

TECHNOLOGY TRENDS
ASSESSMENT

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Advanced technical ceramics — Unified classification system

*Céramiques avancées —
Système de classification
unifiée*

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Cover:

Photograph of a 0,2 mm × 0,2 mm square single crystal of the high temperature superconductor $\text{YBa}_2\text{Cu}_3\text{O}_{7-x}$ showing the orthogonal twin structure characteristic of this material.

Photograph courtesy of Frank W. Gayle, Debra L. Kaiser and Leonard C. Smith, Materials Science and Engineering Laboratory, National Institute of Standards and Technology.

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

To respond to the need for global collaboration on standardization questions at early stages of technological innovation, the ISO Council, following recommendations of the ISO/IEC Presidents' Advisory Board on Technological Trends, decided to establish a new series of ISO publications named "**Technology Trends Assessments**" (ISO/TTA). These publications are the results of either direct cooperation with prestandardization organizations or ad hoc workshops of experts concerned with standardization needs and trends in emerging fields.

Technology Trends Assessments are thus the result of prestandardization work or research. As a condition of publication by ISO, ISO/TTAs shall not conflict with existing International Standards or draft International Standards (DIS), but shall contain information that would normally form the basis of standardization. ISO has decided to publish such documents to promote the harmonization of the objectives of ongoing prestandardization work with those of new initiatives in the Research and Development environment. It is intended that these publications will contribute towards rationalization of technological choice prior to market entry.

This Technology Trends Assessment, ISO/TTA 1, has been developed by the Versailles Project on Advanced Materials and Standards (VAMAS) (see [1] and [2] for further information on this organization) and is published under a Memorandum of Understanding concluded between ISO and VAMAS. It reports the results of the Technical Working Area (TWA) 14 of VAMAS, which had the task of proposing a classification of advanced technical ceramics and which retains the responsibility for the technical content of this ISO/TTA. Users of this ISO/TTA who would like information on the research project should refer to the full report of VAMAS TWA 14 [3] which was prepared under the leadership of Dr S. Schneider, Jr., from NIST, Gaithersburg, Maryland 20899-0001, USA. The ISO Technical Board approved the publication of this classification as an ISO/TTA in August 1993.

Whilst ISO/TTAs are not standards, it is hoped that they will be used as a basis for standards development in future national and international standardization processes. In the particular case of ISO/TTA 1, the publication has been brought to the attention of Technical Committee ISO/TC 206, *Fine ceramics*, for use in its standardization work.

EXECUTIVE SUMMARY

As a consequence of modern day technology needs, materials technologies have seen a waning of commodity materials usage in parallel with a commensurate increased demand for engineered materials that perform totally new functions or old functions in much better ways. Accordingly, a wave of new products using advanced materials are appearing with regularity on the marketplace. Among these new materials types, advanced ceramics have emerged as a premier class that has enabled current technologies to be improved, and new technologies possible.

Advanced ceramics currently are market entities and have been for many years. With more in the offing, estimates place world markets to be tens of billions of dollars by year 2000. Even so, advanced ceramics have not been generally recognized as a separate materials class, distinct from other types of ceramic materials. Currently standardization systems are out of date and must be adjusted to factor in a coherent way, advanced ceramics and other new material products along with the more traditional materials. Otherwise every facet of science and technology and associated parts of the economy, from the individual researchers and consumers, to manufacturers, to whole industries, to the financial community, to governments and nations, will devise their own set of advanced ceramic definitions, append various labels and develop tabulation specifications that more often than not, conflict one to another. This discordant process is already underway.

The standardization issue is complex, but one obvious first need is the development of a classification system for advanced ceramics products that defines what they are, what they are good for, and when statistics or other data are compiled, tells the level of associated activity, element by element. In recognition of this need, the Versailles Project on Advanced Materials and Standards (VAMAS) in 1988 established a new project, Technical Work Area, Number 14 (TWA 14) on the classification of advanced ceramics to provide the pre-standards foundation and building block guide for an internationally acceptable system. Three strategic objectives of TWA 14 set the directions of the international effort:

1. To identify and assess the issues inherent in developing a classification system for advanced ceramics;
2. To establish a classification structure suitable for international use in a compendium of ways, including industrial economic statistical indicators,

materials and property databases, and products, standards and literature categorizations; and,

3. To develop mechanisms and international institutional links for system implementation.

The objectives were achieved through a work plan that included: an assessment of existing classifications systems and terminology; a worldwide survey of the classification practices and preferences of industry; and, an international workshop to develop a detailed technical basis for the preferred industrial scheme. These, and associated work activities culminated in the development of a full range classification system for advanced technical ceramics, having the following features:

- Defines "advanced technical ceramics" for classification purposes as "a highly engineered, high performance, predominately non-metallic, inorganic, ceramic material having specific functional attributes". This definition encompasses a diverse range of materials and product classes separated along physical applications like mechanical, thermal, electrical, etc., but excludes commodity products, such as building materials and refractories.
- Identifies and lists 500 different product types as advanced technical ceramics;
- Establishes a comprehensive classification system for advanced technical ceramics that is capable of expansion to accommodate new products or the inclusion of other ceramic classes;
- Provides a non-hierarchical, matrix-type scheme of classification that is accessible by a number of entry and retrieval routes to build relational databases; and,
- Provides a machine readable coding system built upon four independent descriptor fields and corresponding subdivisions that may be sequenced in any order to match the users preference. Each descriptor field is separately identified by a unique initial code letter:

A for application,
C for chemical character and product form,
P for processing and
D for property data.

The unique code letters act as field separators in long coding strings. Detailed listings are provided for complete coding by subdivision categories of each of the independent descriptor fields.

Overall the utility of the classification system is multi-fold. Its use is advantageous at the company level for purposes involving assembly of design and materials property databases, or tabulation of inventories, or invoicing. Industry can use the system for gathering and sorting trend data on market behavior or R&D expenditures, or for literature categorization. At the government level, the system can be used for gathering national and international economic data, or other vital statistics, or for determining demographics of the field.

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RESUME

Les besoins de la technologie moderne ont entraîné une diminution de l'usage des matériaux de commodités et parallèlement, une augmentation de la demande pour des matériaux de spécialités capables d'assurer des fonctions complètement nouvelles ou de remplir des fonctions traditionnelles d'une manière beaucoup plus efficace. Ainsi, de nouveaux produits utilisant ces matériaux avancés apparaissent régulièrement sur le marché. Parmi ces classes de nouveaux matériaux, les céramiques avancées se signalent comme la première génération qui a permis l'amélioration des technologies actuelles et l'émergence de nouvelles technologies.

Les céramiques avancées sont devenues des produits industriels et ce depuis plusieurs années. Les estimations placent le marché mondial de ces produits à plusieurs milliards de dollars à l'horizon de l'an 2000, et ce n'est qu'un début ! Malgré cela, les céramiques avancées n'ont pas été généralement reconnues comme constituant une classe à part de matériaux, distincte des autres types de matériaux céramiques. A l'heure actuelle, les systèmes de normalisation sont périmés et doivent être refondus pour classer d'une manière cohérente les céramiques avancées et d'autres nouveaux matériaux ainsi que des matériaux plus traditionnels. Si cette tâche n'est pas menée à bien, chaque domaine de la science et de technologie et les acteurs économiques qui lui sont associés, des chercheurs et des consommateurs aux producteurs en passant par l'industrie toute entière, la communauté financière, les gouvernements et les états, tous vont mettre sur pied leur propre dictionnaire des céramiques avancées, donner des noms variés et des spécifications de codage qui trop souvent entreront en conflit l'une avec l'autre. Ce processus dit de la "Tour de Babel" a déjà commencé.

Le problème de la standardisation est complexe, mais l'un des premiers et des plus évidents besoins est le développement d'un système de classification pour les céramiques avancées qui définit ce qu'elles sont ; à quoi elles sont bonnes ; et quand des statistiques ou d'autres données auront été rassemblées, donnera le niveau d'activité qui leur est associé, élément par élément. Prenant conscience de ce besoin, le projet "Versailles Advanced Materials and Standards (VAMAS)", créé en 1988 une nouvelle commission "Technical Work Area" numéro 14 (TWA 14) sur la classification des céramiques avancées pour jeter les bases d'une pré-standardisation et rédiger un guide des éléments constitutifs d'un système de classification acceptable à l'échelon international. Les 3 objectifs stratégiques du TWA 14 montrent bien les axes de l'effort international :

1. Identifier et évaluer les problèmes inhérents à la création d'un système de classification des céramiques avancées.

2. Etablir un schéma de classification permettant un usage international, pour des usages diversifiés tels que : des bases de données économiques et industrielles ; des tables des matériaux des produits existants et de leurs propriétés ; un classement des standards et de la littérature scientifique ; etc...
3. Développer les mécanismes et les liens institutionnels internationaux nécessaires à l'épanouissement du système.

Ces objectifs furent atteints grâce à un plan de travail qui inclut une évaluation des systèmes de classification et des terminologies existantes et une recherche mondiale des pratiques en matière de classification et des préférences de l'industrie, suivie d'un séminaire international pour mettre sur pied les bases techniques détaillées du schéma ayant la préférence des industriels. De tout cela et du travail qui lui a été associé émergea un système de classification complet des céramiques avancées ayant les caractéristiques suivantes :

- Il définit pour les besoins de la classification les "céramiques avancées" comme des "matériaux céramiques, de conception évoluée, à hautes performances, inorganiques à dominante non métallique et présentant des attributs fonctionnels spécifiques". Cette définition englobe des types de matériaux et de produits assez divers qui sont classés selon leurs applications physiques comme la mécanique, la thermique, l'industrie électrique etc..., mais exclut les produits de commodités comme les matériaux de construction et les réfractaires.
- Il identifie et liste en temps que céramiques techniques avancées 500 types de produits différents.
- Il établit un vaste système de classification pour les céramiques techniques avancées qui est susceptible de recevoir des extensions et d'inclure de nouveaux produits voire même de nouveaux types de céramiques.
- Il apporte un système de classification non-hiérarchique de type matriciel qui est accessible par plusieurs entrées et permet donc de construire des bases de données relationnelles.
- Il propose un système de codage lisible par une machine, bâti autour de 4 champs de descripteurs indépendants, eux-mêmes sous-divisés, qui peuvent être séquencés dans un ordre quelconque selon la préférence de l'utilisateur. Chaque champ de descripteurs est identifié séparément par une unique lettre initiale de code.

A pour les Applications.

C pour la nature Chimique et le type du produit.

P pour le Procédé de fabrication.

D pour les Données sur les propriétés.

Ces lettres de code servent à séparer les champs dans les longues chaînes de codage. Des listes détaillées sont fournies pour un codage complet par sous-catégories pour chacun des champs de descripteurs indépendants.

Les usages que l'on peut faire de ce système de classification sont multiples. Son utilisation au niveau d'une entreprise est intéressante pour rassembler des bases de données sur la conception et les propriétés des matériaux, pour la tabulation des inventaires, ou pour la facturation. L'industrie peut utiliser le système pour collecter et trier des données sur le comportement du marché, les dépenses R & D ou pour les classement de la documentation scientifique. Au niveau gouvernemental, le système pourra être utilisé pour collecter des données économiques à l'échelon national et international, ou d'autres statistiques stratégiques, ou encore pour déterminer l'évolution démographique du domaine.

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AUSFÜHRLICHE ZUSAMMENFASSUNG

Die modernen technologischen Erfordernisse führen zu einer Minderung im Gebrauch der Massenwerkstoffe bei einem gleichzeitigen Anstieg des Bedarfs an maßgeschneiderten Werkstoffen, die vollständig neue Funktionen oder alte Funktionen auf viel bessere Weise erfüllen. Dementsprechend erscheint regelmäßig eine Welle neuer Produkte im Handel, bei denen Hochleistungswerkstoffe eingesetzt werden. Unter diesen neuen Werkstofftypen hat sich die Technische Hochleistungskeramik als ein Werkstoff erster Güte herausgestellt, hat die Verbesserung der gegenwärtigen Technologien zugelassen und neue Technologien ermöglicht.

Die Technische Hochleistungskeramik ist seit Jahren eine Marktgröße, und das Leistungspotential ist noch nicht ausgeschöpft. So wird der Weltmarkt im Jahr 2000 auf mehrere 10 Milliarden Dollar geschätzt. Trotzdem wurde Technische Hochleistungskeramik nicht als eine getrennte Werkstoffklasse, die sich von anderem keramischen Material unterscheidet, allgemein anerkannt. Heutige Standardisierungssysteme sind veraltet. Sie müssen schlüssig der Tatsache entsprechend weiterentwickelt werden, daß Technische Hochleistungskeramik und andere neue Werkstoffprodukte zusammen mit den mehr traditionellen Werkstoffen übereinstimmend klassifiziert sind. Anderenfalls würde jede Facette in Wissenschaft und Technologie, die jeweiligen Bereiche der Wirtschaft, vom einzelnen Wissenschaftler und Verbraucher zu den Herstellern und ganzen Industrien, zur Finanzwelt, den Regierungen und Nationen ihr eigenes System zur Kennzeichnung und Klassifikation Keramischer Werkstoffe entwickeln, eigene Bezeichnungen einführen und Listenspezifikationen entwickeln, die eher häufig als gar nicht zueinander im Widerspruch stehen. Dieser auseinanderlaufende Prozeß ist bereits im Gange.

Die Standardisierungsfrage ist komplex, aber eine erste offensichtliche Notwendigkeit ist die Entwicklung eines Klassifikationssystems für Produkte aus Technischer Hochleistungskeramik, das Stück für Stück bestimmt, wofür sie sind, wozu sie dienen und, falls Statistiken oder andere Datensammlungen erstellt werden, das den Grad der damit verbundenen Bearbeitung mitteilt. In der Erkenntnis dieses Erfordernisses erstellte das Versailles Project on Advanced Materials and Standards (VAMAS) im Jahr 1988 ein neues Projekt, die Technische Arbeitsgruppe Nr. 14 (TWA 14) zur Klassifizierung von Technischer Hochleistungskeramik, um eine pränormative Grundlage zu schaffen und einen Rahmen zu erstellen für ein international annehmbares System. Drei strategische Ziele von TWA 14 kennzeichneten die Zielrichtung der internationalen Bemühungen:

1. Bestimmung und Bewertung der Fragen im Zusammenhang mit der Entwicklung eines Klassifikationssystems für Technische Hochleistungskeramik
2. Erstellung einer Klassifikationsstruktur, die zum internationalen Gebrauch in einer vielfältigen Weise einschließlich industrieller, wirtschaftlicher, statistischer Indikatoren, Werkstoff- und Werkstoffeigenschaftsdatenbanken, Produkt-, Normen- und Literatur-Einordnung geeignet ist
3. Entwicklung von Mechanismen und internationalen institutionalisierten Verbindungen für die Einführung des Systems.

Die Ziele wurden durch einen Arbeitsplan erreicht, der die folgenden Elemente einschloß: Bewertung der existierenden Klassifikationssysteme und Terminologie; eine weltweite Übersicht der Klassifikationspraxis und Prioritäten der Industrie sowie einen internationalen Workshop zur Entwicklung einer detaillierten technischen Grundlage für das von der Industrie bevorzugte Schema. Diese und die daraus folgenden Arbeiten gipfelten in der Entwicklung eines umfassenden Klassifikationssystems für Technische Hochleistungskeramik, das durch die folgenden Elemente gekennzeichnet ist:

- Es bezeichnet "Technische Hochleistungskeramik" zum Zweck der Klassifikation als "eine hochentwickelte Hochleistungskeramik, die überwiegend nichtmetallisch anorganisch ist und spezifische funktionale Eigenschaften aufweist". Diese Definition schließt eine Vielzahl von Werkstoffen und Produktklassen ein, die durch physikalische Anwendungen, wie mechanisch, thermisch, elektrisch usw., gegliedert sind, aber schließt Massenprodukte wie Baumaterial und Feuerfestmaterial aus.
- Es benennt und führt 500 verschiedene Produkttypen als Technische Hochleistungskeramik auf.
- Es erstellt ein zusammengefaßtes Klassifikationssystem für Technische Hochleistungskeramik, das erweiterbar ist, um neue Produkte oder andere Keramikklassen zu berücksichtigen bzw. einzuschließen.
- Es stellt ein nichthierarchisches Klassifikationsschema im Matrixformat dar, das über eine Vielzahl von Zugangs- und Abfragewegen zugänglich ist und eine relationale Datenbank bildet.

