]	–	⟨100⟩	650–700	2	C	H_2/H_2S	–	–	–
SiC									
Hirai and Niihara [149]	–	Various	1400–1500	–	Hot hardness	–	–	–	520
TiC									
Williams and Schaal [150]	–	–	800–2200	15–490	B	Vac.	–	–	–
Williams [139]	200	⟨100⟩	800–1600	–	CSR	Vac.	F	–	–
Hollox and Smallman [151]	–	⟨100⟩	900–1250	–	CSR	Vac.	F	–	–

TABLE AI Continued

Reference	Experimental conditions						Experimental results		
	Total metallic impurity or dopant (ppm)	Orientation of stress axis	Test *temperature* (° C)	Applied stress (MPa)	Test technique	Atmosphere	Type of creep curve	Stress exponent, *n*	Activation energy, *Q* (kJ mol^{-1})
TiO									
Vere and Smallman [152]	300	⟨100⟩	1000–1250	–	CSR	Vac.	F	–	–
TiO_2									
Ashbee and Smallman [153]	300	⟨100⟩, ⟨110⟩	RT–1300	–	CSR	Air, Vac.	F	–	–
Ashbee and Smallman [154]	Various	⟨100⟩, ⟨110⟩	600–1100	–	CSR	Air	–	–	–
Hirth and Brittain [155]	"pure"	⟨111⟩	777–1052	20–90	C	Air, Vac., He	A	1.5–2.0	160–330
Farb *et al.* [156]	Various	⟨001⟩	572–1230	38–70	B	N_2, O_2	A, D	–	210–750
Bell *et al.* [157]	< 75	⟨100⟩	900–1040	3.4–83	C	Air	A	1.8	275
Bell *et al.* [158]	< 75	⟨111⟩	1000–1040	2.8–69	C	Vac.	A	1.6	215
Krishnamachari *et al.* [159]	< 75	⟨111⟩	1000–1040	13.8–69	C	Vac.	A	1.6	215
Krishnamachari *et al.* [160]	< 75	⟨111⟩	1000–1040	2.8–69	C	Air, Vac.	A	–	–
Blanchin and Faisant [161]	360	Various	527–1427	10–150	CSR	P_{O_2} varied	E	–	–
Blanchin *et al.* [162]	360	[001]	523–1423	–	CSR	P_{O_2} varied	E	–	–
UO_2									
Armstrong *et al.* [163]	100	⟨110⟩, ⟨111⟩	1340–1685	25–56	B	H_2	D	3.3	490
Nadeau [164]	–	⟨100⟩, ⟨111⟩	1100–1600	–	CSR	CO/CO_2	–	–	–
Sawbridge and Sykes [165]	350	Various	1327	–	CSR	Ar	F	–	–

TABLE AI Continued

Reference	Experimental conditions						Experimental results		
	Total metallic impurity or dopant (ppm)	Orientation of stress axis	Test temperature (° C)	Applied stress (MPa)	Test technique	Atmosphere	Type of creep curve	Stress exponent, n	Activation energy, Q (kJ mol^{-1})
Seltzer *et al.* [166]	< 500	⟨100⟩	1100–1300	38–124	C	CO/CO_2, H_2	A	1.7–17	230–560
Mordike [167]	–	⟨$\bar{1}$11⟩, ⟨011⟩	500–1600	30–225	CSR	–	F, G	–	–
Alamo *et al.* [168]	–	–	700–1400	–	CSR	–	–	–	–
$VC_{0.85}$									
Hollox and Venables [169]	–	Various	1000–1700	–	CSR	Vac.	–	–	–
Y_2O_3									
Gaboriaud [170]	–	⟨110⟩	1700–1800	20–140	CSR	Air	–	–	–
Gaboriaud [171]	1000	⟨110⟩	1550–1800	20–140	C	Air	A	4	400
$Y_3Fe_5O_{12}$									
Rabier *et al.* [172]	–	⟨100⟩, ⟨110⟩, ⟨111⟩	1200–1350	–	CSR	Air	–	–	–
ZrC									
Williams [139]	–	⟨100⟩	800–1600	–	CSR	Vac.	–	–	–
Lee and Haggerty [173]	–	⟨111⟩	1400–2000	30–700	–	–	–	5	460
Zubarev and Dement'yev [174]	"pure"	–	2200–3000	80–210	B	–	–	3.0	335

TABLE AII High temperature mechanical properties of ceramic bi-crystals and tri-crystals

Reference	Boundary misorientation	Test temperature (° C)	Applied stress (MPa)	Test technique	Atmosphere
Al_2O_3					
Davis and Palmour [175]	Various angles to [0001]	1700–1900	10–24	CSR	Vac.
Bertolotti [176]	Various	1500–1700	–	C	Vac.
Becher and Palmour [177]	Tri-crystal	1210–1820	–	CSR	Vac.
NaCl					
Adams and Murray [178]	–	440–700	1–2	C	Air, Ar
MgO					
Adams and Murray [178]	–	1355–1495	2–30	C	Ar
Murray *et al.* [179]	Various	1300–1500	2–14	C	Ar
Mountvala and Murray [180]	Various (tilt and twist)	1200–1500	5–120	C	Ar
UO_2					
Poteat and Yust [181]	–	1430	27	CSR	–

TABLE AIII High temperature mechanical properties of ceramic polycrystals

Reference	Experimental conditions							Experimental results			
	Total metallic impurities or dopant (ppm or %)	Density (% theoretical)	Grain size (μm)	Test temperature (° C)	Applied stress (MPa)	Test technique	Atmosphere	Type of creep curve	Stress exponent, n	Grain size exponent, p	Activation energy, Q (kJ mol^{-1})
AgBr											
Christy [1]	300	–	1000	320–380	0.6	C	Air	C, D	–	–	–
Al_2O_3											
Stavrolakis and Norton [182]	5000	–	–	25–1500	13–48	Torsion	–	A	–	–	–
Coble and Kingery [183]	–	50–95	15	1275	1.7–27.6	Torsion	–	A	1	–	–
Chang [184]	Various	95–97	25–30	1510–1570	–	T	Air	A	–	–	840
Folweiler [185]	MgO-doped	99+	1–34	1400–1700	1.4–172	CSR	Air	F	~ 1	2	545
Warshaw and Norton [186]	300 MgO	99+	3–13	1600–1800	0.7–6.9	B	Vac.	–	~ 1	~ 2	545
Beauchamp *et al.* [187]	Various	92–96	2.5–100	1000–1350	–	B	–	A	1	–	545
Chang *et al.* [188]	–	–	20, 75	1700–1800	–	CSR	Vac.	G	–	–	–
Coble and Guerard [189]	Various	–	100	1640–1900	4–26.9	B	Vac.	A	–	–	1170
Dawihl and Klinger [190]	Various	93.5–95	7–10	1000–1250	73–294	C	–	A	~ 1	–	90, 495
Fryer and Roberts [191]	~ 1%	92–93	2–20	1384–1675	0.34–1.7	T	Air	A	1.8–2.3	–	505, 775
Passmore and Vasilos [192]	300 MgO	99.5	2	1357–1497	6.7–62	B	Vac.	A	1–2	–	595
Passmore *et al.* [193]	–	98	2	1200–1500	–	CSR	Air	G	–	–	–
Bakunov *et al.* [194]	3000	96.3	45	1650–1850	1.4	B	Vac.	–	–	–	825
Hewson and Kingery [195]	(a) 1–1500 MgO (b) 500 $MgTiO_3$	> 98	15–100	1641–1830	~ 6.9	B	Vac.	–	–	–	–
Trostel [196]	0.25% MgO	99.5	3	1450	9.8–49	C	Air	A	~ 1	–	770
Shapiro *et al.* [197]	–	97–99	20–120	1650–1900	1–3	B	–	–	1	–	590

TABLE AIII Continued

Reference	Experimental conditions							Experimental results			
	Total metallic impurities or dopant (ppm or %)	Density (% theoretical)	Grain size (μm)	Test temperature (° C)	Applied stress (MPa)	Test technique	Atmosphere	Type of creep curve	Stress exponent, n	Grain size exponent, p	Activation energy, Q (kJ mol^{-1})
Sugita and Pask [198]	2300 MgO+ 2200 NiO	99+	3	1300–1470	6.7–10	C	Air	–	1.1–1.3	–	400–520
Heuer *et al.* [199]	"pure", 2500 MgO	99.5	1.2–11	1300–1700	6.7–172	CSR	–	F	1.1–1.6	2.5	490–570
Engelhardt and Thümmler [200]	1000 MgO+ 1000 SiO_2	95–98	~ 12	1450–1700	9.8–73.5	B	Vac.	A	1, 4	–	585
Mocellin and Kingery [201]	260–1300 MgO	99+	34–65	1600–1850	6.7	C	Vac.	–	–	–	295–525
Becher [202]	< 1000	99+	2–20	1210–1700	41.3–344	C	Vac.	–	–	–	–
Vishnevskii *et al.* [203]	2000	98	10	1300–1800	1.5–77	B	–	–	0.8–1.2	–	570
Davies and Sinha Ray [204]	–	–	–	1600–1750	11–55	T	Air	A	–	–	–
Heuer *et al.* [14]	2500 MgO	–	2	1000–1200	–	Triaxial	–	–	–	–	–
Andrianov *et al.* [205]	–	94.5	15–80	1450	6.9–16	B	–	–	1.0–1.5	1	–
Vishnevskii *et al.* [206]	1000 MgO+ 1000 others	98	10	1500–1800	7.8–24.5	B	–	A	1.1–1.2	–	585
Fryer and Thompson [207]	–	71–98	–	1356–1468	–	C	Vac.	A	1–2	–	400–505
Davies and Sinha Ray [208]	150% Si	99.5	13–18	1500–1700	4.1–41.3	T	Air	A	1, 2	~ 2	590–690
Sugita and Pask [209]	2500 MgO	99.5	3	1450	9.8–49	C	Air	A	1.8	–	–
Crosby and Evans [210]	"pure" 2% Ni	95.5–98.8	9–28	1450–1800	6.9–44.8	C	Air	A	0.7–2.5	2.7	410–625
Hollenberg and Gordon [211]	Various	> 98	6–42	1400–1525	1.0–49	B	Air, P_{O_2} varied	A	1.0–2.6	1.7–1.9	475–620
Crosby and Evans [212]	< 1000	95.5–95.8	13–28	1600–1700	20	C	Ar	D	–	–	–
Krohn *et al.* [213]	7300	–	18	775–900	–	CSR	Air	–	–	–	285
Lessing and Gordon [214]	Various	98	6–71	1400–1500	3.9–49	B	P_{O_2} varied	A	1.0–1.3	2.0–2.2	410–625
Davies [215]	1000 MgO	99.5	15–30	1450–1750	5–50	T	Air	A, B	1–2	2	640

TABLE AIII Continued

Reference	Experimental conditions							Experimental results			
	Total metallic impurities or dopant (ppm or %)	Density (% theoretical)	Grain size (μm)	Test temperature (° C)	Applied stress (MPa)	Test technique	Atmosphere	Type of creep curve	Stress exponent, n	Grain size exponent, p	Activation energy, Q (kJ mol^{-1})
Lessing *et al.* [216]	Various	> 98	5–1200	1200–1500	4–100	B	–	–	–	–	–
Cannon and Sherby [217]	100–5000 MgO	99+	14–65	1600–1700	27.5–124	C	Ar	B	1.2, 2.6	2, 0	595
Lessing and Gordon [218]	Various	> 98.5	9–1200	1350–1550	1–55	B	Controlled P_{O_2}	A	1.0–2.9	0, 3	390–600
Hou *et al.* [219]	Various	98.1–99.9	3–100	1400–1550	6–50	C	Controlled P_{O_2}	A	1.0–2.7	0, 2	400–590
Cannon *et al.* [220]	< 1000 + 2500 MgO	99	1.2–15	1192–1337	2–150	CSR	Ar, Air	F	1–2	2.7–2.9	–
Heuer *et al.* [221]	–	–	1–5	1315–1450	19.3–55.8	CSR, B	–	–	–	–	–
Ikuma and Gordon [222]	Various	–	8–100	1100–1500	2–17	B	–	–	~ 1	1.0–1.8	–
El-Aiat *et al.* [223]	Various	99.3–99.8	1–40	14	~ 30	C	Controlled P_{O_2}	–	1.2–1.3	2, 3	–
Porter *et al.* [224]	2500	–	2	1273–1479	8–200	CSR	–	–	1.8	–	460
Al_2O_3–MgO											
Palmour [38]	600	99.2, 97.5	0.5–200	1350–1800	–	CSR	Vac.	F	1.8–6.7	−0.3	695–900
Bakunov *et al.* [194]	3000	95.5	15	1650–1750	1.4	B	Vac.	–	–	–	580
Shapiro *et al.* [197]	–	96–97	12–20	1300–1500	2–16	B	–	–	1	–	–
Al_2O_3–SiO_2											
Hulse and Pask [225]	6.6%	75–83	–	950–1100	0.3–8.5	C	–	A	–	–	740
Bakunov *et al.* [194]	3000	98.1	5	1700–1800	1.4	B	Vac.	–	–	–	515
Penty and Hasselman [226]	> 100	99+	~ 1	1450–1512	10–60	CSR	Air	–	1.1–1.4	–	700
Lessing *et al.* [227]	"high purity"	~ 100%	~ 5	1350–1450	12–40	B	Air	–	1.0	–	685
Dokko *et al.* [48]	Various	98–100	1–20	1400, 1500	–	CSR	Air	F	1	− 2	170