- Es stellt ein maschinenlesbares Codiersystem zur Verfügung, das auf vier unabhängigen Beschreibungsfeldern und zugehörigen weiteren Unterteilungen basiert, das in beliebiger Reihenfolge angeordnet werden kann, so daß der Priorität des Anwenders entsprochen wird. Jedes Descriptorfeld ist einzeln durch einen einzigen Schlüsselbuchstaben gekennzeichnet:

A für Anwendung
C für chemischen Charakter und Produktform
P für Verarbeitung und
D für Eigenschaftsdaten.

Die einzelnen Codierungsbuchstaben trennen die einzelnen Felder in langen Codierfolgen. Es werden detaillierte Listen zur vollständigen Codierung durch Untergruppenbildung für jedes der unabhängigen Descriptorfelder aufgeführt.

Das Klassifikationssystem erweist sich als vielfältig verwendbar. In den Unternehmen kann es vorteilhaft zu Zwecken der Herstellung, der Konstruktion und für Werkstoffeigenschaftsdatenbanken, zur Erstellung von Listen zur Lagerhaltung oder Buchhaltung eingesetzt werden. Die Wirtschaft kann das System zur Sammlung und Gliederung von Trenddaten zum Marktverhalten oder für Forschungs- und Entwicklungs-Ausgaben oder zur Literaturordnung verwenden. Auf Regierungsebene kann das System zur Sammlung nationaler und internationaler Wirtschaftsdaten, für andere wesentliche Statistiken und für die Bestimmung des demographischen Umfeldes eingesetzt werden.

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SOMMARIO

A seguito delle variate necessita' delle tecnologie moderne, si assiste oggi a un declino dell' impiego dei materiali di largo consumo al quale corrisponde un aumento della domanda di materiali ingegneristici capaci di offrire funzioni totalmente nuove oppure di svolgere funzioni tradizionali ma in modo notevolmente migliore. Di conseguenza, vengono introdotti sul mercato con consistente flusso un insieme di nuovi prodotti basati sull'impiego di nuovi materiali. Tra questi tipi di nuovi materiali, le ceramiche avanzate si sono proposte come una classe tra le piu' interessanti in quanto hanno consentito il miglioramento di tecnologie tradizionali e reso possibili nuove tecnologie.

Le ceramiche avanzate sono attualmente, e lo sono gia' da vari anni, un interessante segmento di mercato. Confidando su aspettative di ulteriore consolidamento ed estensione degli impieghi, si stima che il mercato mondiale nel 2000 possa raggiungere decine di miliardi di dollari. Nonostante queste premesse, le ceramiche avanzate non sono state in generale considerate come una classe separata di materiali, distinta cioe' dagli altri tipi di materiali ceramici. Attualmente i sistemi di normazione sono arretrati e necessitano di correzioni onde renderli idonei a descrivere in modo coerente le ceramiche avanzate a gli altri prodotti a base di nuovi materiali, rispetto ai materiali piu' tradizionali. In caso contrario, ciascuna realta' operativa della scienza e della tecnologia e delle componenti economiche a queste associate, dai singoli ricercatori ai consumatori, ai produttori, all' industria utilizzatrice, alla comunita' finanziaria, ai governi e alle nazioni, vorranno darsi proprie definizioni di ceramica avanzata, proprie etichette, proprie specifiche che, piu' spesso che non, saranno in conflitto tra di loro. Questo processo di scarsa sintonia e' gia' in atto.

Il problema della normazione e' complesso, ma una prima ovvia necessita' e' di procedere allo sviluppo di un sistema di classificazione per i prodotti che usano ceramiche avanzate il quale definisca cosa esse siano e a quali fini esse siano idonee, e che una volta completato sia capace di fornire le informazioni di dettaglio per ciascun suo elemento. Sulla base della predetta esigenza, nel 1988 il VAMAS (Versailles Project on Advanced Materials and Standards) ha attivato un nuovo progetto TWA 14 (Technical Working Area, Number 14) indirizzato specificamente alla classificazione delle ceramiche avanzate al fine di offrire le basi di pre-normazione e una guida a blocchi per un sistema fruibile a livello internazionale.

L'attivita' del TWA 14 e' stata indirizzata su tre obiettivi strategici:

1. Identificare e valutare le problematiche inerenti alla messa a punto di una classificazione per le ceramiche avanzate;

2. Creare una struttura di classificazione appropriata all' uso internazionale e fruibile per una molteplicita' di funzioni quali indicatori statistici industriali/economici, banche dati per materiali/proprietà'/prodotti, categorizzazione di norme e dati bibliografici, ecc.
3. Sviluppare un meccanismo di collegamenti istituzionali internazionali per implementare il sistema.

I suddetti obbiettivi sono stati conseguiti attraverso un piano di lavoro che comprendeva; una valutazione dei sistemi di classificazione e della terminologia esistenti; una rassegna a livello mondiale delle modalita' seguite dall' industria nella classificazione e relativi orientamenti preferenziali; un "workshop" internazionale inteso a individuare e realizzare una dettagliata base tecnica per lo schema di classificazione preferito dall' industria. Le suddette attivita', e quelle loro associate, sono culminate nello sviluppo di un sistema di classificazione onnicomprensivo per le ceramiche tecniche avanzate, che presenta le seguenti caratteristiche:

- Definisce, a scopo di classificazione, le "ceramiche tecniche avanzate" come un "materiale ceramico altamente ingegnerizzato, di alte prestazioni, inorganico ed essenzialmente non metallico, avente specifici attributi funzionali";
- Identifica ed elenca, come ceramiche tecniche avanzate, 500 differenti tipi di prodotto;
- Stabilisce un sistema completo di classificazione per le ceramiche tecniche avanzate suscettibile di essere esteso per accogliere nuovi prodotti o altre classi di ceramiche;
- Fornisce uno schema di classificazione a base matriciale, non gerarchico fruibile mediante varie chiavi di accesso e procedure iterative per costruire banche dati;
- Fornisce un sistema codificato e informatizzato costruito con quattro campi descrittivi indipendenti, e corrispondenti suddivisioni, che possono essere sequenzate in qualsiasi ordine al fine di soddisfare le preferenze dell' utilizzatore. Ciascun campo descrittore viene identificato da una lettera:

A per l'impiego (Application)

C per la chimica e la forma del prodotto (Chemistry)

P per la tecnologia di fabbricazione (Processing)

D per le proprietà' (Data)

Le singole lettere del codice hanno anche la funzione di separare i campi, nel caso di codici molto lunghi. Vengono forniti dettagliati elenchi per una codificazione completa delle categorie in cui viene suddiviso ciascun campo descrittore.

Nell'insieme, il sistema di classificazione elaborato si presenta di grande utilità sotto vari aspetti. Il suo impiego è vantaggioso a livello di azienda per scopi che coinvolgono la progettazione, banche dati sui materiali, tabulazione di inventari, fatturazione. L'industria può utilizzare il sistema per ottenere e selezionare dati di tendenza del mercato o sugli investimenti di R&S, o per la categorizzazione di informazioni bibliografiche. A livello governativo il sistema può essere impiegato per acquisire dati economici nazionali e internazionali, e altre statistiche di grande interesse, o per studi demografici del settore.

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委員会総括

新しい時代の技術上の要請は材料技術における日用品の使用形態が減少し、同時にこれにともなって全く新しい機能や、仮に古い機能でもよりよいものを実現するエンジニアリング材料の要求が高まってきた。先進材料を使用した新製品の波が市場に定期的に登場するに至った。このような新材料の範疇のなかでも、ファインセラミックスは現在の技術を進展させ、かつ新技術を可能とすることができる重要なものとして浮上している。

ファインセラミックスは現在市場に存在し、これまでも多年それが続いていた。さらに先の展望としては、2000年には世界市場は100億ドルに達すると推定されている。にもかかわらず、ファインセラミックスは一般には独立した材料として明らかに他のセラミックスと異なる分類はされていない。現在のセラミックスの規格システムは明らかに古く、従来セラミックスと共にファインセラミックスやその他の新材料製品とも整合性をとりつつ再構築すべきである。それなくしては、科学技術とそれに付随する経済的側面あるいは各々の研究者、消費者から、また製造業者へ、全産業へ、財界へ、政府や国家への各側面でファインセラミックスの定義がそれぞれ異なってくる。製品に付随する種々の名称、製品表が欠落していたり、それぞれが混乱している結果を招いてしまう。

規格化の問題は複雑であるが、明らかにまず必要なことはファインセラミックス製品の分類システムを構築することである。ひとつひとつの要素ごとに、それ何か定義され、有用であり、いつ統計やその他の資料が記録され、付随する現状のレベルがわかるものが構築されるべきである。この要請が認められ、ベルサイユサミット先端材料と規格に関するプロジェクトが1988年に第14委員会(TWA14)を発足させ、同委員会はファインセラミックスの分類とそれを先行的規格化に資し、国際的に受け入れられる構築された指標を作る作業を担当することとなった。TWA14では以下の目的を国際的に達成することとした、すなわち、

- (1) ファインセラミックスの分類システムを開発するときの固有の問題を見きわめ評価すること。
- (2) 国際的に明細表の形で使用できる分類システムを設定すること。これには産業的、経済的な統計資料、材料と特性のデータベース、製品、規格、参考資料の階層化を含むこと。
- (3) システム使用のための国際的な機関の結合とそのメカニズムを発展させること。

これらの目的はつぎのような作業計画により達成される、すなわち現存する分類システムと項目づけの検討、世界的な分類の現状および産業での有用性のサーベイ、および産業的視野での有効性に対する詳細な技術的基盤を把握するためのワークショップの開催などである。これらと、さらにこれにともなうファインセラミックス

の分類システム全般の開発を完結させる作業活動も含まれている。これらは、「ファインセラミックスを分類の目的で”高度の技術的、高度の性能のある、非金属無機物を主体とするセラミックスで特別な機能的特性を有するもの”と定義する。この定義は応用目的上機械的、熱的、電氣的などの応用目的にそって、広い領域の材料や製品を包含しているが、建築材料や耐火物などは除外する。」

「約500の異なる製品型態をもつファインセラミックスとりあげ、対応づけた。」

「新製品または他の種類のセラミックスを含有するものにも拡張適用が可能なファインセラミックスの包含的な分類システムの構築。」

「優先性のないマトリクス型の分類概念でそれが多数の入力、関連するデータベースの構築に適合できるもの。」

「独立した4系列の大要素(フィールド)記述で構成された、コンピュータが解読できるコードシステムを提供し、ユーザーの要求にマッチしたどのような順位付けも可能な中要素も付加する。各々の独立な大要素は唯一の先付けコードで分割同定できること。大要素は

- A. 応用分類
- C. 化学組成などの特性と製品の形態
- P. 製造プロセス
- D. 製品特性

とする。これらの大要素記号は長い数字列の間をしきる役割も果たす。各大要素中の詳細な中要素以下の数字列記号化も提供する。」

全体の分類システムの有用性は多岐にわたる。これの利用は、企業ベースでは設計群、物性データベース、特許情報の表式化、発注仕様の作製などに有用である。企業はこのシステムを市場動向データの集積や仕分け、研究開発課題の発掘、参考資料の階層分けなどにも使用できる。政府レベルではこのシステムを国内および国際的経済データ統計の現状の集積、この分野の統計の位置づけに使用できる。

「付記」本委員会に呼応してセラミックス系新素材の国際標準化に関する国内委員会を(財)日本ファインセラミックス協会において設置し技術的な検討を行ってきたが、分類システムとして完成したものではなく、さらに検討が必要である。しかし、ECなどではこれを本格的な規格にする作業が進行しており、今後それらをISOにおいてさらに全世界共通の分類規格にする努力をはらう必要がある。わが国の広範囲なファインセラミックス製品の製造あるいは研究開発は他を断然越えているので、国際的にもわが国が寄与するところははなはだ大きいと言うべきである。

Introduction

An international survey and workshop on the classification of advanced ceramics [3] found that most respondents defined advanced technical ceramics as

“highly engineered, high performance, predominantly non-metallic, inorganic, ceramic materials having specific functional attributes”.

This definition describes a diverse range of materials and product classes usually distinguished by their primary physical application, e.g. mechanical, thermal, electrical, etc.

The principle behind the system proposed in this ISO/TTA was established in meetings of the Versailles Project on Advanced Materials and Standards (VAMAS), Technical Working Area (TWA) 14, and the task of the consultants was to establish the terminology and a means of coding it [3]. [See annex F for a list of the VAMAS working group members of Technical Working Area (TWA) 14, *Classification of Advanced Ceramics*.]

The primary objective of this ISO/TTA is thus to propose a classification system for advanced technical ceramics which can form the basis for a multi-level database (to be defined elsewhere). A further objective is to define categories within the classification in order to define fully an advanced technical ceramic component or product which is encompassed by the following descriptor fields:

- Application
- Chemistry
- Form
- Processing
- Properties

These descriptor fields were identified by the international survey [3] as being the most important fields in the identification and categorization of advanced technical ceramics. The fields Application and Chemistry were found to be of primary importance, whereas the others were recognized as being important if a more rigorous identification or description was required.

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Advanced technical ceramics — Unified classification system

1 Scope

This ISO/TTA proposes a unified classification system for advanced technical ceramics, intended to meet the following objectives.

- It should provide a comprehensive description of materials, products and applications of advanced technical ceramics.
- It should be able to accommodate new materials and products as they become available.
- It should be accessible via the following four descriptor fields, either individually or in combination:

- Application
- Chemical character (including form)
- Processing
- Property data

- Its coding system should be machine readable, thereby providing a means of sorting data within the descriptor fields.
- Its coding system should be such that it can be simplified by truncation and elimination of redundant characters or, where only limited information is required, by limitation of the number of descriptor fields.
- The coding system should be simple to use and employ characters and strings which are both easy to recognize and relate to classification information.

The term “advanced technical ceramics” covers a wide range of materials (some having complex chemistry) which may be used in diverse applications. For the purposes of this ISO/TTA it is assumed that advanced technical ceramics include materials in the following forms:

- monolithic ceramics
- powders
- composite ceramics
- fibres
- glasses
- glass ceramics
- coatings
- porous materials

and, in addition to the readily recognized “ceramic” materials, halides and single crystals.

Specifically excluded from the classification system are the following:

elemental carbon, except for specific ceramic forms such as diamond, vitreous carbon and chemical vapour deposited (CVD) graphite;

elemental silicon, other than when it forms an integral component of or precursor for an advanced technical ceramic;

elemental germanium and other elemental or compound semi-metallic substances;

traditional ceramics based on clay, including

whitewares (e.g. tableware and fine porcelain),
sanitary wares,
floor and wall tiles, and
building ceramics (e.g. bricks and pipes);

unshaped and shaped refractories and bulk glasses for tonnage applications.

The mode of use of the classification system will be determined by the objective behind its use. It is not the purpose of this ISO/TTA to define how the system should be used, but examples are given of how it might be used. It is intended that the user can define the coding combination and the level of detail to suit his particular purpose.

2 Rationale for the coding system

It is clear that for a multicomponent classification system such as that proposed, the associated coding system is vital in ensuring that the system is workable. The coding system should also be comprehensive enough to encompass and describe adequately the wide range of data covered by the classification.

Since a fundamental objective is to provide a means of classifying any combination of descriptor fields in any sequence appropriate to user needs, each field is identified by a unique upper case letter code:

Application	A
Chemical character (including form)	C
Processing	P
property Data	D

These letters do not appear in any other part of the coding system and hence can be used uniquely to identify a given descriptor field and hence the sequence in which the fields are used need not be fixed. The letters also act as field separators in long coding strings — the presence of one of the letters indicating that what follows (i.e. until the next descriptor field letter occurs) relates to that descriptor field.

In addition, it is envisaged that for most users only a limited number of descriptor fields will be relevant. An example of the use of the classification system by limited descriptor use may be the user seeking statistical information on product manufacture or sales where only application and/or chemical character will be of interest. A more detailed outline of the likely use of this form of classification system is given in table 1.