TABLE AIII Continued

Reference	Experimental conditions							Experimental results			
	Total metallic impurities or dopant (ppm or %)	Density (% theoretical)	Grain size (μm)	Test temperature (°C)	Applied stress (MPa)	Test technique	Atmosphere	Type of creep curve	Stress exponent, *n*	Grain size exponent, *p*	Activation energy, *Q* ($kJ\ mol^{-1}$)
$BaO-Fe_2O_3$											
Hodge *et al.* [228]	–	–	3	1000–1200	6.9–41.3	C	–	A	2–5	–	–
BeO											
Chang [184]	Various	97–99	25–30	1510–1570	0.41–1.5	T	Air	A	1	–	505
Chang *et al.* [188]	"pure", 1% MgO	99.9	20–40	1900	–	CSR	Vac.	G	–	–	–
Vandervoort and Barmore [229]	–	96.5	7.5–10	1371–1538	10–41	C	Air	A	~1	–	400
Shishkov *et al.* [230]	Various	–	20–65	1400–1850	2–30	B	Vac.	A	1.0–1.2	–	295
Fryxell and Chandler [231]	Various	85–4100	5–100	1200	6.9–69	C	–	A	1, > 1	–	420
Barmore and Vandervoort [232]	"pure"	99+	8–45	1400–1700	6.9–31	B	Vac.	A	~1	~2	415
Bentle and Kniefel [233]	< 200, 1% MgO	99.7–99.8	18–77	1700–1900	–	CSR	–	F	–	–	–
Bakunov *et al.* [194]	2000	94.1	30	1700–1900	1.4	B	Vac.	–	–	–	240
Barmore and Vandervoort [234]	< 500	99.5	63±5	1850–2000	10–41	C	Vac.	–	2.5	–	610
Cline *et al.* [235]	200	96.5	6–10	1370–1570	21	C	Air	–	–	–	420
Walker *et al.* [236]	–	79–97	7.3–1.1	850–1250	–	CSR	–	–	5.5	–	420
$BeO-UO_2$											
Vandervoort and Barmore [237]	< 250	98	6–16	1350–1523	10.3–41.3	C	Air	A	1	2	385–420
CeO_2											
Poluboyarinov *et al.* [238]	3000	96	15	1350–1450	6.17–24.5	B	Air, He	–	2.2	–	390

TABLE AIII Continued

Reference	Experimental conditions							Experimental results			
	Total metallic impurities or dopant (ppm or %)	Density (% theoretical)	Grain size (μm)	Test temperature (°C)	Applied stress (MPa)	Test technique	Atmosphere	Type of creep curve	Stress exponent, *n*	Grain size exponent, *p*	Activation energy, *Q* ($kJ\ mol^{-1}$)
CoO											
Strafford and Gartside [239]	< 15	–	–	925–1050	–	B	P_{O_2} varied	–	2.3	–	195
Clauer *et al.* [240]	–	94	25–30	925–1250	2.7–38	C	O_2, Ar/O_2	A	2.0, 6.5	–	215–335
Krishnamachari *et al.* [58]	–	–	–	1000	13.78	C	–	–	–	–	–
Vinjamuri *et al.* [241]	"pure", 1% Li	> 99	10	1000	27.6–41.4	C	Air	A	3.1–4.4	–	–
CsCl											
Heard and Kirby [242]	< 1000	98	–	150–400	–	CSR (Triaxial)	–	G	4.4	–	150
Cu_2O											
Vagnard and Washburn [243]	"high purity"	–	1000–3000	RT–600	–	CSR	Ar	F	–	–	–
Menzies and Aldred [244]	–	–	–	RT–400	–	CSR	O_2, Ar	F	–	–	–
Schmidt-Whitley *et al.* [245]	–	92	50	630–890	5–15	C	O_2	A	6–8	–	195
Gervais *et al.* [246]	–	95	50	1050–1100	0.2–0.8	C	Air	A	1.3–1.5	1.5–2.5	170
Bretheau *et al.* [73]	> 1000	95	55	780–1060	5–15	C	P_{O_2}	A	5.4	–	180
Eu_2O_3											
Moore and Morrow [247]	5000	88.1–97.4	3.7–20.7	1100–1400	3–30	C, B	H_2/H_2O	A	1	–	460–470
FeO											
Ilschner *et al.* [248]	"Analytical grade"	~ 100%	100–300	1000–1500	1.8–17.6	C	P_{O_2} varied	A	4.2	–	330
Reppich [74]	"Analytical grade"	–	100–300	650–1300	1.8–19.0	CSR	P_{O_2} varied	F	3.7–4.1	–	340
Fe_2O_3											
Crouch [249]	< 10	69–97	1.5–35	770–1105	2–100	B, C	P_{O_2} varied	A	1.1–3.5	2, 0	310–375

TABLE AIII Continued

Reference	Experimental conditions							Experimental results			
	Total metallic impurities or dopant (ppm or %)	Density (% theoretical)	Grain size (μm)	Test temperature (° C)	Applied stress (MPa)	Test technique	Atmosphere	Type of creep curve	Stress exponent, n	Grain size exponent, p	Activation energy, Q (kJ mol^{-1})
Crouch [250]	< 10	80–84	5–10	920–1255	0.2–10	T	P_{O_2} varied	A	1.3–1.6	–	380
Pascoe [251]	< 10	76–97	1.5–6	900–1251	1–50	C	–	A	2–3	–	250
Hay *et al.* [252]	–	–	–	770–1250	–	C, B	–	–	1, 3	–	210, 450
Graphite											
Wagner and Driesner [253]	–	–	–	2000–2500	–	CSR	He	–	3.8	–	210
Wagner *et al.* [254]	–	–	–	2000–3000	–	CSR	He	–	3.8	–	290
Green [255]	–	–	–	2500	13.7–22.2	T	He	A	6.5	–	–
Zukas and Green [256]	–	–	–	2500	–	T	He	A	5.5	–	–
Kotlensky [257]	–	–	–	2400–2760	82.7	T	He	A	–	–	1000–1090
Green *et al.* [258]	–	–	–	2500	–	T	He	–	–	–	–
Green and Zukas [259]	–	–	–	2200–2500	25–32	T	He	A	5.5	–	–
Fischbach [260]	–	–	–	2500–2900	34–207	T	He	A	1–4	–	1050–1470
Zukas and Green [261]	–	"High"	"Very fine"	–	–	T, C	He, Ar	A	8	–	1160
Green *et al.* [262]	–	–	–	2300–2700	10.5–30	T	–	A	6–10	–	900–1000
Green and Zukas [263]	–	–	–	2500	6.6–22	T	–	A	–	–	–
Zukas and Green [264]	–	> 95	–	2300–2500	23–33	T	He	A	6–8	–	1050
Dergunov *et al.* [263]	–	–	Fine to coarse	RT–3227	–	T	Ar	A	2.3–7.7	–	–
Zukas and Green [266]	–	–	Fine	2200–2500	–	T	He	A	5–8	–	1000
Zukas *et al.* [267]	–	–	Fine	2400	–	T	He	–	–	–	–
Hirth *et al.* [268]	–	–	–	2500–4000	–	–	–	–	8	–	1160
Barabanov *et al.* [269]	–	–	–	20–3200	–	T	–	G	–	–	–

TABLE AIII Continued

Reference	Experimental conditions							Experimental results			
	Total metallic impurities or dopant (ppm or %)	Density (% theoretical)	Grain size (μm)	Test temperature (° C)	Applied stress (MPa)	Test technique	Atmosphere	Type of creep curve	Stress exponent, n	Grain size exponent, p	Activation energy, Q (kJ mol^{-1})
KBr											
Yavari and Langdon [77]	< 350	100	550	240–500	0.6–10	C	Air	A	4.3–6.7	0	106–183
KBr–KCl											
Stoloff *et al.* [270]	6	100	350	25–350	–	CSR	Air	–	–	–	–
Cannon and Sherby [271]	"Analytical grade"	~ 100	–	600	0.6–6.9	C	N_2	A	5	–	–
LiF											
Budworth and Pask [272]	30	100	3000	23–500	–	CSR	Air	F	–	–	–
Budworth and Pask [82]	30	100	3000	200–700	–	CLR	Air	F	–	–	–
Cropper and Langdon [273]	< 150	~ 100	100–3000	300–550	3–30	C	Air	A	7–8	0	210
Langdon [274]	< 150	100	160–3000	400–550	3–30	C	Air	–	6	0	–
MgO											
Wygant [275]	7000	88–98	~ 10	1100–1300	8.3–17	Torsion	Air	A, B	5.5	–	195
Hulse *et al.* [102]	4%	91–95	40–120	26–1250	–	CLR	Air	G	–	–	–
Vasilos *et al.* [276]	2000	~ 100	1–3	1180–1260	14–19	B	Air	–	1	–	310
Copley and Pask [277]	300–15 000	> 96	5–400	400–1500	–	CLR	Air	G	–	–	–
Passmore *et al.* [278]	2000	99.5	2–5.5	1110–1530	6.9–37	B	Air	A	1	2, 5	400–425
Bakunov *et al.* [194]	3000	96.9	50	1650–1800	1.4	B	Vac.	–	–	–	370
Day and Stokes [279]	–	99.5–100	30–800	600–2150	–	CSR	Ar	F	–	–	–
Kreglo and Smothers [280]	1.8–5.4%	~ 85	–	1204–1371	0.17–0.67	C	Air	A	3.8–4.5	–	260
Hensler and Cullen [281]	"Analytical grade"	–	56	1200–1500	6.9–41	C	"reducing"	–	–	–	225

TABLE AIII Continued

Reference	Experimental conditions							Experimental results			
	Total metallic impurities or dopant (ppm or %)	Density (% theoretical)	Grain size (μm)	Test temperature (° C)	Applied stress (MPa)	Test technique	Atmosphere	Type of creep curve	Stress exponent, n	Grain size exponent, p	Activation energy, Q (kJ mol^{-1})
Hensler and Cullen [282]	1000	97.3–98.9	13–68	1200–1500	6.9–44.8	C	Air	A	2.6	–	465
Hensler and Cullen [283]	1000	98	56	1500	29–32	C	"reducing"	A	–	–	–
Tagai and Zisner [284]	1000	88.5–97	4–50	1200–1500	–	B	Air	–	> 1	–	435
Zisner and Tagai [285]	0.35–2.26%	83–100	7–48	1150–1510	–	B	Air	–	~ 1	–	235–605
Shapiro *et al.* [197]	–	95–98	10–90	1300–1500	3–25	B	–	–	1	–	590
Langdon and Pask [286]	"pure"	99.8	12–52	1200	34.4–138	C	Air	A	3.3	0	215
Terwilliger *et al.* [287]	Various	99.5	3–40	1100–1400	4.9–54	B	Air	A	1.0–3.6	2–3	–
Hart and Pask [288]	3% LiF	99.4	< 1	770–850	–	–	–	A, C	1.1–1.2	–	320
Langdon and Pask [289]	200–1900	98.4–99.8	12–80	RT–1400	–	CLR	Air	G	–	–	–
Bilde-Sörensen [290]	–	99.8	100–190	1300–1460	24–54	C	Vac.	–	3.2	0	–
Gordon and Terwilliger [291]	0.1–5%	95–99.5	4–30	1100–1400	12.2–46.4	B	Air	A	1	2–3	–
Yasuda *et al.* [292]	Various	–	10–80	1500–1620	–	C	–	–	1	–	–
Crouch [293]	"impure" (94% MgO)	83.7	–	1100–1750	–	CSR	–	F	–	–	–
Hurm and Escaig [294]	Various	97.7–99.9	13–150	1200–1700	14–110	C	O_2	A	2.8–3.6	0	250–495
Bilde-Sörensen [295]	–	> 99.8	100–190	1300–1460	25–55	C	Vac.	–	3.2	0	320
Tremper *et al.* [296]	0.1–10% Fe_2O_3	95–99.5	6–43	1297–1400	2.35–26	B	O_2 and CO/CO_2	A	0.9–1.4	1.9–2.4	305–565
Birch and Wilshire [297]	1500	94–96	10–14	1323	52–85	C	Air	A	3	0	–

TABLE AIII Continued

Reference	Experimental conditions							Experimental results			
	Total metallic impurities or dopant (ppm or %)	Density (% theoretical)	Grain size (μm)	Test temperature (° C)	Applied stress (MPa)	Test technique	Atmosphere	Type of creep curve	Stress exponent, *n*	Grain size exponent, *p*	Activation energy, *Q* ($kJ\ mol^{-1}$)
Birch and Wilshire [298]	1500	94–96	10–14	1323	53–84	C	Air	A	–	–	–
Birch and Wilshire [299]	1500	93–95	10–14	1323	70–85	C	Air	A	–	–	–
Snowden and Pask [300]	"Reagent grade"	99	12–17	1200–1400	55.1–138	CSR	Air	A	1.8–7.0	–	290–460
Birch and Wilshire [120]	Various	95–99	13–19	1303–1343	53–68	C	Air	A	3.0–3.3	–	450
Beeré [301]	"Analytical grade"	41–86	< 2	800–1400	2–22	Hot-pressing	Ar	–	~ 1	–	245–535
Snowden and Pask [302]	"Reagent grade", 5–15% $CaMgSiO_2$	97.7–99.1	17–30	1200–1400	45–165	CSR	Air	F	–	–	–
Lessing and Gordon [303]	5300 Fe	98	58–487	1350–1500	2.9–34.3	B	Air	A	2.8–4.1	0	210–295
Birch *et al.* [304]	1500	94–96	10–14	1323	96	C	Air	A	–	–	–
Langdon [305]	–	> 99.8	12–52	1200	34–103	C	Air	–	–	1.4	–
Coath *et al.* [306]	1500	94–96	10–14	1323	62	C	Air	A	–	–	–
Birch *et al.* [307]	5000	93–95	10–14	1600	96	C	Air	A	–	–	–
Lessing *et al.* [216]	–	> 98	5–1200	1200–1500	4–100	B	–	–	–	–	–
Hodge *et al.* [308]	0.05–5.3% Fe	99	7–10	1250–1500	<10	B	O_2 (0.86 atm)	–	–	–	280–475
Hodge *et al.* [309]	0–2.65% Fe	–	–	–	–	B	–	–	1, 3	–	–
Yasuda *et al.* [310]	Various	> 95	19–175	1600	–	C	Air	–	1	2	340
Coath and Wilshire [311]	1500	94–96	10–14	1200	–	C	–	A	1–3	–	450
Hodge and Gordon [312]	Various	~ 100	3–25	1350	2.31–10.09	B	Air	A	~ 1	2.0, 2.6	–
Crampon and Escaig [313]	5000 Fe	> 91	0.1–1	700–1050	50–140	C	Air	A	~ 1	2.9	–