One of the findings of the questionnaire on this topic [3] was the relative importance (or perceived usefulness) of the application and chemical character descriptors, and it is clear that the use of the classification system by these two descriptors should be as convenient as possible.

3 Abbreviations

CVD	chemical vapour deposition
HIP	hot isostatically pressed
PSZ	partially stabilized zirconia
PVD	physical vapour deposition
TZP	tetragonal zirconia polycrystals

4 Descriptor fields

4.1 Application

This field is identified by the upper case letter A.

Information in this field is contained in a three-digit code corresponding to a particular application. A full list of applications and corresponding numbers is given in annex A.

The coding format for this descriptor is

A nnn

where *nnn* is the number corresponding to the particular application.

In the list in annex A, applications are separated into, initially, a hierarchical series of areas by the principal functions of the product as defined by

- electrical insulation;
- electronic/ionic conduction;
- mechanical functions, including wear, at or near ambient temperature;
- thermal and thermomechanical functions, where dimensional stability at raised temperature, heat insulation, heat conduction or resistance to thermal shock are the principal functions, and where additionally mechanical loads may be applied;
- nuclear functions, where the component plays either an active or a passive nuclear role;
- optical functions, where the component plays a functional role as an optical element in reflection, refraction, transmission or absorption of electromagnetic radiation;
- chemical functions, including biomedical, where the component is employed for handling melts, chemicals, solutions or atmospheres because of its resistance to attack by them, and in the case of biomedical materials, a degree of biocompatibility;
- magnetic functions, where the component possesses properties allowing a functional magnetic role.

The first digit of the three-digit code is given by the principal physical function as above. The subsequent digits are non-hierarchical, and follow the listing in annex A. To aid the identification of codes, an alphabetical index of applications is given in A.3.

4.2 Chemical character (including form)

4.2.1 General

This field contains information relating to chemical character and form, and is identified by the upper case letter C.

Owing to the relatively complex chemistry and the likelihood of the presence of a number of compounds and forms, this part of the coding system is required to be particularly versatile. It is proposed that the chemical character code should contain at least three essential items of information:

- a) descriptor field identifier (C);
- b) overall form of the item expressed as one or two upper case letters, i.e. powder, fibre, rigid ceramic body, etc;
- c) numerical identification of the chemical formula (of the major constituent at least) or material type.

Subsequent coding items may be included to identify the purity of the major component, and the form and chemistry of minor constituents. In these cases the form descriptors also act as separators between related compounds.

4.2.2 Options for numerical codes

The complexity of the chemistry associated with advanced technical ceramics places a heavy responsibility on the numerical coding system used to describe it. A number of options are suggested to accommodate the user's preference to describe a product's chemical character (i.e. chemical formula or generic material type, and purity or compositional range).

4.2.2.1 Options for denoting chemical formula or generic material type

The options are based on a four-digit code to denote chemical formula or material type. A list of code numbers and associated definitions are given in annex B.

4.2.2.2 Options for the definition of chemical purity or compositional range

NOTE 1 Identification of an option as option 1 or option 2 does not infer or rank order of priority.

4.2.2.2.1 Option 1

The addition of a fifth digit, following the four-digit chemical character code, indicating the quantity of the material defined by the preceding four-digit code. The fifth digit would indicate the mass fraction as follows:

1	≤ 1 %
2	> 1 % ≤ 10 %
3	> 10 % ≤ 30 %
4	> 30 % ≤ 50 %
5	> 50 % ≤ 70 %
6	> 70 % ≤ 90 %
7	> 90 % ≤ 99 %
8	> 99 %

If the value is undefined or undefinable then the digit may be omitted.

4.2.2.2.2 Option 2

The addition of the purity or mass fraction in parentheses (...) following the four-digit code. The use of this option is governed by the following set of rules.

- a) The sole presence of a number within the parentheses indicates the percentage of the material present. For single-constituent strings, this figure would define the purity level; for multiple items, i.e. where the chemical character is described in the long form, this would denote the composition.

- b) The presence within the parentheses of the symbol < or > followed by a number indicates the maximum or minimum content of the constituent, e.g.

(< 90) indicates maximum content 90 %;

(> 99,99) indicates minimum content 99,99 % (probably used to signify purity).

- c) The presence within the parentheses of two numbers separated by a hyphen (-) indicates a range of composition, e.g.

(95-98,5) indicates that the material contains between 95 % and 98,5 % of the constituent in question.

4.2.3 Coding principle

In simple form a chemical character code would have the following appearance:

CFB $nnnn$

where FB identifies the material as fibre blanket and $nnnn$ defines its composition.

A chemical character coding could, however, have the appearance

CEE $xxxx$ 7MF $yyyy$ 2MB $zzzz$ 1 (option 1)

which indicates that the material is a powder (diameter < 100 μ m) of a compound $xxxx$ (> 90 % \leq 99 %) physically mixed (MF) with a chemical compound (MB) of $yyyy$ (> 1 % \leq 10 %) and $zzzz$ (\leq 1 %), or

CEE $xxxx$ (> 90)MF $yyyy$ (0,5-4,5)MB $zzzz$ (0,5) (option 2)

Form descriptors (single letters or pairs of letters) and the numeric codes for individual compounds are given in annex B.

4.3 Processing

This field is identified by the upper case letter P.

The information contained in this part of the coding system relates to the processes to which the product has been subjected and hence may contain several independent items. To accommodate this, the coding system comprises a series of strings comprising the following elements:

P mm

where mm is a number relating to a process stage defined in the list in annex C.

The process coding for a ceramic body might have the appearance

P7P12P18P30P61

indicating that the powder used was prepared by chemical precipitation (7) and then spray dried (12) prior to isostatic pressing (18) followed by sintering in air (30). The component produced in this way was then surface ground (61).

4.4 Property data

4.4.1 General

This field is identified by the upper case letter D.

The coding format of this field is designated to reflect the fact that many ceramic products are developed for specific property attributes appropriate to particular end uses.

The code shall contain the following items of information:

- a) descriptor field identifier (D);
 - b) a single digit (j) identifying the property group;
 - c) two digits (k_1k_2) identifying the specific property within the property group;
- and, in addition, may contain
- d) a single digit (l) identifying the property range;
 - e) a single digit (m) identifying the temperature at which or up to which the property range applies;
 - f) a single digit (n) identifying the frequency at which or up to which the property range applies (electrical properties only).

Details concerning the use of the coding options are given in 4.4.2 and 4.4.3.

Since a number of properties may need to be identified, the descriptor field identifier D also acts as a separator in a multi-element data coding string.

4.4.2 Code for property group(s) only

This code is intended for cases in which one or more properties are considered to be of relevance in the classification of a ceramic product but where it is either

adequate to indicate simply this fact, or

not possible to ascribe a numerical value because there is no standard test method.

The use of this type of coding shall be taken to imply that the property is important for the function of the material, either by design of the material or by the application for which it is intended.

The format for this code has the appearance

$$Djk_1k_2$$

where D, j , k_1 and k_2 are described in 4.4.1.

Examples are

an acid-resistant material: D802

an electro-optic material: D617

a material designed for (unspecified) thermal shock resistance: D303

4.4.3 Code for property group(s) and numerical property value(s)

This code is intended for cases in which it is considered important to ascribe a numerical property value for which a specified standard test method exists. For properties for which no standard method exists at present, this type of coding shall not be used.

Thus the complete format for this code has the appearance

$$Djk_1k_2lmn$$

where D, j , k_1 , k_2 , l , m and n are described in 4.4.1.

In many cases the last two digits, m and n , may be redundant and could be omitted to yield a simplified code such as

$$Djk_1k_2l$$

or

$$Djk_1k_2lm$$

Unless the temperature code m is indicated, the property shall be that at room temperature. The temperature code m shall, however, always be used for thermal expansion data. If the frequency code n is included (i.e. for electrical properties) it shall be preceded by the temperature code m to avoid ambiguity.

5 Use of the classification system

The proposed classification system has been designed to accommodate all likely inputs in each of the prescribed fields and in its entirety represents a fairly complex matrix such that a "full" classification coding could have the appearance

$$AaaaCEEbbbbMFccccMBddddPeePffPggDhhhhhhDiiiDjjj$$

It is recognized that in this complete form the coding would be unattractive from most users' point of view. However, it is envisaged that for most needs it is unlikely that the system would be used in its entirety and that

- only a limited number of fields will be used — hence the field identifiers should be readily recognized,
- within those fields used, the information may be limited to only a few items — hence the order of information should be logical,
- with use, the regularly encountered items, such as specific chemical types, will become familiar — hence sectors of the code such as chemical character, should "scan" easily, and
- for ease of use, coding lists should be accessible by both item and code.

A number of potential uses for the classification system are given together with the descriptors likely to be of most interest in table 1.

Table 1 — Examples of uses of the classification system

Use	Application	Chemical character (including form)	Processing	Property data
Technical, e.g. databanks	▲	▲	▲	▲
Ceramic trade statistics	○	▲		
Powder trade	▲	▲		
Equipment	▲		○	
Brochures	▲	○		▲
Invoices	○	▲		
Shipping notes	○	▲		
Labels/bags		▲		
Boxes	▲			
▲, essential information. ○, desirable information.				

Table 1 is not intended to be an exhaustive survey but illustrates

- a) how the classification system can operate with limited descriptors, and
- b) the relative importance of the application and chemical character fields.

6 Construction of a classification code

6.1 Routes for selecting field codes

The flowcharts given in figures 1 to 4 indicate the routes for selecting a particular field code when constructing a full classification code. The flowcharts should be used in conjunction with the lists and tables in annexes A to D.

It should be noted that it may not always be possible to assign a particular product to one of the listed codes in annexes A to D. In such cases, the code representing "other" in the appropriate field should be employed.

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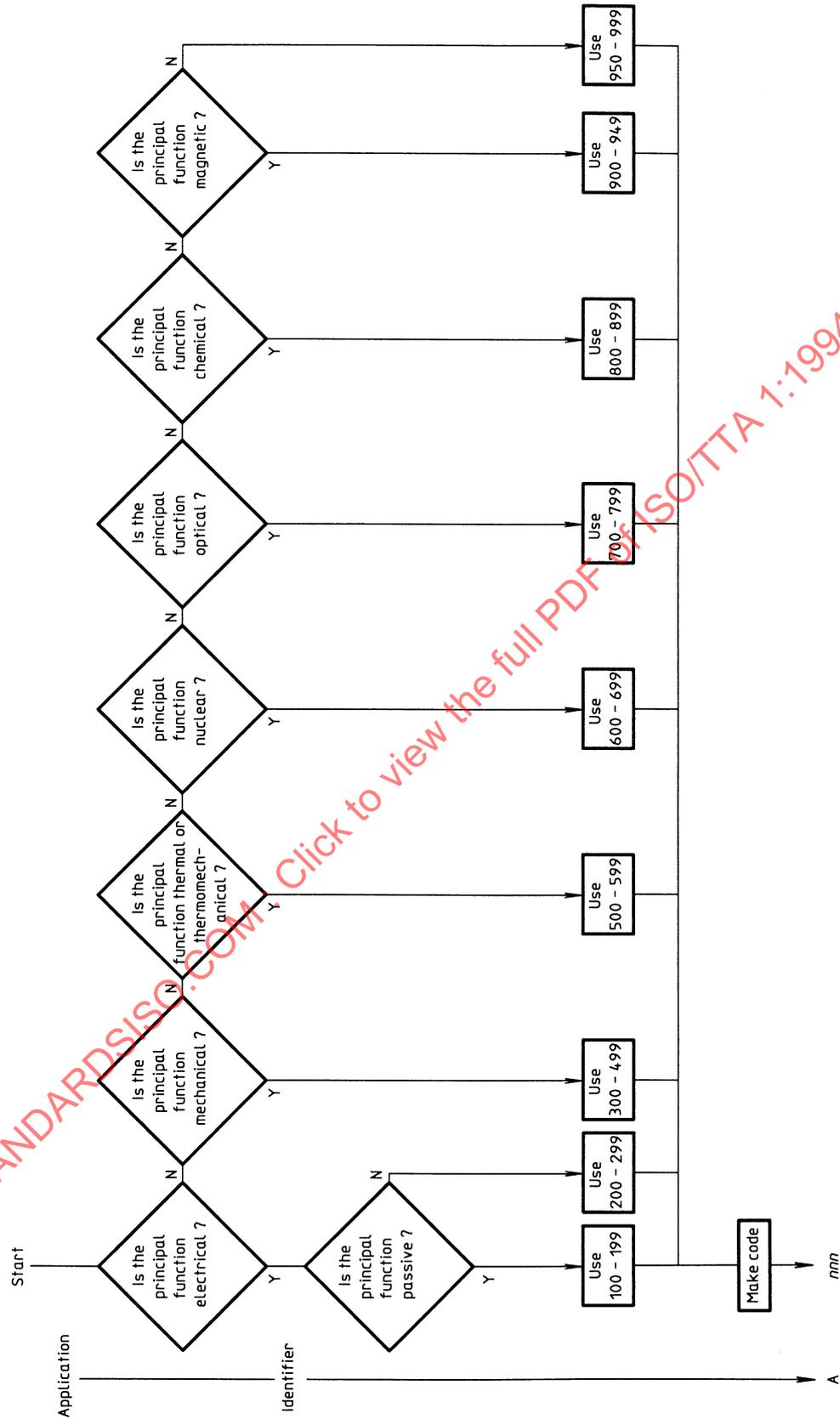


Figure 1 — Flowchart for construction of the code for applications — to be used in conjunction with annex A

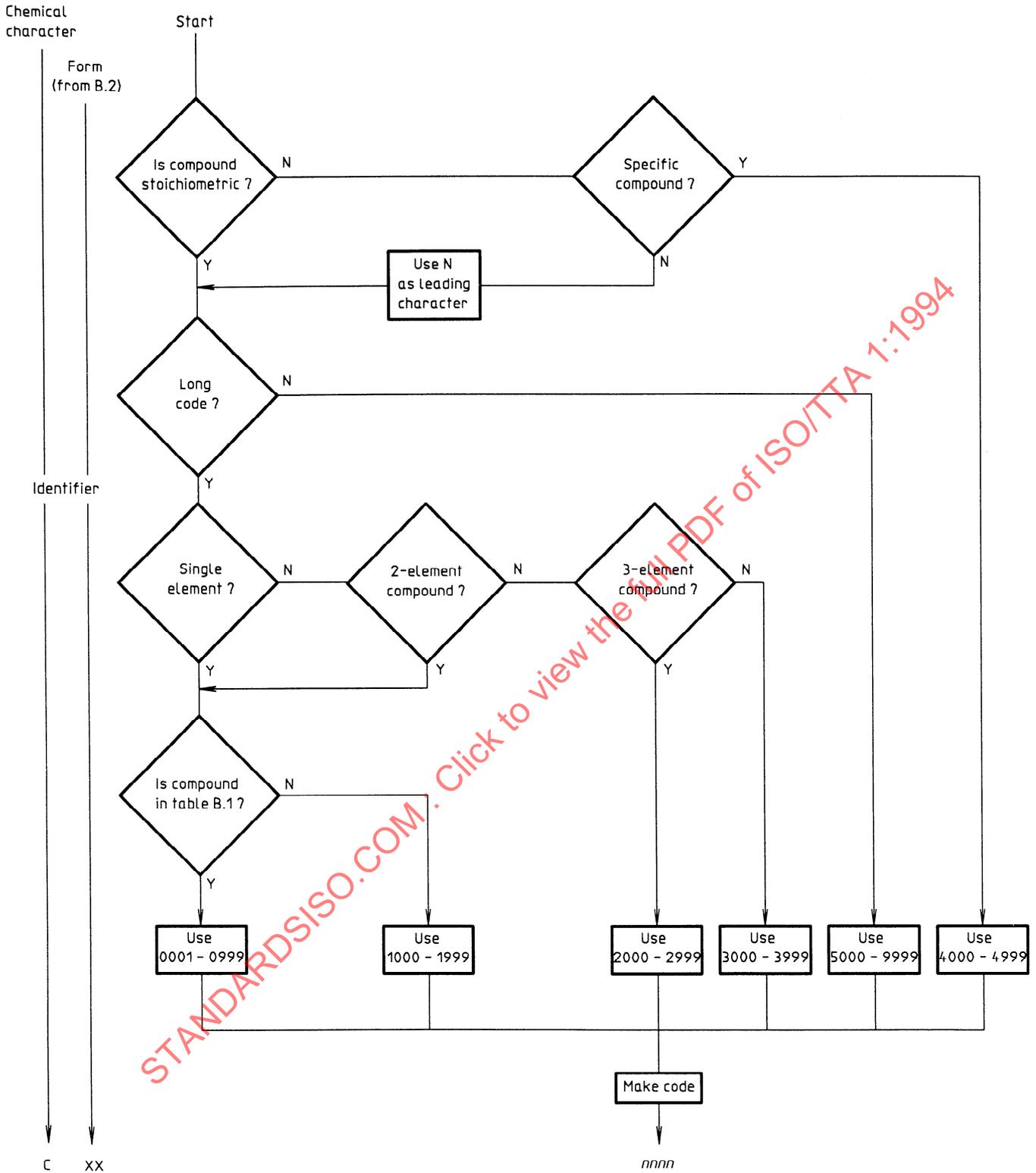


Figure 2 — Flowchart for construction of the code for chemical character (including form) — to be used in conjunction with annex B