TABLE AIII Continued

Reference	Experimental conditions							Experimental results			
	Total metallic impurities or dopant (ppm or %)	Density (% theoretical)	Grain size (μm)	Test temperature (° C)	Applied stress (MPa)	Test technique	Atmosphere	Type of creep curve	Stress exponent, n	Grain size exponent, p	Activation energy, Q (kJ mol^{-1})
Dokko and Pask [124]	Various	94.7–100	1–600	1100–1400	–	CSR	A	E, F	–	–	–
Sugarman and Blanchere [314]	"pure", 0.5–2% C	98.5	5–87	1000–1300	8–40	B	Ar	–	1.3	2–3	250
Shetty and Gordon [315]	5300	–	43	1450	–	B	Air	–	1.2, 4.1	–	–
Dixon-Stubbs and Wilshire [126]	Various	74–96	10–14	1323	50–80	C	Air	A	3, 1.8–3.8	0	475
Crampon and Escaig [316]	5000	92	0.1–1.0	900–1150	10–600	CSR	Air	G	1.2	–	–
Duclos and Crampon [46]	–	–	0.1–1.0	900–1150	10–600	CSR	–	G	1	3	–
Crampon [317]	5000	91	0.1–1.0	700–1050	50–140	C	–	–	–	–	–
Crampon [318]	–	–	0.1–1.0	700–1050	50–150	C	–	–	1.1	2.8	–
Dixon-Stubbs and Wilshire [319]	"Low"	> 82	40–60	1247–1337	0.9–4	C	Air	A	1	–	350
MgO–CaO											
Coath and Wilshire [311]	< 1%	94–96	3–16	1123–1323	50–70	C	Air	–	1.8–4.0	–	385–435
Coath and Wilshire [320]	< 1%	93.8–98.8	3–15	1100–1323	58–62	C	Air	–	3.5	–	380
$MgO–CaMgSiO_4$											
Snowden and Pask [321]	5% $CaMgSiO_4$	~ 100	31	1200–1450	3–120	C	Air	A, B	1.0–3.8	–	435–1000
NaCl											
Kingery and Montrone [322]	"Reagent grade" +600–1000 Al_2O_3	95.5–96.1	65–140	740	0.58–0.82	B	Air	B	1	~ 3	–
Le Comte [323]	"Chemically pure"	98	100–150	29–300	3.4–13.8	C	Oil	–	~ 3–4	–	52–126
Burke [324]	Various	99.7	200–3000	365–741	0.3–9.6	C	Air	A	5.0	0	155, 205
Heard [325]	200	99.5–99.7	2000–3000	23–400	–	CSR (Triaxial)	CO_2	–	5.5	–	98

TABLE AIII Continued

Reference	Experimental conditions							Experimental results			
	Total metallic impurities or dopant (ppm or %)	Density (% theoretical)	Grain size (μm)	Test temperature (°C)	Applied stress (MPa)	Test technique	Atmosphere	Type of creep curve	Stress exponent, *n*	Grain size exponent, *p*	Activation energy, *Q* ($kJ\ mol^{-1}$)
Blum [135]	*1–12 Cu*	*~100*	–	*150–T_m*	*6–41*	C	Ar	A	4, 74	–	–
Robinson *et al.* [326]	–	–	2000	741	0.48–0.96	C	Air	A	5.2	–	200
Sinha and Blanchere [327]	3000 Al_2O_3	–	–	580–620	0.4–1.8	C	Air	–	1	–	160
Sinha and Blanchere [328]	Various	97	5.5–37	580–620	0.45–1.1	C	Air	A	1	~0	165
NaCl–KCl											
Cannon and Sherby [271]	"Analytical grade"	~100	100–300	600	0.6–3.5	C	N_2	C	3.4–2.9	–	–
NbC											
Kelly and Rowcliffe [329]	–	83.6–100	–	1600–2300	–	CSR	Ar	–	–	–	–
Kats *et al.* [330]	Various	70–93	3–15	2700–3200	13–50	C	–	A	1.7	–	340, 430
NiO											
Krishnamachari and Notis [331]	–	99.7	70	1273–1373	34.5–79.8	C	Air	A	3.2	–	235
PuO_2											
Petrovic [332]	–	84–87	–	800–1500	–	CSR	Vac.	–	4.9–90	–	120–155
Petrovic and Land [333]	–	84–87	10	800–1500	–	CSR	–	F	37–53	–	565–655
Si–Al–O–N											
Osborne [334]	–	–	–	1227–1370	77	B	Air	A	–	–	–
Lumby *et al.* [335]	–	3.09–3.16 $g\ cm^{-2}$	5	1227	77	–	–	–	–	–	–
Seltzer [336]	Various	–	–	1250–1475	14–275	T, C	Air, N_2, Vac.	A	1.7–2.	–	390, 635
Birch and Wilshire [337]	–	95	–	1277–1390	150–400	C	Air	A	2.1–2.4	–	730–850
Karunaratne and Lewis [338]	1% MgO or MgO/Mn_3O_4	–	1	1200–1300	44–77	B	Air	A	1.0–1.6	–	495, 830
Lewis *et al.* [339]	Various	–	–	1300–1350	50–250	C	–	–	0.8–1.5	–	350–835

TABLE AIII Continued

Reference	Experimental conditions							Experimental results			
	Total metallic impurities or dopant (ppm or %)	Density (% theoretical)	Grain size (μm)	Test temperature (° C)	Applied stress (MPa)	Test technique	Atmosphere	Type of creep curve	Stress exponent, n	Grain size exponent, p	Activation energy, Q (kJ mol^{-1})
SiC											
Farnsworth and Coble [340]	~ 2.5%	99+	2.6	1900–2200	–	CSR	Ar	F	~ 1	–	305
Rumsey and Roberts [341]	–	–	–	RT–1200	–	B	–	A	–	–	–
Francis and Coble [342]	2.5%	95–99	9.8–27.7	1975–2120	5.7–143	CSR	Ar	F	~ 1	~ 3	305
Marshall and Jones [343]	< 1000	92	10	1000–1200	207–496	B	Air	A	1–2	–	230
Osborne [334]	–	96–99	–	1227–1370	77	B	Air	A	–	–	–
Seltzer [336]	–	–	–	1250–1475	55–344	T, C	Air, N_2, Vac.	A	0.9	–	–
Krishnamachari and Notis [344]	Various	97	65	1300–1400	34.47–86.19	B	Air	A	0.9	–	145
Djemel *et al.* [345]	–	94–96	3.5–5	1300–1500	500–700	C	Ar	A	1	–	170–300
Si_3N_4											
Glenny and Taylor [346]	Various	(a) 59–82 (b) 94–~100	–	1200	28	CSR	–	–	–	–	–
Engel and Thümmler [347]	~ 2%	64–73	–	1200–1400	20–60	B	Air	–	–	–	–
Kossowsky [348]	1–2.5%	~ 100	~ 1	1149–1260	35–100	T	Ar, Air	A	2	–	–
Mangels [349]	1.3–1.5%	72–74	–	1093–1282	7–140	B	Air	A	1.2–2.0	–	–
Washburn and Baumgartner [350]	–	–	–	1260	140	B	–	A	–	–	–
Mazidiyasni and Cooke [351]	2.5% Ce_2O_3	98–99.9	–	1250–1400	70	B	Air	–	–	–	–
Kossowsky *et al.* [352]	0.05–2%	~ 100	~ 1	1149–1315	30–115	T	He, Air	A	2–3	–	510, 545–630
Din and Nicholson [353]	3%	98	Duplex 0.5–5	1200–1400	55–172	B	Air	A	1.7	–	590
Din and Nicholson [354]	1.2%	74–85	–	1200–1450	7–138	B	Air	A	1.4	–	545