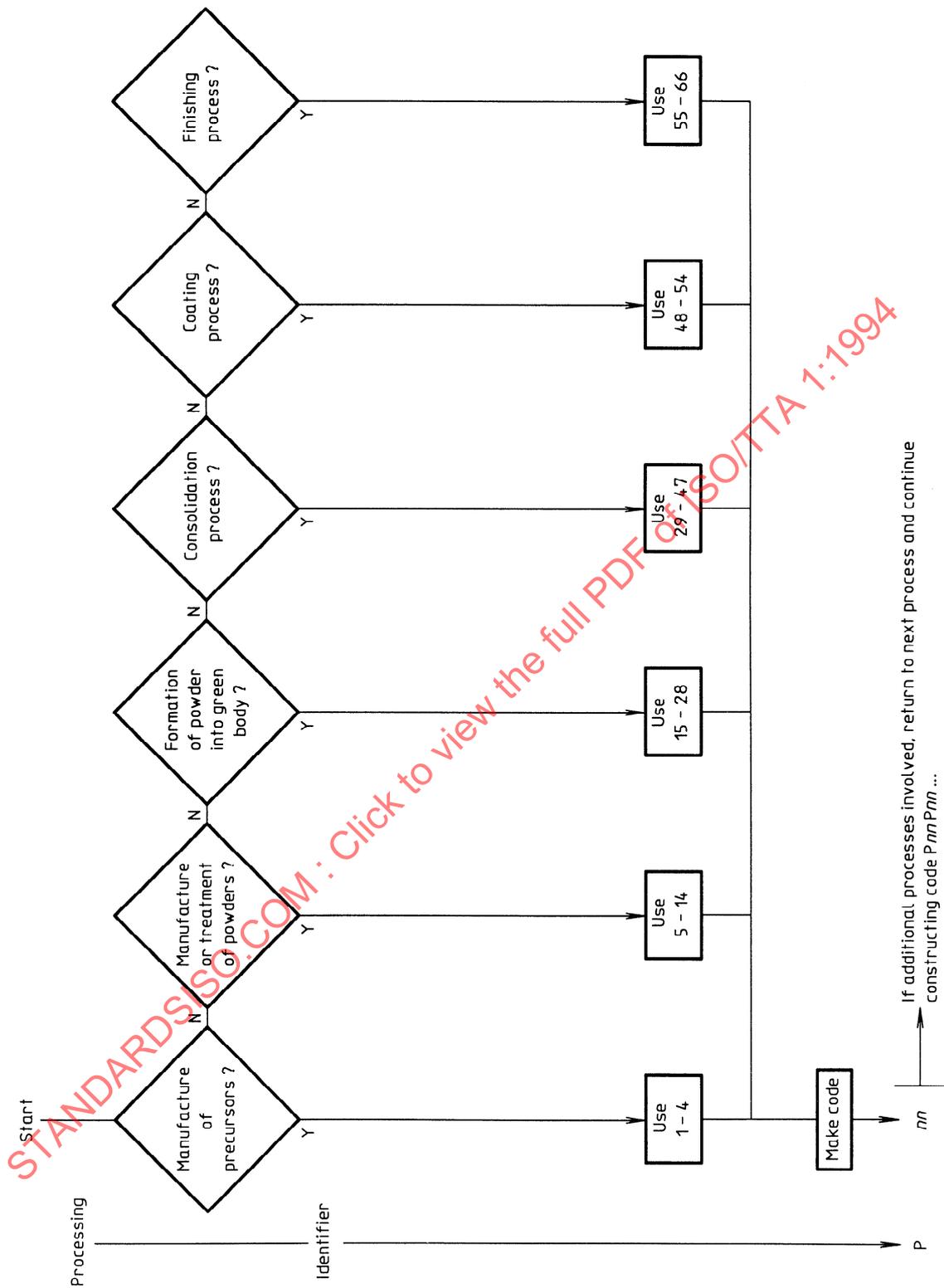


Figure 3 — Flowchart for construction of the code for processing — to be used in conjunction with annex C

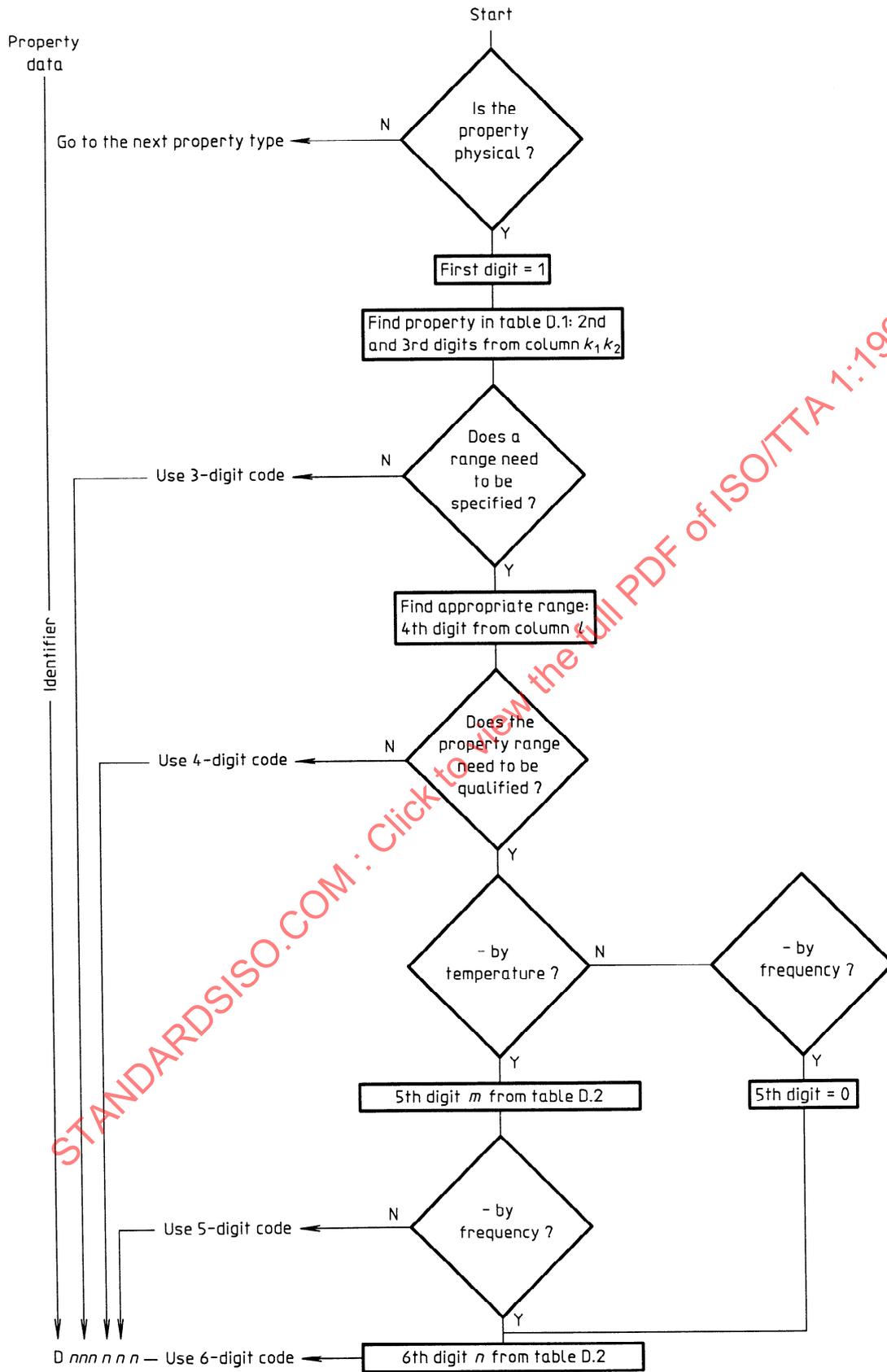


Figure 4 — Flowchart for construction of the code for property data — to be used in conjunction with annex D and tables D.1 and D.2

6.2 Worked examples

The following examples are intended to illustrate some of the ways in which the classification system may be constructed to describe a range of materials and applications.

EXAMPLE 1

Wire drawing die fabricated from yttria partially stabilized zirconia by isostatic pressing followed by green machining and sintering in air. After sintering the components are finish ground and lapped.

For this particular application the relevant properties are

- high density
- small grain size
- high hardness
- moderate elastic modulus
- high strength at 100 °C to 300 °C

The full code for this material/application based on the above proposal would be

A361CKB0449MB0448P18P17P30P61P62D1017D1031D20163D2052D2063

This code is compiled as follows:

A361 Wire drawing die

CKB0449MB0448 Rigid ceramic body (with zero intentional porosity) (KB) composed of zirconia (0449) in a chemical mixture (MB) with a minor undefined amount of yttria (0448) [alternative simple code (see B.3.3.6): CKB6645]

P18 Isostatically pressed

P17 Green machined

P30 Sintered in air

P61 Ground (fixed grit)

P62 Lapped

D1017 Density > 99 % of theoretical

D1031 Grain size $\leq 1 \mu\text{m}$

D20163 Flexural strength at > 100 °C $\leq 300 \text{ °C}$, > 400 MPa $\leq 1\ 000 \text{ MPa}$

D2052 Hardness > 1 000 HV 1 $\leq 1\ 500 \text{ HV 1}$

D2063 Young modulus > 100 GPa $\leq 200 \text{ GPa}$

For a full technical enquiry the full code may be desirable; however, for most users a truncated version will be more appropriate. For example, as clause 2 suggests, for users wanting statistical information on ceramic goods, chemical character may be the most important feature and hence the code

CKB0449MB0448

would give all the relevant information. Even this may be more information than is required. For example, if a user wants information solely on monolithic ceramics manufactured from zirconia (without specifying the existence or type of stabilizer) then

CKB0449

conveys that information, and could be used to access the system.

In brochures and publicity literature the most important features are likely to be application and property data. Hence for this use, the relevant form of the above code would be written

A361D1017D1031D20163D2052D2063

Even this could be further simplified to give the application, together with only the most important (or most commonly associated) property data; for example

A361D20163

refers to the application (wire drawing die) and flexural strength at $> 100\text{ °C}$ to $\leq 300\text{ °C}$.

Limitation of the property data information to the most relevant item would significantly reduce the length of the code strings but would raise the problem of identifying the items for inclusion. A possible solution would be to enter the data in the code in the order of the most important property (for a given application) first.

EXAMPLE 2

Alumina substrate for thick film applications manufactured by uniaxial pressing and sintering from a 96 % alumina.

In this particular application the relevant properties are

flexural strength
thermal conductivity
thermal expansion
volume resistivity
dielectric properties

The temperature of service, including processing, will be up to 600 °C , and the frequency at which the associated components will be required to operate will be up to 1 MHz .

The full code to describe the above would be

A140CKB0407MEP16P30P58D1017D20152D30142D30446D60124D606303D609423D6102

This code is compiled as follows:

A140 Substrate for electronic components

CKB0407ME Rigid ceramic body (with zero intentional porosity) (KB) manufactured from alumina (0407) containing a trace of unspecified additive (ME) [alternative simple code: CKB5040]

P16 Uniaxially pressed

P30 Sintered in air

P58 As-manufactured finish

D1017 Density $> 99\%$ of theoretical

D20152 Flexural strength at $> 0\text{ °C} \leq 100\text{ °C}$, $> 200\text{ MPa} \leq 400\text{ MPa}$

D30142 Thermal conductivity at $> 0\text{ °C} \leq 100\text{ °C}$, $> 10\text{ W/(m·K)} \leq 30\text{ W/(m·K)}$

D30446 Thermal expansion coefficient at $> 900\text{ °C} \leq 1\,200\text{ °C}$, $> 8 \times 10^{-6}\text{ K}^{-1} \leq 10 \times 10^{-6}\text{ K}^{-1}$

D60124 Volume resistivity at $> 300\text{ °C} \leq 600\text{ °C}$, $< 10^{14}\ \Omega\cdot\text{cm} \geq 10^{10}\ \Omega\cdot\text{cm}$

D606303 Relative permittivity at $> 10^3\text{ Hz} \leq 10^6\text{ Hz}$ (no temperature specified), $> 8 \leq 12$

D609423 Loss tangent at $> 0\text{ °C} \leq 100\text{ °C}$, and at $> 10^3\text{ Hz} \leq 10^6\text{ Hz}$, $< 0,001 \geq 10^{-4}$

D6102 Dielectric strength $> 5\text{ kV}\cdot\text{mm}^{-1} \leq 10\text{ kV}\cdot\text{mm}^{-1}$

As with the other worked examples, the full code will rarely be specified or required. Most users will restrict themselves to application and chemical character, which in this case would give

A140CKB0407ME

or

A140CKB5040

Further truncation of the code is, in this case, limited.

EXAMPLE 3

Heating element supports for coiled wire heating elements manufactured in cordierite (as defined in IEC 672-3:1984, group C-500) by extrusion, green machining and sintering.

In this example the material properties deemed to be important are

- density
- flexural strength
- thermal shock resistance
- thermal conductivity
- thermal expansion coefficient
- volume resistivity

The full code for this component would be written

A502CKG5950P26P30P61D1016D1022D20132D30112D3034D30436D60134

This code is compiled as follows:

A502 Coiled wire heating element supports

CKG5950 Open ceramic body, ≥ 95 % cordierite

P26 Auger extruded

P30 Sintered in air

P61 Ground surface

D1016 Density > 95 % ≤ 99 % of theoretical

D1022 Porosity > 1 % ≤ 5 %

D20132 Flexural strength at > 0 °C ≤ 100 °C, > 50 MPa ≤ 100 MPa

D30112 Thermal conductivity at > 0 °C ≤ 100 °C, ≤ 2 W·m⁻¹·K⁻¹

D3034 Thermal shock resistance > 400 K

D30436 Thermal expansion coefficient at > 900 °C $\leq 1\ 200$ °C, $> 4 \times 10^{-6}$ K⁻¹ $\leq 8 \times 10^{-6}$ K⁻¹

D60134 Volume resistivity at > 300 °C ≤ 600 °C, $< 10^{10}$ Ω·cm $\geq 10^6$ Ω·cm

EXAMPLE 4

Yttria stabilized zirconia powder supplied as a "ready to press" powder for advanced ceramics manufacture.

In this case the important features of the product are its chemical character and process route.

The full code for this product would be

CEH0449MB0448P7P12

This code is compiled as follows:

CEH0449MB0448 Spray-dried powder granules (EH) of zirconia (0449) chemically mixed (MB) with yttria (0448)

P7 Powder manufactured by chemical precipitation

P12 Granulated by spray drying

In this instance, no information is contained in the application or property data descriptor fields, hence the descriptor field letters A and D are absent.

EXAMPLE 5

Boron carbide grit blasting nozzle manufactured by slip casting followed by sintering in a controlled atmosphere.