TABLE AIII Continued

Reference	Experimental conditions							Experimental results			
	Total metallic impurities or dopant (ppm or %)	Density (% theoretical)	Grain size (μm)	Test temperature (°C)	Applied stress (MPa)	Test technique	Atmosphere	Type of creep curve	Stress exponent, *n*	Grain size exponent, *p*	Activation energy, *Q* ($kJ\ mol^{-1}$)
Engel *et al.* [355]	22%	64–67	–	1200–1400	20–60	B	Air	–	–	–	–
Grathwohl and Thümmler [356]	~ 2% + 1.5% MgO	66–75	–	1200–1400	34–70	B	Air, Vac.	A	–	–	–
Lenoe and Quinn [357]	–	–	–	1350	7–51	T, Torsion	O_2	–	–	–	–
Thümmler *et al.* [358]	~ 2%	~ 70	–	1200–1400	34–70	B	Air, Vac.	A	–	–	–
Engel *et al.* [359]	Various	98	–	1200–1400	20–45	B	Air	A	2.1–3.3	–	460–710
Iskoe *et al.* [360]	2000–3000 + 5% MgO, 0–0.2% CaO	> 98.5	–	1400	103	B	–	A	–	–	–
Grathwohl *et al.* [361]	–	66–80	–	1300–1350	40	B	Air	A	–	–	–
Birch *et al.* [307]	–	85	–	1550–1650	160–400	C	Air, Ar	A	2.3	–	650
Mangels [362]	1.7%	–	–	1260–1316	20–200	CSR	Air	–	–	–	–
Seltzer [336]	–	–	–	1250–1475	13.8–275	T, C	Air, N_2, Vac.	A	1.3–2.0	–	700
Birch and Wilshire [337]	–	81–100	–	–	150–400	C	Air	A	2.1–2.4	–	650
Birch *et al.* [363]	2% MgO	81–100	–	1400	200–400	C, T	Air, N_2	A	2.3	–	650
Grathwohl and Thümmler [364]	Various	68–80	–	1300–1350	21–70	B	Air, Vac.	A	~ 2	–	–
Grathwohl *et al.* [365]	Various	68–80	–	1300–1450	40–100	B	Air	–	–	–	–
Talty and Dirks [366]	–	–	–	1250–1300	65–250	B	Air	A	2	–	–
Lange *et al.* [367]	< 200 Ca	~ 100	–	1260	100–170	T	Air	A	–	–	–
Dixon-Stubbs and Wilshire [368]	2% Y_2O_3	–	1	1350	200–400	C	–	A	2.1–2.3	–	650
Grathwohl and Thümmler [369]	Various	67–81	–	1300–1500	50–100	B	Air	A	1.7–1.8	–	360–390
Lange *et al.* [370]	Various	–	–	1400	50–700	C	Air	A	2	–	–

TABLE AIII Continued

Reference	Experimental conditions							Experimental results			
	Total metallic impurities or dopant (ppm or %)	Density (% theoretical)	Grain size (μm)	Test temperature (° C)	Applied stress (MPa)	Test technique	Atmosphere	Type of creep curve	Stress exponent, n	Grain size exponent, p	Activation energy, Q (kJ mol^{-1})
Lange *et al.* [371]	Various	–	–	1400	350	C	Air	–	–	–	–
Lange *et al.* [372]	Various	–	–	1400	50–500	C	Air	A	1, 2	–	–
Arons and Tien [373]	Various	~ 100	0.2–11.5	1177–1260	68.9–103.3	T	–	A	4.1, 1.7	–	400–850
Palm and Greskovich [374]	5–7% $BeSiN_2$	98–99	0.8	1250–1500	20–125	B	Air	–	1.1–2.0	–	540–750
Cohrt *et al.* [375]	–	–	–	1300–1400	100	B	Air	–	–	–	–
Clarke [376]	–	–	–	1400	–	C	Air	–	–	–	–
$SrZrO_3$											
Nemeth *et al.* [377]	1.35% Fe_2O_3	~ 99	0.45–2.04	1160–1275	5.3–21	B	Air	A	3	1	710
TaC											
Johansen and Cleary [378]	2000	90–95	–	1750–2300	70–170	B	Ar	–	–	–	–
Kelly and Rowcliffe [329]	–	83.6–100	–	1600–2300	10–430	CSR	Ar	–	–	–	–
Becher [379]	–	~ 93	13	1280–1640	200–700	CSR	–	–	4.5, 13	–	90, 96
ThO_2											
Morgan and Hall [380]	–	97–98	10	1465	55	C	Air	–	–	–	–
Poteat and Yust [381]	100	97.5	10	1400–1800	27–76	CSR	Neutral	–	1.0–1.6	–	470
Poteat and Yust [181]	–	97.5	10	1430–1770	13–103	CSR	Neutral	–	1, 5	–	–
ThO_2–CaO											
Morgan and Hall [380]	350	97–98	4–20	1400–1465	3.3–55	C	–	A	–	–	–
TiC											
Keihn and Kebler [382]	1900	100	300	1638–1809	48–55	T	Vac.	A	–	–	520–730

TABLE AIII Continued

Reference	Experimental conditions							Experimental results			
	Total metallic impurities or dopant (ppm or %)	Density (% theoretical)	Grain size (μm)	Test temperature (°C)	Applied stress (MPa)	Test technique	Atmosphere	Type of creep curve	Stress exponent, n	Grain size exponent, p	Activation energy, Q (kJ mol^{-1})
Kelly and Rowcliffe [329]	–	83.6–100	–	1600–2300	10–430	CSR	Ar	–	–	–	–
Spivak *et al.* [383]	–	–	43–750	2000–2650	–	–	–	–	1, 3–4	2, 0	380–600
Chermant *et al.* [384]	–	–	7	1400–2000	–	CSR	Vac.	G	2.7–3.5	–	485–725
TiO											
Vere and Smallman [152]	300	–	1000	1000–1250	–	CSR	Vac.	–	–	–	–
UC											
Chang [385]	–	–	300–400	1500–1900	4–18	CSR	Vac.	F	5	–	155
Chang *et al.* [188]	110	100	350	1500–1900	–	CSR	Vac.	–	–	–	155
Norreys and Wheeler [386]	–	–	–	1200–1500	40–43	C	Vac.	A	–	–	–
Norreys [387]	–	–	300	1000–1500	14–55	C	Vac.	A	1.8	–	205
Carniglia [388]	–	–	"Coarse"	1500–2000	6–35	CSR	Vac.	–	5	–	155
Accary *et al.* [389]	–	–	–	1600–2300	–	C	Vac.	A	–	–	–
Magnier *et al.* [390]	–	–	–	1600–2300	26.5–41.3	C	Vac.	A	–	–	–
Stellrecht *et al.* [391]	–	–	–	1200–1600	20–69	C	Vac.	A	3	–	375
Killey [392]	–	–	150	900–1100	28–55	C	Vac.	A	1	–	190
Killey *et al.* [393]	0–1000 Ni	95	5–150	900–1300	7–60	C	Vac., Air	A	2.1	–	120–215
Routbort [394]	–	99.5	–	700–1600	–	CSR	He	–	4–30	–	–
Seltzer *et al.* [395]	Various	75	–	1400–1550	4.5–28	C	Vac.	–	2, 1.6	–	170–205
Seltzer *et al.* [396]	Various	98	200	1400–1700	7–69	C	Vac.	–	3–6	–	445
Guerin *et al.* [397]	–	90–94	5–25	20–1700	24–156	CSR	Vac.	F	5.8	–	460
Burton [398]	–	–	–	–	–	–	–	–	1	–	360

TABLE AIII Continued

Reference	Experimental conditions							Experimental results			
	Total metallic impurities or dopant (ppm or %)	Density (% theoretical)	Grain size (μm)	Test temperature (°C)	Applied stress (MPa)	Test technique	Atmosphere	Type of creep curve	Stress exponent, *n*	Grain size exponent, *p*	Activation energy, *Q* (kJ mol^{-1})
$UC_{1.5}$											
Kurasawa [399]	–	96.8	–	1200–1400	20.7–103.5	C	Vac.	–	1.2, 2.8	–	170
UC_2											
Kurasawa and Kikuchi [400]	Various	90	–	1200–1400	13.8–103.4	C	Vac.	–	0.9, 4.5	–	40–120
UC–PuC											
Killey *et al.* [393]	–	94–99	8–40	1000–1150	3–25	C	Vac., Ar	–	–	–	–
Tokar [401]	2000	86–92	20–30	1300–1500	14–41	C	Vac.	A	2.4	–	530
UC–UN											
Uchida and Ichikawa [402]	–	91	6–26	1310–1500	14–74	C	Vac.	A	1–4	–	–
UC–ZrC											
Seltzer *et al.* [395]	4% W	75–85	–	1400–1550	4.5–28	C	Vac.	–	1.4–2.3	–	200–335
Seltzer *et al.* [396]	4% W	~100	–	14–1700	30–65	C	Vac.	–	1.8	–	650
UN											
Vandervoort *et al.* [403]	"pure"	–	130–2000	1500–1800	14–34	CSR	N_2	–	5.3–6.4	0	315
$UN–UO_2$											
Brucklacher and Dienst [404]	–	89	6–10	700–850	39.2	C	–	–	–	–	–
UO_2											
Scott *et al.* [405]	–	95	2–10	860–1650	5.5–44.8	B	H_2, Ar	–	–	–	270–400
Armstrong *et al.* [406]	< 200	94.5–98	(a) 6 (b) 13–40	(a) 1250 (b) 1400	(a) 28–111 (b) 28–90	B	H_2	A	1–4	2, 0	380
Armstrong and Irvine [407]	–	96	6 6	975–1300	6.9–48.2 6.9–20.7	B	Ar/O_2	–	1	–	235–265
Armstrong and Irvine [408]	Various	96–99	10–31	1200–1450	13.8–96.5	B	H_2	A	1	–	235–545

TABLE AIII Continued

Reference	Experimental conditions							Experimental results			
	Total metallic impurities or dopant (ppm or %)	Density (% theoretical)	Grain size (μm)	Test temperature (°C)	Applied stress (MPa)	Test technique	Atmosphere	Type of creep curve	Stress exponent, n	Grain size exponent, p	Activation energy, Q (kJ mol^{-1})
Wolfe and Kaufman [409]	–	97.5–98.5	18–55	1600–2000	6.89–39.4	C	–	A	1.0–4.8	–	300
Byron [410]	100	97	18.6	600–2000	–	CSR	Ar/O_2	F	–	–	210
Poteat and Yust [181]	–	97.5	~ 10, coarse	1430–1666	13.8–75.8	CSR	–	–	1, 5	–	–
Bohaboy *et al.* [411]	< 200	92–98	4–35	1400–1760	6.9–105	C	H_2	A	1.0, 4.5	2	375, 555
Nadeau [164]	–	95	4	900–1600	–	CSR	CO/CO_2	–	–	–	–
Bohaboy and Evans [412]	< 200	89–95	22–25	1475–1625	6.2–55.1	C	H_2/H_2O	A	1.0, 4.5	–	460, 590
Marples and Hough [413]	–	94–99	10–80	1150–1500	13.8–48.2	C	H_2/H_2O	A	1.5–7.0	–	390–585
Seltzer *et al.* [414]	–	95–99	5–55	1430–2000	6.9–68.9	C	C, B	–	–	1, 4.5	–
Canon *et al.* [415]	< 300	97	8–31	500–1800	20–140	CSR	Vac.	F	4.2	–	345–365
Roberts [416]	< 200	–	9	1320–1800	20–200	B	Vac.	–	–	–	–
Perrin [417]	–	98	27	1030–1190	10.3–27.6	C	H_2	–	1	–	385–410
Roberts and Wrona [418]	300	88–97	0.6–8	RT–1700	–	CSR	He	F	1.9–2.3	–	505
Langdon [419]	–	97.5	10	1430–1660	14–70	C	–	–	1.0, 4.5	–	–
Brucklacher and Dienst [404]	–	96	10–35	250–850	0–40	C	–	–	1	–	–
Seltzer *et al.* [420]	350	97.8	27	1300 1100–1300	1–50 1–150	C	CO/CO_2	–	1–7	–	220–490
Roberts and Ueda [421]	< 600	84–95	12–17	500–1600	–	–	–	–	–	–	375–420
Burton and Reynolds [422]	–	97	7	1250–1450	8–150	C, CSR	H_2/Ar	–	1, ~ 5	–	320
Burton *et al.* [423]	–	97	7–50	1150–1450	8–150	C, CSR	H_2/Ar	–	1, ~ 5	–	–
Burton and Reynolds [424]	–	97	7	1250–1400	4–100	C, CSR	CO/CO_2	–	1, ~ 5	–	225–380
Solomon [425]	620	96	22	81–191	14.5–20	T	–	A, D	–	–	–