The important properties for this application are defined as

density
flexural strength
elastic modulus
abrasion resistance

The full code for this application would be written

A320CKB0203MEP19P31P58D1015D20152D2065D701

This code is compiled as follows:

A320 Shot blast nozzles

CKB0203ME Rigid ceramic body (with zero intentional porosity) (KB) composed of boron carbide (0203) chemically mixed (ME) with an unspecified species (sintering aid) [alternative simple code: CKB5511]

P19 Slip cast (unassisted)
P31 Sintered in a controlled (non-ambient) atmosphere
P58 As-manufactured surface finish

D1015 Density $> 80 \% \leq 95 \%$ of theoretical
D20152 Flexural strength at $> 0 \text{ }^\circ\text{C} \leq 100 \text{ }^\circ\text{C}$, $> 200 \text{ MPa} \leq 400 \text{ MPa}$
D2065 Young modulus $> 400 \text{ GPa}$
D701 Resistant to abrasive wear

EXAMPLE 6

Heating element support manufactured from vacuum-formed hardened and machined ceramic fibre block.

The properties identified as important for this application are

density
flexural strength
compressive strength
thermal conductivity
thermal shock resistance
maximum temperature of use

The full code for the above would be written as

A502CFV0407MEP28P45P61D1011D20112D20332D30118D3034D3057

This code is compiled as follows:

A502 Coiled wire heating element supports

CFV0407ME Vacuum-formed fibre block (FV) manufactured from alumina (0407) with a trace of unspecified additive (ME) [alternative simple code: CFV5030]

P28 Other green-forming process
P45 Chemical bonding
P61 Ground surface

D1011 Density $\leq 20 \%$ of theoretical
D20112 Flexural strength at $> 0 \text{ }^\circ\text{C} \leq 100 \text{ }^\circ\text{C}$, $\leq 20 \text{ MPa}$
D20332 Compressive strength at $> 0 \text{ }^\circ\text{C} \leq 100 \text{ }^\circ\text{C}$, $> 50 \text{ MPa} \leq 100 \text{ MPa}$
D30118 Thermal conductivity at $> 1 \text{ } 400 \text{ }^\circ\text{C} \leq 1 \text{ } 600 \text{ }^\circ\text{C}$, $\leq 2 \text{ W}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$
D3034 Thermal shock resistance $> 400 \text{ K}$
D3057 Maximum temperature of use (self-loaded deformation temperature in air) $> 1 \text{ } 600 \text{ }^\circ\text{C}$

Annex A

Application descriptor field

A.1 Introduction

See 4.1 for details of this descriptor field content.

The classification list for applications of advanced technical ceramics is given below. The list is composed of a hierarchy of application types grouped as follows.

Code No.	Application type
100 - 199	Passive electrical applications
200 - 299	Active electrical applications
300 - 499	Mechanical applications
500 - 599	Thermal and thermomechanical applications
600 - 699	Nuclear applications
700 - 799	Optical applications
800 - 899	Chemical applications, including biomedical applications
900 - 949	Magnetic applications
950 - 999	Other applications

Since the application range for advanced ceramic products is widening rapidly, this list may not include recently developed applications. Until the classification is updated, the most appropriate "other" identification should be employed where there is any doubt.

Some applications may not appear to fall uniquely into a single category listed above by virtue of employing several advantageous features. An example would be a chemical plant pump rotating shaft seal. This performs a mechanical function in a chemical environment and is listed under mechanical applications.

To assist in the identification of the appropriate class and code as determined by its principal function, an alphabetical index is given in A.3 following the hierarchical listing in A.2.

A.2 Applications codes

100 - 199 Passive electrical applications

Power insulators

- 101 Structural electrical power insulators
- 102 Small low-tension electrical insulators (e.g. stand-off insulators, bus bar supports, terminal blocks)
- 103 Spark-plug insulators
- 104 Igniter insulators
- 105 Glow-plug insulators
- 106 Eyelets and cable cleats
- 107 Bushes, sleeves — up to 200 °C
- 108 Bushes, sleeves — above 200 °C
- 109 Aerial insulators
- 110 Low-power coil formers
- 111 High-power coil formers
- 112 Precision coil formers
- 113 Coil formers for high-frequency applications

- 114 Coil formers for high-temperature applications
- 115 Low-power fuse bodies
- 116 High-power fuse bodies
- 117 Vacuum envelopes
- 118 Vacuum leadthroughs
- 119 Electrical insulators for use in vacuum
- 120 Other electrical components for use in vacuum
- 139 Other power electrical insulators

Insulators for electronics

- 140 Substrates for electronic components, monolithic, including pin-grid arrays
- 141 Multilayer interconnects for electronic circuits, including pin-grid arrays
- 142 Heat sinks
- 143 Power semiconductor housings
- 144 Resistor cores
- 169 Other electronic packaging applications

Microwave insulators

- 170 Radomes and missile nosecones
- 171 Windows for use in microwave devices
- 172 Absorbers and attenuators for microwave devices
- 173 Phase shifters for use in microwave devices
- 179 Other applications in microwave devices

- 199 Other passive electrical applications

200 - 299 Active electrical applications

Ohmic electrical conductors

- 201 Ohmic heating elements
- 202 High-frequency susceptors
- 203 Electrodes
- 204 Igniters, jet engine
- 219 Other ohmic electrical conducting applications

Ionic conductors

- 220 Battery electrolytes
- 221 Fuel cell electrolytes
- 222 Gas detectors
- 223 Exhaust oxygen sensors
- 224 Molten metal oxygen sensors
- 229 Other ionic conducting applications

Capacitor applications

- 230 Monolithic single-layer capacitors
- 231 Multilayer chip capacitors
- 239 Other capacitors

Non-ohmic electrical conductors

- 240 Varistors
- 241 Thermistors
- 242 Attenuators
- 243 Applications based on superconducting ceramic components
- 249 Other non-ohmic electrical conductors

Piezoelectric applications

- 250 Microphone membranes, including telephone handsets
- 251 Loudspeaker membranes, including telephone handsets
- 252 Other buzzers and vibrators
- 253 Force, pressure and acceleration transducers
- 254 Sonar emitters and detectors
- 255 Impact igniters
- 256 Mechanical actuators
- 257 Motor elements
- 258 Ink-jet printer heads
- 259 Resonators
- 269 Other piezoelectric devices

- 270 Electrostrictive devices

- 280 Pyroelectric devices

- 299 Other functional electrical devices

300 - 499 Mechanical applications*Milling and crushing machinery*

- 301 Mill linings
- 302 Milling media
- 303 Other mill parts
- 304 Pestle-and-mortar linings for grinding soft materials
- 305 Pestle-and-mortar linings for grinding hard materials
- 309 Other milling or crushing applications

Agricultural applications

- 310 Agricultural implements for soil working
- 311 Agricultural pulverizing nozzles
- 319 Other agricultural applications

Wear-resistant facings for plant and machinery

- 320 Shot blast nozzles
- 321 Pipelines and cyclones
- 322 Chute linings
- 323 Food-processing applications
- 324 Mould and die liners
- 325 Crushing rolls
- 326 Slideways, wear-resisting pads
- 329 Other wear-resistant facings

Ballistic applications

- 330 Ballistic armour
- 331 Ballistic projectiles
- 339 Other ballistic applications

Material-cutting applications

- 340 Indexable inserts for cutting and machining of hard alloys
- 341 Indexable inserts for cutting and machining ferrous metals
- 342 Indexable inserts for cutting and machining non-ferrous metals
- 343 Inserts for rock drilling
- 344 Paper-, tape-cutting knives
- 345 Domestic knives
- 346 Scissors and shears

- 347 Tool-dressing components
- 359 Other material-cutting applications

Material-shaping applications

- 360 Cold die parts
- 361 Extrusion and drawing dies
- 362 Wire-drawing cones
- 363 Dies for hot processes
- 364 Stamping dies and roller dies
- 369 Other material-shaping applications

Pump applications

- 370 Vanes and impellers for pumps
- 371 Rotating shaft seals (stationary or rotating components)
- 372 Hydraulic plungers and cylinders
- 373 Pump bearing sleeves
- 374 Pump shafts
- 375 Pump housings
- 379 Other pump applications

Valve and tap (faucet) applications

- 380 Tap (faucet) valve faces, single-lever action
- 381 Tap (faucet) valve faces, multiple-lever action
- 382 Tap (faucet) valves, for water, other
- 383 Pneumatic valves
- 399 Other valve facings for non-corroding liquids

Guides for thread, paper, tape, etc.

- 400 Thread-spinning nozzles
- 401 Friction discs for thread texturing
- 402 Thread guides
- 403 Guides, runners for paper handling
- 404 Applications in printer heads
- 405 Guides and other components for magnetic tape transport
- 419 Other thread, paper or tape guide applications

Bearing applications

- 420 Plain bearing sets
- 421 Roller bearing sets
- 422 Precision balls for bearings
- 423 Precision rollers for bearings
- 424 Thrust bearing sets
- 439 Other bearing applications

Precision jigs and metrological devices

- 440 Sizing rings
- 441 Gauge blocks
- 442 Jigs
- 443 Vee blocks
- 444 Surface plates and angle plates
- 459 Other precision-tooling applications

Sports goods

- 460 Shoe studs
- 461 Golf-club inserts
- 462 Fishing-rod ring liners
- 463 Ice-skate blades
- 469 Other applications in sports goods

499 Other mechanical applications

500 - 599 Thermal and thermomechanical applications

Temperature-resistant electrical applications

- 501 Thermocouple insulators and sheaths
- 502 Coiled wire heating element supports
- 503 Supports for rod heating elements
- 504 Insulators for lamp elements
- 505 Resistance thermometer element bases
- 506 Lamp holders
- 509 Other temperature-resistant electrical applications

High-temperature materials processing applications

- 510 Applications in hot-metal immersion probes
- 511 Muffle tubes for furnaces
- 512 Saggars for material processing
- 513 Kiln furniture (ware support) for high-temperature processing
- 514 Pins for refractory insulation
- 515 Furnace rollers, runners and guides
- 516 Burner parts
- 517 High-duty heat exchangers
- 518 Low-duty heat exchangers
- 519 High-temperature gas valves
- 520 Weld pool rings
- 521 Welding nozzles
- 522 Welding jigs
- 523 Casting tubes for molten metals
- 524 Shell moulds
- 525 Casting cores
- 526 Filters for liquid metals
- 527 Break rings for the continuous-casting process
- 528 Crucibles for metal melting and handling
- 529 Other liquid-metal handling applications
- 539 Other high-temperature materials processing applications

Aerospace applications

- 540 Rocket nozzles
- 541 Ablation shields
- 542 Jet engine petals/nozzles
- 543 Brake discs
- 549 Other aerospace applications

Domestic applications

- 550 Domestic cooker tops
- 551 Cookware
- 559 Other domestic applications

Reciprocating engine applications

- 560 Cylinder blocks in reciprocating engines
- 561 Pistons and piston crowns in reciprocating engines
- 562 Fuel-injector nozzles for reciprocating engines
- 563 Pre-combustion chambers for reciprocating engines
- 564 Piston pins
- 565 Applications in exhaust valves
- 566 Cam followers
- 567 Cylinder liners

- 568 Exhaust port liners
- 569 Exhaust pipe liners
- 570 Turbocharger rotors
- 571 Turbocharger stators
- 572 Turbocharger housing
- 573 Fuel-injection pins
- 574 Diesel particulate filters

NOTE 2 See 843 for vehicle exhaust catalyst supports.

- 579 Other reciprocating engine applications

Applications in turbine engines

- 580 Rotors and blades for gas turbines
 - 581 Stators for gas turbines
 - 582 Combustion chambers for gas-turbine applications
 - 583 Fuel injectors for gas turbines
 - 584 Regenerators and heat-exchanger components for gas turbines
 - 585 Thermal-barrier coating of metallic components
 - 586 Shrouds and shroud components
 - 589 Other gas-turbine applications
- 599 Other thermal and thermomechanical applications

600 - 699 Nuclear applications

- 601 Nuclear fuel elements
- 602 Element separators in nuclear applications
- 603 Moderators in nuclear applications
- 699 Other nuclear applications

700 - 799 Optical applications

Reflective applications

- 701 Telescope mirrors
- 702 Synchrotron mirrors
- 709 Other reflective applications

Non-optical structural components for optical systems

- 710 Optical benches
- 711 Ferrules for fibre optics
- 719 Other structural components for optical applications

Laser components

- 720 Laser waveguides
- 721 Laser rods
- 729 Other components for lasers

Optical window applications

- 730 Windows for optical wavelengths
- 731 Windows for infrared wavelengths
- 739 Other optical window applications

Lamp envelopes

- 740 High-power lamp envelopes
- 741 Envelopes for high-pressure sodium-vapour lamps
- 749 Other lamp envelopes

Active optical components

- 750 Optical modulators
- 759 Other active optical components

- 799 Other optical applications

800 - 899 Chemical and biomedical applications*Laboratory chemical equipment*

- 801 Crucibles and boats for laboratory use
- 802 Funnels for laboratory use
- 803 Filter media for laboratory use
- 809 Other laboratory ware applications

Chemical plant applications

- 810 Tower packing in large-scale chemical plants
- 811 Vessels and pipes in large-scale chemical plants
- 812 Floats and tubes in large-scale chemical plants
- 813 Ball valves in large-scale chemical plants
- 814 Flowmeter applications
- 815 Gas percolation elements
- 819 Other chemical plant applications

Chemical moulding parts

- 820 Rubber dipping formers
- 829 Other mould components

Filter bodies and materials

- 830 Filter elements for liquid media, monolithic
- 831 Filter elements for gaseous media, monolithic
- 832 Ceramic filter membranes
- 839 Other filter applications

NOTE 3 Filters for molten metals are coded 526.

Catalysts and catalyst supports

- 840 Ceramic catalysts
- 841 Catalyst supports, granular
- 842 Catalyst supports, plate
- 843 Catalyst supports, monolithic honeycomb, including vehicle exhaust applications
- 849 Other applications in catalysis

- 859 Other chemical applications

Biomedical applications

- 861 Orthopaedic biomedical implants
- 862 Dental implants
- 863 Vascular biomedical implants
- 899 Other biomedical implants

900 - 949 Magnetic applications

- 901 Cores for loudspeakers and microphones
- 902 Components for transducers
- 903 Components for microwave devices
- 904 Components for coils
- 905 Components for yokes

906	Components in flyback transformers
907	Magnetic components for data-recording heads
908	Non-magnetic components for data-recording heads
909	Magnets for motors
949	Other magnetic applications

950 - 999 Other applications (see note 4)

NOTE 4 In the formulation of this coding scheme the codes 950 - 999 are available for other applications to be identified by user demand.