TABLE AIII Continued

Reference	Experimental conditions							Experimental results			
	Total metallic impurities or dopant (ppm or %)	Density (% theoretical)	Grain size (μm)	Test temperature (°C)	Applied stress (MPa)	Test technique	Atmosphere	Type of creep curve	Stress exponent, n	Grain size exponent, p	Activation energy, Q (kJ mol^{-1})
Roberts [426]	400–1400	96–97	8–31	1400–1800	2.5–150	Stress relaxation	Vac.	–	1.3, 4.5–20	–	385
Burton and Reynolds [427]	–	–	–	1050–1400	5–20	C, CSR	–	–	–	–	–
Solomon [428]	620	96	22	100–1500	6.2–20	T	–	A	–	–	–
Reynolds *et al.* [429]	–	97	7–55	1450	10–80	C, CSR	CO/CO_2	–		–	–
Burton and Reynolds [430]	–	97	~ 7	1250–1500	4–150	C	H_2, CO/CO_2	–	1, ~ 5	> 1	380, 240
Radford and Terwilliger [431]	< 146	82.5–96.5	1–17	600–1600	50–800	CSR	CO/CO_2, Air	E, F	10–32	–	920
Burton [432]	–	–	7–18	1250–1800	5–100	C	–	–	1	–	–
Javed [433]	–	95	10–13	1400–1700	6.9–82.8	C	–	–	1, 4.3	–	80, 120
Assmann [434]	–	87.5–92.7	10	1300–1560	40–100	C	Vac.	A	4.5	–	590
Singh [435]	–	96–97	20–44	1800–2000	–	CSR	–	–	–	–	–
Chung and Davies [436]	Various	95–97	2–10	1000–1600	4–60	C	H_2/H_2O	A	1	2–3	250–350
Chung and Davies [437]	Various	–	2–10	1200–1400	4–50	C	H_2/H_2O	A	1, 4	2–3	250–350
Chung and Davies [438]	–	–	2–10	1377–1477	4–50	C	H_2/H_2O	–	–	–	–
Ainscough *et al.* [439]	4000 Nb_2O_5	98	40–45	1300–1500	5–40	B, C	H_2/H_2O	A	1.0, 2.4	–	225–425
Sawbridge *et al.* [440]	Various	–	12–43	1150–1300	6–80	C	Ar	–	1	–	213–445
UO_2–PuO_2											
Houston *et al.* [441]	–	94	3–15	1100–1500	7.6–17	C	Vac.	A	1.4	2	325
Bohaboy and Evans [412]	< 200	93	22–28	1550	6.9–41.3	C	H_2/H_2O	A	–	–	–
Perrin [442]	–	95	3–5	910–1125	13.8	C	He	–	–	–	–
Routbort *et al.* [443]	< 300	97	6.4–12.7	1300–1700	6.9–110	C	H_2/H_2O	A	1.0, 4.4	2	300–560
Routbort and Voglewede [444]	150–800	95	5–44	1500–1600	–	C	–	A	4.4	–	440–755

TABLE AIII Continued

Reference	Experimental conditions							Experimental results			
	Total metallic impurities or dopant (ppm or %)	Density (% theoretical)	Grain size (μm)	Test temperature (° C)	Applied stress (MPa)	Test technique	Atmosphere	Type of creep curve	Stress exponent, *n*	Grain size exponent, *p*	Activation energy, *Q* (kJ mol^{-1})
Brucklacher [445]	–	96–98	10	300–980	14.7–39.2	C	–	A	–	–	–
Javed [433]	–	95	10–13	1400–1700	6.9–82.8	C	–	–	1.0, 4.3	–	75, 130
Assmann [434]	–	88–95	> 10	1500	40–100	C	Vac.	A	2.1–3.4	–	130–155
Dienst [446]	–	86, 93.5	–	300–1000	15–40	C	–	–	~ 1	–	220
WC											
Atkins and Tabor [108]	–	99	–	RT–1550	–	Indentation	Vac.	–	–	–	460
Atkins *et al.* [107]	–	99	–	RT–1550	–	Indentation	Vac.	–	–	–	–
Kelly and Rowcliffe [329]	–	83.6–100	–	1600–2300	10–430	CSR	Ar	–	–	–	–
Ueda *et al.* [447]	10% Co or TaC	–	1–3	750–950	50–300	T	Vac.	A	2.9–5.9	1.5–2.6	290–440
Doi *et al.* [448]	10% Co or 10% TaC–10% Co	–	1–3	800–900	100–250	T	Vac.	A	3.1–4.7	1.5–2.8	290–405
Ueda *et al.* [449]	6–20% Co	–	1–3	RT–1000	–	CSR	Ar	G	–	–	–
ZrC											
Chang *et al.* [188]	–	–	–	1700–2000	–	CSR	Vac.	–	–	–	580
Leipold and Nielson [450]	1%	100	–	1800–2600	2.5–34.4	T	He	A	3	–	315–840
Zubarev and Dement'yev [451]	–	–	–	2200–3000	78–205	T	–	–	2.5	–	750
Miloserdin *et al.* [452]	4000	93	3–5	2180–2540	3.5–18	T	–	A	–	–	530
Dement'yev *et al.* [453]	–	95–97	6–45	2200–2700	5–70	C	Neutral	–	1.0, 3.4	1.0, 0	690
Darolia and Archbold [454]	Various	–	–	1700–1800	–	CSR	Vac.	G	–	–	–
Darolia and Archbold [455]	400	~ 100	250	1200–1800	–	CSR	Vac.	E, G	–	–	500

TABLE AIII Continued

Reference	Experimental conditions							Experimental results			
	Total metallic impurities or dopant (ppm or %)	Density (% theoretical)	Grain size (μm)	Test temperature (°C)	Applied stress (MPa)	Test technique	Atmosphere	Type of creep curve	Stress exponent, n	Grain size exponent, p	Activation energy, Q ($kJ\ mol^{-1}$)
Zubarev and Shmelev [456]	Various	95–97	3–20	2200–2750	2–75	T	Ar	C	–	–	–
Zubarev and Shmelev [457]	Various	95–97	5–20	2200–2750	1–75	T	Ar	–	1.0, 2.7–3.1	–	710–750
$ZrC-NbC$											
Avgustinik *et al.* [458]	< 1%	–	9–15	2327–2877	14.7–53.9	C	Vac.	A	1.1–1.2	–	790–490
ZrO_2											
Stavrolakis and Norton [182]	5%	–	–	1300	25	Torsion	–	A	–	–	–
Bakunov *et al.* [194]	5000	94.7	40	1700–1820	1.4	B	Vac.	–	–	–	750
Evans [459]	Various	–	0.6–10	1163–1535	4.1–71	C	Air	A	1, 6	2	360, 210
Fehrenbacher *et al.* [460]	~ 1%	95	10–20	1400–1535	5.5–52	C	Air	A	~ 1	–	460
St-Jacques and Angers [461]	–	99.5	7–29	1200–1400	3.4–27	C	Air, Vac.	–	~ 1	1	395
St-Jacques and Angers [462]	1.2%	99.5	7–29	1200–1400	3.4–27	C	Air	–	1	1	380–415
Seltzer and Talty [463]	> 1%	91.9–93.1	12.5–72	1480–1995	0.7–43	C	Air, Vac., Ar	–	1.5–3.0	–	535
Seltzer and Talty [464]	> 1%	73	–	1647–1882	2–20	C	Air, Vac., Ar	–	3.2	–	535
ZrO_2-CaO											
Vishnevskii *et al.* [465]	–	96	15–20	1550–2000	2–50	B	Vac.	–	1.1	–	420

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