A.3 Alphabetical index for applications codes

Ablation shields, aerospace	541	Break rings for continuous casting	527
Abrasion-resistant applications, miscellaneous	329	Burners, parts for	516
Abrasives		Bus bar supports	102
linings for process plant for	321	Bushes	
Absorbers, microwave devices	172	above 200 °C	108
Acceleration transducers, accelerometers	253	up to 200 °C	107
Actuators, piezoelectric	256	Buzzers	252
Aerial insulators	109	Cable cleats	106
Aerospace applications	540 - 549	Cam followers	566
Agricultural implements		Capacitors	230 - 239
nozzles	311	miscellaneous	239
for soil working	310	monolithic	230
Angle plates, precision	444	multilayer	231
Applications, miscellaneous	950 - 999	Casting, continuous, break rings for	527
Armour, ballistic	330	Casting cores	525
Attenuators		Casting tubes for molten metals	523
electrical	242	Catalysis, miscellaneous	849
microwave devices	172	Catalyst supports	
Ballistic armour	330	granular	841
Ballistic projectiles	331	monolithic, honeycomb, vehicle	
Balls		exhaust	843
for bearings	422	plate	842
for milling	302	Chemical applications	800 - 859
Ball valves, chemical plant	813	miscellaneous	859
Battery electrolytes	220	Chemical plant components, large scale	810 - 819
Bearings, miscellaneous	439	Chute linings	322
Bearing sets		Circuits, electronic, interconnects	141
plain	420	Coatings, thermal barrier, for metallic components	585
roller	421	Coiled wire heating element supports	502
thrust	424	Coil formers	
Biomedical applications	861 - 899	high frequency	113
Biomedical implants		high power	111
dental	862	high temperature	114
miscellaneous	899	low power	110
orthopaedic	861	precision	112
vascular	863	Coils, magnetic components for	904
Brake discs, aerospace	543	Cold die parts	360

Combustion chambers, gas turbines	582	Exhaust gas sensors	223
Cooker tops, domestic	550	Exhaust pipe liners	569
Cookware	551	Exhaust port liners	568
Conductors		Exhaust valves, reciprocating engine	565
electrical, ohmic	201 - 219	Extrusion dies	361
electrical, non-ohmic	240 - 249	Eyelets, electrical	106
ionic	220 - 229		
Cones, wire-drawing	362	Faucets (taps), valve faces (water)	380 - 382
Continuous casting, break rings for	527	Fibre optics, ferrules for	711
Cores		Filter applications, chemical, miscellaneous	839
casting	525	Filter elements	830 - 839
for resistors	144	gaseous media	831
Crucibles for metal melting	528	liquid media	830
Crushing rolls	325	Filter media, laboratory	803
Cutting, materials	340 - 359	Filters	
Cyclones	321	diesel exhaust particulate	574
Cylinder blocks, reciprocating engine	560	for liquid metals	526
Cylinder liners, reciprocating engine	567	membranes	832
Cylinders, hydraulic	372	Fishing-rod ring liners	462
		Flowmeter applications	814
Data-recording heads		Flyback transformers, magnetic components for	906
magnetic components for	907	Food processing, applications in	323
non-magnetic components for	908	Force transducers	253
Dental implants	862	Formers, rubber dipping	820
Dies		Friction discs for thread texturing	401
cold	360	Fuel cells, electrolytes for	221
drawing	361	Fuel injectors	
extrusion	361	gas turbine	583
for hot processes	363	reciprocating engine, nozzles	562
liners	324	reciprocating engine, pin valves	573
roller	364	Funnels, laboratory	802
stamping	364	Furnace components	
Diesel engines		guides	515
particulate filters	574	kiln furniture	513
precombustion chambers for	563	muffle tubes	511
Domestic applications, miscellaneous	559	rollers	515
Drawing dies	361	runners	515
		saggars	512
Electrical applications		Fuse bodies	
active	200 - 299	high power	116
active, miscellaneous	299	low power	115
passive	100 - 199		
passive, miscellaneous	199	Gas detectors	222
Electrical devices, functional, miscellaneous	299	Gas percolation elements	815
Electrical insulators	101 - 139	Gas turbines (see also Jet engines)	
Electrodes	203	combustion chambers	582
Electrolytes		components for	580 - 589
batteries	220	fuel injectors	583
fuel cells	221	heat-exchanger components	584
Electronic components, substrates for	140	igniters	204
Electronic packaging, miscellaneous applications	169	miscellaneous applications	589
Electrostrictive devices	270	regenerators	584
Element separators, nuclear	602	rotors	580
Envelopes, lamps	740 - 749	shrouds	586
Exhaust gas catalyst supports	843	stators	581

Gas valves, high temperature	519	low tension, small	102
Gauge blocks	441	spark-plug	103
Glow-plug insulators	105	structural power, large	101
Golf-club inserts	461	thermocouples	501
Grinding, pestles and mortars	304 - 305	vacuum envelopes	117
mill liners	301	vacuum leadthroughs	118
Guides		vacuum, use in (degassable)	119
furnace	515	Ionic conductors	220 - 229
magnetic tape	405	Jet engines (see also Gas turbines)	
paper handling	403	nozzles	542
thread	402	petals	542
Heat-exchanger components		Jigs	442
gas turbines	584	Kiln furniture	513
high duty	517	Knives	
low duty	518	domestic	345
Heating elements, ohmic	201	paper cutting	344
Heating element supports		tape cutting	344
coiled wire	502	Laboratory ware	801 - 809
rods	503	miscellaneous	809
Heat sinks, electronic	142	Lamp elements, insulators	504
High-temperature processing	510 - 539	Lamp envelopes	
kiln furniture	513	high power	740
saggars	512	high pressure sodium vapour	741
Honeycomb catalyst supports	843	miscellaneous	749
Housings		Lamp holders	506
power semiconductor	143	Lasers	
pumps	375	components for	720 - 729
turbochargers	572	waveguides	720
Hydraulic cylinders	372	Liners, linings	
Hydraulic plungers	372	chutes	322
Hydrophones	252	cyclones	321
Ice-skate blades	463	cylinder	567
Igniter insulators	104	dies	324
Igniters		exhaust pipe	569
impact	255	exhaust port	568
jet engine	204	mills	301
Immersion probes, hot metal	510	moulds	324
Impact igniters	255	pestle-and-mortar, for grinding soft	
Impellers for pumps	370	materials	304
Implants		pestle-and-mortar, for grinding hard	
biomedical	861 - 899	materials	305
dental	862	pipes	321
miscellaneous	899	process plant	321, 322
orthopaedic	861	Loudspeakers	
vascular	863	magnetic cores for	901
Indexable inserts, machine tools	340 - 342	piezoelectric membranes for	251
Ink-jet printer heads	258	Machine tools	
Inserts, rock drilling	343	indexable inserts for	340 - 342
Insulation, refractory pins for	514	slideways	326
Insulators, electrical		Magnetic applications	900 - 949
aerial	109	loudspeaker cores	901
fuse bodies	115 - 116	microphone cores	901
glow-plug	105	miscellaneous	949
igniter	104		
lamp elements	504		

Magnetic tape, guides	405	Optical modulators	750
Mechanical actuators	256	Orthopaedic implants	861
Mechanical applications	300 - 499	Oxygen sensors	
miscellaneous	499	exhaust gas monitors	223
Metallic components, thermal barrier coatings for	585	for molten metal	224
Metals, liquid, handling	523 - 529	Paper-cutting knives	344
casting tubes for	523	Petals, jet engine	542
miscellaneous	529	Phase shifters, microwave devices	173
Microphones		Piezoelectric applications	250 - 269
magnetic cores for	901	miscellaneous	269
piezoelectric membranes for	250	Pin-grid arrays, electronic substrates	140 - 141
Microwave devices		Pins, for refractory insulation	514
absorbers	172	Pipe linings, abrasion resistant	321
attenuators	172	Pipes, chemical plant	811
magnetic components for	903	Piston crowns, reciprocating engine	561
miscellaneous	179	Piston pins	564
phase shifters	173	Pistons, reciprocating engine	561
windows	171	Plungers, hydraulic	372
Milling media	302	Pneumatic valves	383
Mills		Power insulators	101 - 139
linings	301	Precision tooling, miscellaneous applications	459
miscellaneous parts for	303	Precombustion chambers, reciprocating engine	563
Mirrors		Pressure transducers	253
synchrotron	702	Printer heads	
telescope	701	piezoelectric components for	258
Missile nosecones	170	wear-resistant components for	404
Moderators, nuclear	603	Projectiles, ballistic	331
Modulators, optical	750	Pumps	370 - 379
Mortar linings, for grinding	304 - 305	bearing sleeves for	373
Motors, parts for		housings	375
magnets	909	impellers for	370
piezoelectric elements	257	miscellaneous applications in	379
Moulds		shafts for	374
liners	324	vanes for	370
miscellaneous, chemical applications	829	Pyroelectric devices	280
rubber dipping formers	820		
shell	524	Radomes	170
Non-ohmic conductors, miscellaneous	249	Reciprocating engines	
Nozzles		components for	560 - 579
agricultural	311	miscellaneous applications in	579
fuel injection	562	Regenerators, gas turbine	584
fuel injection, control pins for	573	Resistance thermometers, element bases	505
jet engine	542	Resistor cores	144
rocket	540	Resonators, piezoelectric	259
shot or grit blast	320	Rock drilling, inserts for	343
thread spinning	400	Rocket nozzles	540
welding	521	Roller bearing sets	421
Nuclear applications	600 - 699	Roller dies	364
miscellaneous	699	Rollers	
Nuclear fuel elements	601	for bearings	421
Optical applications	700 - 799	furnace	515
miscellaneous	799	Rolls, crushing	325
Optical benches	710	Rotating shaft seals	371

Rotors		Thermocouple sheaths	501
gas turbine	580	Thermometers, resistance, element	
turbocharger	570	bases for	505
Rubber dipping formers	820	Thread guides	402
Runners		Thread-spinning nozzles	400
furnace	515	Thread texturing, friction discs	401
paper handling	403	Thrust bearing sets	424
Saggars for material processing	512	Tool-dressing components	347
Scissors	346	Tower packing, chemical plant	810
Seal rings, for pumps	371	Transducers	
Semiconductors, housings	143	force, pressure, acceleration	253
Shaft seals, rotating	371	magnetic components for	902
Shafts, for pumps	374	Tubes, chemical plant	812
Shears	346	Turbochargers	
Sheaths, thermocouple	501	housings	572
Shell moulds	524	rotors	570
Shoe studs	460	stators	571
Shot blasting nozzles	320	Vacuum devices, insulating com-	
Shrouds, gas turbine	586	ponents	119
Sizing rings	440	Vacuum envelopes	117
Sleeves, electrically insulating		Vacuum leadthroughs	118
above 200 °C	108	Valve facings	380 - 399
up to 200 °C	107	miscellaneous, non-corrosive liquids	399
Slideways	326	miscellaneous, water	382
Sonar emitters and detectors	254	taps (faucets)	380 - 381
Spark-plug insulators	103	Valves	
Sports goods applications	460 - 469	ball, chemical plant	813
miscellaneous	469	exhaust, reciprocating engine	565
Stamping dies	364	high-temperature gas	519
Stators		miscellaneous, water	382
gas turbine	581	pneumatic	383
turbocharger	571	Vanes for pumps	370
Substrates, for electronic components	140	Varistors	240
Superconducting ceramics, appli-		Vee blocks	443
cations	243	Vessels, chemical plant	811
Supports		Vibrators, piezoelectric	252
bus bar	102	Water faucets (taps)	380 - 382
coiled wire heating elements	502	Waveguides, laser	720
kiln furniture	513	Wear-resisting pads	326
rod heating elements	503	Welding jigs	522
Surface plates	444	Welding nozzles	521
Susceptors, high frequency	202	Weld pool rings	520
Synchrotron mirrors	702	Windows	
Tape-cutting knives	344	infrared wavelengths	731
Taps, valve faces (water)	380 - 382	microwave devices	171
Telescope mirrors	701	optical	730
Terminal blocks	102	optical, miscellaneous	739
Thermal and thermomechanical appli-		Wire drawing	
cations	500 - 599	cones	362
miscellaneous	599	dies	361
Thermal-barrier coatings	585	Yokes, magnetic components	905
Thermistors	241		
Thermocouple insulators	501		

Annex B

Chemical character (including form) descriptor field

B.1 Introduction

See 4.2 for details of this descriptor field content.

B.2 Form descriptors

B.2.1 The form descriptors, which also act as separators in the chemical character coding, are given in the following list.

- B = Precursor
 - BG = gas
 - BL = liquid
 - BS = solid

- E = Powder
 - EE = conventional
 - EF = powder coated with an inorganic material
 - EG = powder coated with an organic material
 - EH = spray-dried powder granules
 - EJ = mechanically granulated powder
 - EK = partly consolidated ceramic/preform/green shape

- W = Whisker
 - WB = whisker mat
 - WE = floated/sized whiskers

- F = Fibres
 - FS = short thin fibres
 - FL = single long thin (continuous) fibres
 - FF = filament (thick fibres)
 - FT = long fibre tows
 - FW = woven fibre mat
 - FP = pre-preg
 - FB = blanket
 - FV = rigid-pressed or vacuum-formed preform or board

- K = Rigid ceramic body
- KB = solid ceramic object (no deliberate porosity)
 - KE = 3D closed cellular ceramic
 - KF = 2D cellular ceramic
 - KG = open porous ceramic
 - KH = graded density (open porous) ceramic
 - KJ = functionally graded ceramic
 - KK = coated ceramic
 - KL = surface-treated or surface-modified ceramic
 - KM = multilayer composite ceramic
 - KS = unidirectional (1D) ceramic matrix long-fibre composite
 - KT = bidirectional (2D) ceramic matrix long-fibre composite (including woven fibres)
 - KU = multidirectional (3D and higher) ceramic matrix long-fibre composite (including knitted fibres)
 - KV = short (chopped) fibre ceramic matrix composite
 - KW = ceramic matrix whisker-containing composite
 - KX = ceramic matrix platelet-containing composite
 - KY = glass
 - KZ = glass-ceramic
- L = Ceramic coating
- LB = thin (< 20 µm) coating
 - LE = thick (≥ 20 µm) coating
 - LF = cementitious material for joining
- S = Single crystal
- J = Platelets
- H = Hollow spheres
- M = Mixture (used for second and subsequent species to indicate relationship with first species)
- MB = chemical mixture of a second or subsequent species with the previous one(s) to indicate a compound or solid solution not specifically listed in B.3, i.e. the code indicates that the following numerical code element refers to a declared second additional compound chemically combined with the previous one (e.g. a solid solution of magnesium dititanate and aluminium titanate, or a glass)
 - ME = physical or chemical mixture of a second or subsequent deliberate minor or trace addition to the previously defined compound (e.g. MgO in alumina or B in SiC), the exact form or nature of which is not specifically identified
 - MF = physically discrete particulate mixture of a second or subsequent species with the previous one(s), i.e. the code indicates that the following numerical code element refers to a declared additional compound in a physically separate form from the previous one (e.g. a second distinct individual discontinuous crystalline phase, a second powder intermixed with a first)
 - MG = physically discrete, nominally continuous second phase in a material comprising principally the previously cited phases
 - MH = the following species is in the form of discrete fibres

MJ = the following species is in the form of discrete whiskers

MK = the following species is in the form of discrete platelets

ML = the following species is in the form of a coating on the previous species

MM = the following species is employed in chemically altering the surface of a material relative to its bulk

MS = the following species is employed as a distinct layer in a layer composite

B.2.2 The following code construction rules apply.

- a) When describing ceramic matrix composite materials, the matrix phase(s) must be defined first.
- b) All particulate-containing ceramic bodies, including metal and ceramic particles, where the particles form a discrete second phase which might be considered to strengthen or toughen the matrix, are described by code KB.

B.3 Chemical formulae descriptors

B.3.1 General

The four-digit codes for metal ions and simple chemical compounds (code Nos. 0001 - 0999) are given in B.3.2; those for other compounds (code Nos. 1000 - 9999) are given in B.3.3.

The following general rules for code construction should be followed.

- a) For precursors and powders of high purity or where purity may need to be defined, four-digit codes shall be used from the range 0001 - 4999.
- b) For precursors, powders, ceramics, glasses or glass-ceramics of general compositional type where purity or detailed composition is not to be defined, a four-digit code from the range 5000 - 9999 shall normally be used.
- c) For ceramics, glasses or glass-ceramics where detailed composition in component form is to be identified, four-digit codes from the range 0001 - 4999 shall be used in combination optionally with codes for amounts present and relational form of secondary components.

B.3.2 Four-digit codes for metal ions and simple chemical compounds

Table B.1 gives four-digit codes to be used for the description of chemical components of precursors, powders and ceramic products where the composition in simple chemical compound form is to be described. Table B.1 lists the most common metal ions, including those of variable valency, and nine commonly met simple anions. Individual codes are obtained by combining the metal ion of appropriate valency from the list on the left-hand side of table B.1 with the required anion given at the top of the table. Each combination of metal ion and anion is identified by a unique number. The four-digit codes are arranged according to the following hierarchy.

Code No.	Description
0001 - 0099	Metal ions
0101 - 0199	Boride
0201 - 0299	Carbide
0301 - 0399	Nitride
0401 - 0499	Oxide
0501 - 0599	Fluoride
0601 - 0699	Silicide
0701 - 0799	Phosphide
0801 - 0899	Sulfide
0901 - 0999	Iodide

In the majority of cases requiring classification by detailed chemistry it will be possible to describe an advanced technical ceramic material in terms of these codes. However, the list is not exhaustive, and the metal ion description "other" may be used for metallic species not appearing in this table. For single-species anions not appearing in table B.1, see codes 1000 - 1999 (B.3.3.2), for two-species anions see codes 2000 - 2999 (B.3.3.3), and for more complex compounds see codes 3000 - 3999 (B.3.3.4).

It is apparent from the matrix of codes for simple binary compounds that many of the possible code numbers will be rarely used, indeed several of the codes are redundant through impossible combinations, e.g. carbon carbide, or through thermodynamic considerations (instability).

For elements which exist in more than one valency, separate rows are provided in the matrix for each valency state. In this way the matrix can provide codes which differentiate between, for example, CeO_2 and Ce_2O_3 , and FeO and Fe_2O_3 . In some cases, the use of simple valencies is not possible. In such cases the formula is quoted after the code number in table B.1, but would not be employed in the use of the code. In other cases, a series of two or more compounds may be formed from the same species. This classification does not attempt to separate them with individual codes, but represents them either in the form A_xB_y or in the form AB_y .

If the component is not normally solid at ambient temperature this is noted in the matrix table as (g) for gaseous and (l) for liquid. If the chemical normally has water of crystallization which would be removed in forming a ceramic product, this is indicated by (h) (= hydrated).

Substoichiometry of compounds is accommodated in one of two ways.

- a) By the inclusion of a leading character (N = non-stoichiometric) in the code. "N" does not appear as a form descriptor, and therefore would not be confused with data in that field. For example, the code for a non-stoichiometric titanium dioxide would be

N0420

- b) As a designated item in the code band 4000 - 4999 (see B.3.3.5).

Table B.1 — Four-digit chemical character codes for metal ions and simple compounds

Metal ion		Code and compound when the metal ion is combined with following anion ¹⁾									
chemical symbol	code	boride	carbide	nitride	oxide	fluoride	silicide	phosphide	sulfide	iodide	
Li	0001	0101 Li _x B _y	0201 Li ₂ C ₂	0301	0401	0501	0601	0701	0801	0901	
Be	0002	0102 Be ₁ B _y	0202 Be ₂ C	0302	0402	0502	x	x	0802 BeS	0902	
B	0003	x	0203 B ₃ C _y	0303	0403	0503 (g)	0603 B _x Si	0703	0803	0903	
C	0004	x	x	x	0404 CO _x (g)	0504	x	x	0804 C _x S	0904	
Na	0005	0105 NaB _y	0205 Na ₂ C ₂	0305	0405	0505	x	0705	0805 Na _x S _y	0905	
Mg	0006	0106 MgB _{2,4}	0206	0306	0406	0506	0606 Mg _x Si _y	x	0806	0906	
Al	0007	0107 Al ₁ B _y	0207	0307	0407	0507	x	0707	0807	0907	
Si	0008	0108 Si _x B _y	0208	0308	0408	0508 (g)	x	x	0808 Si _x S _y	0908	
P(I)	x	x	x	x	x	x	x	x	x	x	
P(III)	x	0110 PB ₆	x	x	0410	0510 (g)	x	x	0810 P _x S _y	0910 PI ₃	
P(V)	0011	x	x	0311	0411	0511 (g)	x	x	x	x	
S(II)	x	x	0212	x	0412 S ₂ O ₃	x	x	x	x	x	
S(IV)	0013	x	x	0313 S ₄ N ₄	0413 SO ₂	0513 (g)	x	x	x	x	
S(VI)	x	0114 B ₁₂ S ₂	x	x	0414 SO ₃	0514 (g)	x	x	x	x	
K	0015	0115 KB ₆	0215 KC ₆	x	0415	0515	x	x	0815 K _x S _y	0915	
Ca	0016	0116 CaB ₆	0216 CaC ₂	0316	0416	0516	0616 CaSi ₂	0716 Ca ₃ P ₂	0816 CaS	0916	
Sc	0017	0117 ScB _{2,12}	0217 Sc ₂ C _y	0317	0417	0517	0617	x	0817 Sc ₂ S _y	x	
Ti(II)	x	x	x	x	0418	x	0618	x	0818 TiS	x	
Ti(III)	x	x	x	0319	0419	0519	0619	0719 Ti ₃ P	0819 Ti ₂ S ₃	0919	
Ti(IV)	0020	0120 TiB ₂	0220 TiC	x	0420	0520	0620	x	0820 TiS ₂	0920	
V(II)	x	x	0221 V ₂ C	x	0421	x	0621 V ₂ Si	x	0821 VS	x	
V(III)	x	x	0222 V ₄ C ₃	0322	0422	0522	0622 V ₃ Si	x	0822 V ₂ S ₃	0922 (h)	
V(IV)	x	x	0223 V ₂ C	x	0423	0523	x	0723 V ₃ P	x	x	
V(V)	0024	0124 V ₄ B _y	0224 V ₄ C _y	x	0424	0524	0624 VSi ₂	0724 VP	0824 V ₂ S ₅	x	
Cr(II)	x	x	x	x	0425	0525	x	x	0825	0925	
Cr(III)	0026	x	0226 Cr ₃ C ₂	0326 CrN	0426	0526	0626	0726 CrP	0826	x	
Cr(VI)	x	0127 Cr _x B _y	x	x	0427	x	x	x	0827 Cr ₃ S ₄	x	
Mn(II)	0028	x	x	x	0428	0528 MnF ₂	0628 MnSi	0728 MnP	0828 MnS	0928	
Mn(IV)	x	0129 Mn _n B _y	0229 Mn _n C _y	x	0429	0529 MnF ₃	0629 MnSi ₂	0729 Mn ₃ P ₂	0829 MnS ₂	x	
Mn(VII)	x	x	x	0330 Mn ₂ N	0430	x	x	x	x	x	

Metal ion		Code and compound when the metal ion is combined with following anion ¹⁾									
chemical symbol	code	boride	carbide	nitride	oxide	fluoride	silicide	phosphide	sulfide	iodide	
Fe(II)	0031	0131 Fe ₂ B	0231 Fe ₃ C	x	0431	0531	0631 FeSi _x	0731 Fe ₂ P	0831 FeS	0931	
Fe(III)	x	0132 FeB	0232 Fe ₂ C ₃	0332	0432	0532	x	0732 Fe ₃ P	0832 Fe ₂ S ₃	x	
Co(II)	0033	0133 Co ₄ B	x	x	0433	0533 (h)	0633 CoSi	0733 Co ₂ P	0833 CoS	0933	
Co(III)	x	x	x	0334	0434	0534	0634 CoSi ₂	x	0834 Co ₂ S ₃	x	
Ni	0035	0135 Ni ₄ B _y	0235 Ni ₃ C	0335	0435 NiO _x	0535	0635 Ni ₂ Si _x	0735 Ni ₃ P	0835 NiS _x	0935	
Cu(I)	x	x	x	x	0436	0536	x	0736 Cu ₃ P	0836 Cu ₂ S	0936	
Cu(II)	0037	0137 Cu ₄ B _y	x	x	0437	0537 (h)	0637	0737 Cu ₃ P ₂	0837 CuS	x	
Zn	0038	0138 ZnB ₂	x	x	0438	0538	x	0738 Zn ₃ P ₂	0838	0938	
Ga	0039	x	x	x	0439	0539	x	0739	0839 Ga ₄ S _y	0939	
Ge(II)	x	x	x	x	x	0540	x	0740 GeP	0840 GeS	0940	
Ge(IV)	0041	x	x	x	0441	0541	0641 Si ₂ Ge _y	x	0841 GeS ₂	0941	
As(III)	x	x	x	x	0442	0542 (g)	0642	x	0842	0942	
As(V)	0043	0143	x	x	0443	0543 (g)	0643	0743	0843	0943	
Se(IV)	x	x	x	x	0444	0544	x	x	0844 SeS	0944	
Se(VI)	0045	x	x	x	x	0545	x	x	0845 SeS ₂	0945 Se ₂ I ₂	
Rb	0046	x	0246	x	0446 Rb ₄ O _y	0546	x	0746	0846 Rb ₂ S _y	0946	
Sr	0047	0147 SrB ₆	0247 SrC ₂	x	0447	0547	x	0747	0847	0947	
Y	0048	0148 YB _{4,6}	0248	0348	0448	0548 (h)	0648	0748	0848	0948	
Zr	0049	0149 ZrB ₂	0249	0349	0449	0549	0649	0749	0849	0949	
Nb(III)	0050	0150 Nb ₃ B ₂	0250	0350	0450 NbO	x	x	x	x	x	
Nb(V)	0051	0151 NbB ₂	0251 NbC	x	0451	0551	x	0751 NbP	x	x	
Mo(III)	0052	x	0252 Mo ₂ C	0352	0452	x	x	0752 MoP	x	x	
Mo(VI)	x	0153 MoB ₂	x	x	0453	0553 MoF ₆	0653 MoSi ₂	0753 MoP ₂	0853 Mo ₂ S _y	0953 MoI ₆	
Ru(III)	x	x	x	x	0454	0554	x	x	x	x	
Ru(IV)	x	x	x	x	0455	0555	x	x	x	x	
Ru(VI)	0056	0156 Ru ₄ B _y	x	x	0456 RuO ₄	0556 RuF ₅	0656 RuSi	x	0856 RuS ₂	0956 RuI ₆	
Rh	0057	0157 Rh ₄ B _y	x	x	0457 Rh ₄ O _y	0557	x	0757	0857 Rh ₄ S _y	x	
Pd	0058	0158 Pd ₄ B _y	x	x	0458 Pd ₄ O _y	0558 Pd ₄ F _y	0658 Pd ₂ Si	x	0858 Pd ₄ S _y	0958	
Ag	0059	x	x	x	0459 AgO	0559 Ag ₄ F	0659	x	0859 Ag ₄ S	0959	
Cd	0060	x	x	x	0460	0560	x	x	0860	0960	

Code and compound when the metal ion is combined with following anion¹⁾

Metal ion		Code and compound when the metal ion is combined with following anion ¹⁾									
chemical symbol	code	boride	carbide	nitride	oxide	fluoride	silicide	phosphide	sulfide	iodide	
In	0061	x	x	x	0461 In ₂ O ₃	0561	0661	0761 InP	0861 In ₂ S ₃	0961 InI ₃	
Sn(II)	x	x	x	x	0462	0562	x	0762 Sn ₃ P ₂	0862	0962	
Sn(IV)	0063	x	x	x	0463	0563	0663 SnSi	x	0863	0963	
Sb(III)	x	x	x	x	0464	0564	x	x	0864	0964	
Sb(V)	0065	x	x	x	0465	0565 (l)	x	x	0865	0965	
Te(IV)	x	x	x	x	0466	0566	x	x	0866 TeS ₂	0966	
Te(VI)	0067	x	x	x	0467	0567	x	x	x	0967	
Cs	0068	x	0268 CsC ₈	x	0468 Cs ₂ O ₃	0568	x	x	0868 CsS ₂	0968	
Ba	0069	0169 BaB ₆	x	x	0469	0569	x	x	0869 BaS	0969 (h)	
La	0070	0170 LaB _{4,6}	0270 LaC ₂	0370	0470	0570	0670	0770	0870	0970	
Ce(III)	x	0171 CeB ₆	0271 Ce ₂ C ₃	x	0471	0571	x	0771	0871 Ce ₂ S ₃	x	
Ce(IV)	0072	0172 CeB ₄	0272 CeC ₂	0372	0472 (h)	0572 (h)	0672 CeSi ₂	x	x	0972 (h)	
Pr	0073	0173 PrB _{4,6}	0273 Pr ₂ C ₃	0373	0473 Pr ₂ O ₃	0573	0673	x	0873 Pr ₂ S ₃	x	
Nd(III)	0074	0174 NdB ₆	0274 Nd ₂ C ₃	0374	0474	0574	0674 Nd ₂ Si ₃	0774	0874 Nd ₂ S ₃	0974	
Nd(IV)	x	0175 NdB ₄	0275 NdC ₂	x	x	x	0675 Nd ₃ Si ₄	x	x	x	
Sm	0076	0176 SmB _{4,6}	0276 Sm ₂ C ₃	0376	0476	0576	0676	0776	0876	0976	
Eu	0077	0177 EuB _{4,6}	0277 Eu ₂ C ₃	0377	0477	x	x	x	0877 EuS	x	
Gd	0078	0178 GdB _{4,6}	0278 Gd ₂ C ₃	x	0478	0578	0678 GdSi ₂	0778	0878 Gd ₂ S ₃	x	
Dy	0079	0179 DyB _{4,6}	0279 Dy ₂ C ₃	0379	0479	x	0679	0779	0879	x	
Ho	0080	0180 HoB _{4,6}	0280 Ho ₂ C ₃	0380	0480	x	x	x	x	x	
Er	0081	0181 ErB _{4,6}	0281 Er ₂ C ₃	0381	0481	x	0681	0781	x	x	
Yb	0082	0182 YbB _{4,6}	0282 Yb ₂ C ₃	0382	0482	0582	x	0782	0882	x	
Hf	0083	0183 HfB ₂	0283 HfC	0383	0483	x	0683	0783 HfP	x	x	
Ta(IV)	x	x	0284 TaC	0384	0484	x	0684 Ta ₂ Si	x	0884 TaS ₂	x	
Ta(V)	0085	0185 TaB _{4,6}	x	0385	0485	0585	0685 TaSi ₂	0785 TaP	x	x	
W(IV)	x	x	0286 W ₂ C	0386 W ₂ N	0486 WO ₂	x	0686 WSi ₂	0786 WP	0886 WS	0986 WI ₂	
W(VI)	0087	0187 W ₂ B ₃	0287 WC	0387 WN	0487 WO ₃	0587 (g)	x	0787 WP ₂	0887 WS ₂	0987 WI ₄	
Re	0088	0188 Re ₂ B ₃	x	x	0488 Re ₂ O ₇	0588 ReF _{4,6}	x	x	x	x	
Ir	0089	0189 Ir ₂ B ₃	x	x	0489 Ir ₂ O ₇	0589 IrF ₆	0689	x	0889 IrS ₂	0989 IrI ₃	
Pt	0090	0190 PtB	x	x	0490 Pt ₂ O ₇	x	0690	x	0890 PtS ₂	0990 PtI _{2,4}	

Metal ion		Code and compound when the metal ion is combined with following anion ¹⁾									
chemical symbol	code	boride	carbide	nitride	oxide	fluoride	silicide	phosphide	sulfide	iodide	
Au	0091	0191 Au _x B _y	x	x	0491 Au _x O _y	x	x	0791	0891	0991	
Ti	0092	x	x	0392 TiN ₃	0492 Ti _x O _y	0592 TiF _{1,3}	x	x	0892 Ti _x S _y	0992 Ti _x I _y	
Pb(II)	x	x	x	x	0493 PbO	0593	x	x	0893 PbS	0993 Pbl	
Pb(IV)	0094	x	x	x	0494 PbO ₂	x	x	x	x	0994 PbI ₂	
Bi	0095	x	x	x	0495	0595	x	x	0895 Bi ₂ S ₃	0995	
Th	0096	0196 ThB ₆	0296 ThC ₂	0396	0496	0596	x	0796	0896	0996	
U(III)	x	x	x	x	0497 U ₃ O ₈	x	0697 U ₃ Si	x	0897 U ₂ S ₃	0997	
U(IV)	0098	x	0298 δ-UC	x	0498 UO ₂	0598	0698 U ₃ Si ₂	0798 U ₃ P ₄	0898 US ₂	0998	
U(VI)	x	0199 U _x B _y	0299 UC ₂	0399	0499 UO ₃	0599 (g)	x	x	x	0999	
Other	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	

1) (g), normally gaseous; (l), normally liquid; (h), normally with water of crystallization; A_xB_y, there may be several distinct compounds with various values of x and y (some may not be truly stoichiometric); x, does not exist, or not appropriate. The existence of more than one distinct compound with a single code is indicated by the use of a semicolon ";", within the subscript "y".

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B.3.3 Four-digit codes for other compounds

B.3.3.1 General

For specific chemical compounds which are not available from table B.1, a four-digit code is specified. The four digits in the chemistry code will identify the item as belonging to one of the specific listed types. The listing is arranged according to the following hierarchy.

Code No.	Description
1000 - 1999	Binary stoichiometric compounds and compositions not directly available from the matrix in table B.1 (see B.3.3.2)
2000 - 2999	Ternary stoichiometric compounds (see B.3.3.3)
3000 - 3999	Other stoichiometric compounds (see B.3.3.4)
4000 - 4999	Non-stoichiometric compounds (see B.3.3.5)
5000 - 9999	Designated compositional bands defined for generic material types (see B.3.3.6)

NOTE 5 This four-digit code system provides sufficient space for the materials of more complex composition which are in current usage and will allow additions of items which may warrant inclusion in the future.

Codes 5000 - 9999 are for specific material types or compositions, and are included in order to provide alternative simple classification codes for complex materials in common usage where full chemical identification is neither practical nor desirable. In practice, this situation leads to the possibility of identifying a product either by a combination of simple compound codes or by a single four-digit code representing a material group. It is not possible to avoid this situation without losing a great deal of flexibility in use, but the numbering system remains unique. In any computer-based method of handling the codes, links between these possibilities must be identified in order to ensure identification of the synonyms.

B.3.3.2 Classification codes for binary stoichiometric compounds and compositions not directly available from the matrix in table B.1: codes 1000 - 1999

The following grouping is employed:

1000 - 1099	Aluminides
1100 - 1199	Antimonides
1200 - 1299	Arsenides
1300 - 1399	Bromides
1400 - 1499	Chlorides
1500 - 1599	Hydrides
1600 - 1699	Selenides
1700 - 1799	Tellurides
1800 - 1999	Binary components with other radicals

Individual classified compounds are as follows.

1000	Nickel aluminide
1099	Other aluminides
1100	Indium antimonide
1101	Lead antimonide
1102	Nickel antimonide
1103	Potassium antimonide
1104	Sodium antimonide
1199	Other antimonides

1200	Cadmium arsenide
1201	Copper arsenide
1202	Indium arsenide
1203	Nickel arsenide
1299	Other arsenides
1300	Beryllium bromide
1301	Boron bromide
1302	Cadmium bromide
1303	Indium bromide
1304	Lithium bromide
1305	Nickel bromide
1306	Silicon bromide
1399	Other bromides
1400	Boron trichloride
1401	Calcium chloride
1402	Cerium chloride
1403	Chromium chloride
1404	Indium chloride
1405	Lithium chloride
1406	Magnesium chloride
1407	Nickel chloride
1408	Potassium chloride
1409	Silicon chloride
1499	Other chlorides
1500	Boron hydride
1501	Lithium hydride
1502	Silicon hydride
1503	Titanium hydride
1599	Other hydrides
1600	Copper selenide
1601	Indium selenide
1602	Zinc selenide
1699	Other selenides
1700	Indium telluride
1701	Lead telluride
1799	Other tellurides
1999	Other binary stoichiometric compounds

B.3.3.3 Classification codes for ternary stoichiometric compounds: codes 2000 - 2999

This classification is divided into the following alphabetical hierarchy:

2000 - 2049	Aluminates
2050 - 2099	Borates
2100 - 2109	Cerates
2110 - 2119	Chromites
2120 - 2149	Cuprates
2150 - 2199	Ferrites
2200 - 2249	Ferrates

2250 - 2299	Germanates
2300 - 2349	Manganates
2350 - 2399	Niobates
2400 - 2449	Phosphates
2450 - 2549	Silicates
2550 - 2599	Stannates
2600 - 2649	Sulfates
2650 - 2749	Titanates
2750 - 2799	Tungstates
2800 - 2849	Vanadates
2850 - 2899	Zirconates
2900 - 2999	Other ternary stoichiometric species

Individual classified compounds are as follows.

2000	Barium aluminate
2001	Beryllium aluminate
2002	Calcium aluminate
2003	Lithium aluminate
2004	Magnesium aluminate
2005	Potassium aluminate
2006	Sodium aluminate
2007	Zinc aluminate
2049	Other aluminates
2050	Aluminium borate
2051	Lithium borate
2052	Potassium borate
2053	Sodium borate
2054	Zinc borate
2099	Other borates
2100	Strontium cerate
2109	Other cerates
2110	Lanthanum chromite
2119	Other chromates or chromites
2120	Aluminium cuprate
2121	Barium cuprate
2122	Lanthanum cuprate
2123	Neodymium cuprate
2124	Praseodymium cuprate
2149	Other cuprates
2150	Calcium ferrite
2151	Cobalt ferrite
2152	Lead ferrite
2153	Magnesium ferrite
2154	Manganese ferrite
2155	Nickel ferrite
2156	Sodium ferrite
2157	Zinc ferrite
2199	Other ferrites

2200	Copper ferrate
2201	Nickel ferrate
2202	Zinc ferrate
2249	Other ferrates
2250	Lithium germanate
2251	Potassium germanate
2252	Sodium germanate
2299	Other germanates
2300	Barium manganate
2301	Nickel manganate
2349	Other manganates
2350	Lead niobate
2351	Lithium niobate
2399	Other niobates
2400	Aluminium phosphate
2401	Cadmium phosphate
2402	Calcium phosphate
2403	Lead phosphate
2404	Lithium phosphate
2405	Magnesium phosphate
2406	Manganese phosphate
2407	Potassium phosphate
2408	Sodium phosphate
2409	Zinc phosphate
2410	Zirconyl phosphate
2449	Other phosphates
2450	Aluminium silicate
2451	Barium silicate
2452	Beryllium silicate (beryl)
2453	Cadmium silicate
2454	Calcium silicate
2455	Cobalt silicate
2456	Iron silicate
2457	Lead silicate
2458	Lithium silicate
2459	Magnesium silicate (MgSiO_3 , enstatite)
2460	Magnesium silicate ($2\text{MgO} \cdot \text{SiO}_2$, forsterite)
2461	Potassium silicate
2462	Sodium silicate
2463	Zinc silicate (willemite)
2464	Zirconium silicate (zircon)
2549	Other silicates
2550	Indium stannate
2599	Other stannates
2600	Barium sulfate
2601	Calcium sulfate
2649	Other sulfates

2650	Aluminium titanate
2651	Barium titanate
2652	Calcium titanate
2653	Iron titanate
2654	Lead titanate
2655	Lithium titanate
2656	Magnesium titanate
2657	Manganese titanate
2658	Potassium titanate
2659	Sodium titanate
2660	Strontium titanate
2749	Other titanates
2750	Calcium tungstate
2751	Cerium tungstate
2752	Iron tungstate
2753	Lead tungstate
2754	Lithium tungstate
2755	Potassium tungstate
2756	Sodium tungstate
2799	Other tungstates
2800	Iron vanadate
2849	Other vanadates
2850	Calcium zirconate
2851	Lead zirconate
2852	Lithium zirconate
2853	Magnesium zirconate
2854	Titanium zirconate
2899	Other zirconates
2999	Other ternary stoichiometric compounds

B.3.3.4 Classification codes for other stoichiometric compounds: codes 3000 - 3999

There is a wide variety of materials falling into this category, so only a broad hierarchy can be defined:

3000 - 3399	Oxide based compounds
3400 - 3699	Non-oxide based compounds
3700 - 3999	Mixed oxide/non-oxide based compounds

Individual classified compounds are as follows.

3000	Aluminium zirconium silicate
3001	Antimony sulfur iodide
3002	Barium aluminium silicate
3003	Barium magnesium aluminium silicate (barium osumilite)
3004	Bismuth strontium calcium copper oxide

3006	Calcium aluminium silicate
3007	Calcium magnesium silicate
3008	Calcium strontium barium zirconate
3011	Lead fluorosilicate
3012	Lead lanthanum zirconate titanate
3013	Lead magnesium tungstate
3014	Lead nickel tungstate
3016	Lead zirconate titanate
3017	Lithium aluminium silicate
3019	Lithium cadmium silicate
3020	Lithium zinc silicate
3022	Magnesium aluminium silicate (cordierite)
3023	Manganese copper ferrite
3024	Manganese magnesium ferrite
3025	Manganese magnesium zinc ferrite
3026	Manganese zinc ferrite
3027	Nickel zinc ferrite
3028	Potassium aluminium silicate (feldspar)
3030	Sodium aluminium silicate (feldspar)
3032	Sodium zirconium aluminate
3033	Ytterbium barium titanate
3034	Yttrium aluminium silicate
3035	Yttrium barium copper oxide
3036	Yttrium iron silicate
3399	Other complex oxide compounds
3400	Titanium carbonitride
3449	Other carbonitrides
3700	Aluminium oxynitride (AlON)
3701	Silicon oxynitride
3702	Silicon aluminium oxynitride
3749	Other oxynitrides
3801	Silicon oxycarbide
3849	Other oxycarbides
3999	Other non-oxide based compounds

B.3.3.5 Classification codes for non-stoichiometric compounds: codes 4000 - 4999

In the formulation of this coding system no specific instances of non-stoichiometric compounds requiring a separate code have been identified. This situation will be revised in accordance with user demand.

The only classification given at present is therefore

4999 Other non-stoichiometric compounds

B.3.3.6 Alternative simple classification codes for designated compositional bands defined for generic material types: codes 5000 - 9999

The four-digit codes in the range 5000 - 9999 defining the generic material types are obtained from the following list which is presented in alphabetical order of the first metallic species by which the product is normally known from its chemical formula.

There may be occasions where there is no preferred name. For example, yttrium aluminate and aluminium yttrate are equivalent names for yttrium aluminium garnet (YAG). In such cases it is recommended to search the coding list for both names. If neither is found, use the "other" classification for the principal metal species appearing highest in the alphabetical list, in this case under aluminium.

For the identification of materials described by mineral or other non-chemical names, it should be noted that porcelains may be found under aluminosilicates, mica-based products may be found under aluminosilicates, cordierites may be found under magnesium aluminosilicates, steatites and forsterites may be found under magnesium silicates, and apatite based materials may be found under phosphates.

5000 - 5099	Materials based on α -alumina
5001	Al_2O_3 materials — ultra high purity ($> 99,99\%$)
5005	Al_2O_3 materials — extreme high purity ($> 99,8\% \leq 99,99\%$)
5010	Al_2O_3 materials — very high purity ($> 99,5\% \leq 99,8\%$)
5020	Al_2O_3 materials — high purity ($> 99\% \leq 99,5\%$, IEC 672-3:1984, group C-799)
5030	Al_2O_3 materials — technical ($> 96,5\% \leq 99\%$ alumina, IEC 672-3:1984, group C-795)
5040	Al_2O_3 materials — technical ($> 94\% \leq 96,5\%$ alumina, IEC 672-3:1984, groups C-786 and C-795)
5041	5040 with CaO/SiO_2 additive
5042	5040 with $\text{MgO}/\text{CaO}/\text{SiO}_2$ additive
5043	5040 with MnO/TiO_2 additive
5049	5040 with other additives
5050	Al_2O_3 materials — technical ($> 90\% \leq 94\%$ alumina, IEC 672-3:1984, group C-786)
5051	5050 with CaO/SiO_2 additive
5052	5050 with $\text{MgO}/\text{CaO}/\text{SiO}_2$ additive
5053	5050 with MnO/TiO_2 additive
5059	5050 with other additives
5060	Al_2O_3 materials — technical ($> 80\% \leq 90\%$ alumina, IEC 672-3:1984, groups C-780 and C-786)
5061	5060 with CaO/SiO_2 additive
5062	5060 with $\text{MgO}/\text{CaO}/\text{SiO}_2$ additive
5063	5060 with MnO/TiO_2 additive
5069	5060 with other additives

5070	Al ₂ O ₃ materials, ≤ 80 % alumina
5080	Al ₂ O ₃ /ZrO ₂ materials
5100 - 5149	Other Al ₂ O ₃ based materials
5100	Gamma alumina
5101	Delta alumina
5110	Tabular alumina
5120	Sapphire
5121	Ruby
5130	Sodium β-alumina
5149	Other types of alumina
5150 - 5199	Alumina matrix composites
5150	— containing SiC long fibres
5159	— containing other fibres
5160	— containing SiC whiskers
5169	— containing other whiskers
5170	— containing SiC platelets
5179	— containing other platelets
5180	— containing SiC particulates
5181	— containing TiC particulates
5182	— containing ZrO ₂ particulates
5189	— containing other particulates
5190	— containing SiC whiskers and ZrO ₂ particulates
5199	Other alumina matrix composites
5200 - 5209	Aluminium nitrides
5200	Electronic grade (metallic impurity level ≤ 200 ppm)
5205	Technical grade (metallic impurity level > 200 ppm)
5209	Other aluminium nitrides
5210 - 5219	Aluminium oxynitrides
5210	Optical grade aluminium oxynitride
5215	Aluminium nitride polytypoids (e.g. 15R)
5219	Other aluminium oxynitrides
5220 - 5349	Aluminosilicate based materials
5220	Fused mullite
5221	Calcined mullite
5222	Molochite based
5223	Sillimanite based
5224	Kyanite based
5225	Andalusite based
5226	Pyrophyllite based
5230	High purity sintered mullite
5231	Mullite/zirconia ceramics
5232	Mullite ceramics (IEC 672-3:1984, group C-600)
5239	Other mullite based materials
5310	Siliceous alkali porcelain materials (IEC 672-3:1984, group C-110)
5311	Siliceous alkali porcelain materials, pressed (IEC 672-3:1984, group C-111)
5320	Siliceous alkali porcelain materials, high strength (IEC 672-3:1984, group C-120)
5330	Siliceous alkali porcelain materials, high strength (IEC 672-3:1984, group C-130)

5340	Natural mica based materials
5341	Fluorine substituted mica based materials
5344	Other mica based materials
5349	Other aluminosilicate based materials
5350 - 5355	Aluminium titanate based materials
5350	Stoichiometric aluminium titanate
5351	Aluminium titanate with stabilizers
5355	Other aluminium titanate based materials
5360	Antimony based materials
5380 - 5449	Barium based materials
5380	Barium carbonate based materials
5390	Barium silicate based materials
5395	Barium aluminosilicate based materials (celsian)
5400	Barium titanate based materials
5440	Barium fluoride based materials
5449	Other barium based materials
5450 - 5489	Beryllium based materials
5450	Beryllia, high purity, high thermal conductivity ($> 99,5$ % BeO, IEC 672-3:1984, group C-810)
5451	Beryllia, medium purity, medium thermal conductivity (95 % \leq $99,5$ % BeO, IEC 672-3:1984, group C-810)
5460	Beryllia/SiC composites
5469	Other beryllia based materials
5470	Beryllium boride based materials
5489	Other beryllium based materials
5490 - 5499	Bismuth based materials
5490	Bismuth oxide based materials
5495	Bismuth calcium strontium copper oxide materials
5499	Other bismuth based materials
5500 - 5529	Boron carbide based materials
5500	Dense pure near-stoichiometric materials
5505	Non-stoichiometric materials
5510	Dense, containing boron additive
5511	Dense, containing carbon additive
5520	Boron carbide/titanium diboride composites
5529	Other boron carbides
5530 - 5549	Boron nitride based materials
5530	Hot-pressed hexagonal boron nitride
5535	CVD hexagonal boron nitride
5539	Cubic boron nitride materials
5540	Boron nitride/titanium diboride composites
5549	Other boron nitride composites
5550 - 5579	Calcium based materials
5551	Calcium oxide based materials
5552	Calcium silicate based materials

5555	Calcium aluminosilicate based materials
5560	Calcium magnesium silicate based materials
5565	Calcium zirconium silicate based materials
5569	Other calcium oxide based materials
5570	Calcium fluoride based materials
5579	Other calcium based materials
5580 - 5599	Carbon based materials
5580	Diamond single crystals
5581	Diamond based composites
5582	Diamond-like films
5585	CVD graphite
5590	Vitreous carbon
5595	Fullerenes
5599	Other carbon based materials
5600 - 5609	Cerium based materials
5600	Cerium oxide based materials
5605	Cerium sulfide based materials
5609	Other cerium based materials
5610 - 5619	Chromium based materials
5610	Chromia based materials
5619	Other chromium based materials
5620	Cobalt based materials
5630 - 5639	Copper based materials
5630	Copper oxide based materials
5639	Other copper based materials
5640	Dysprosium based materials
5650	Erbium based materials
5660	Europium based materials
5670 - 5679	Gadolinium based materials
5670	Gadolinium iron garnet materials
5679	Other gadolinium based materials
5680	Gallium oxide based materials
5690	Germanium oxide based materials
5700 - 5709	Hafnium based materials
5700	Hafnium oxide based materials
5705	Hafnium carbide based materials
5709	Other hafnium based materials
5710 - 5749	Iron based materials
5710	Iron oxide based materials
5720	Iron silicate based materials
5730	Iron chromate based materials
5740	Iron sulfide based materials
5749	Other iron based materials

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