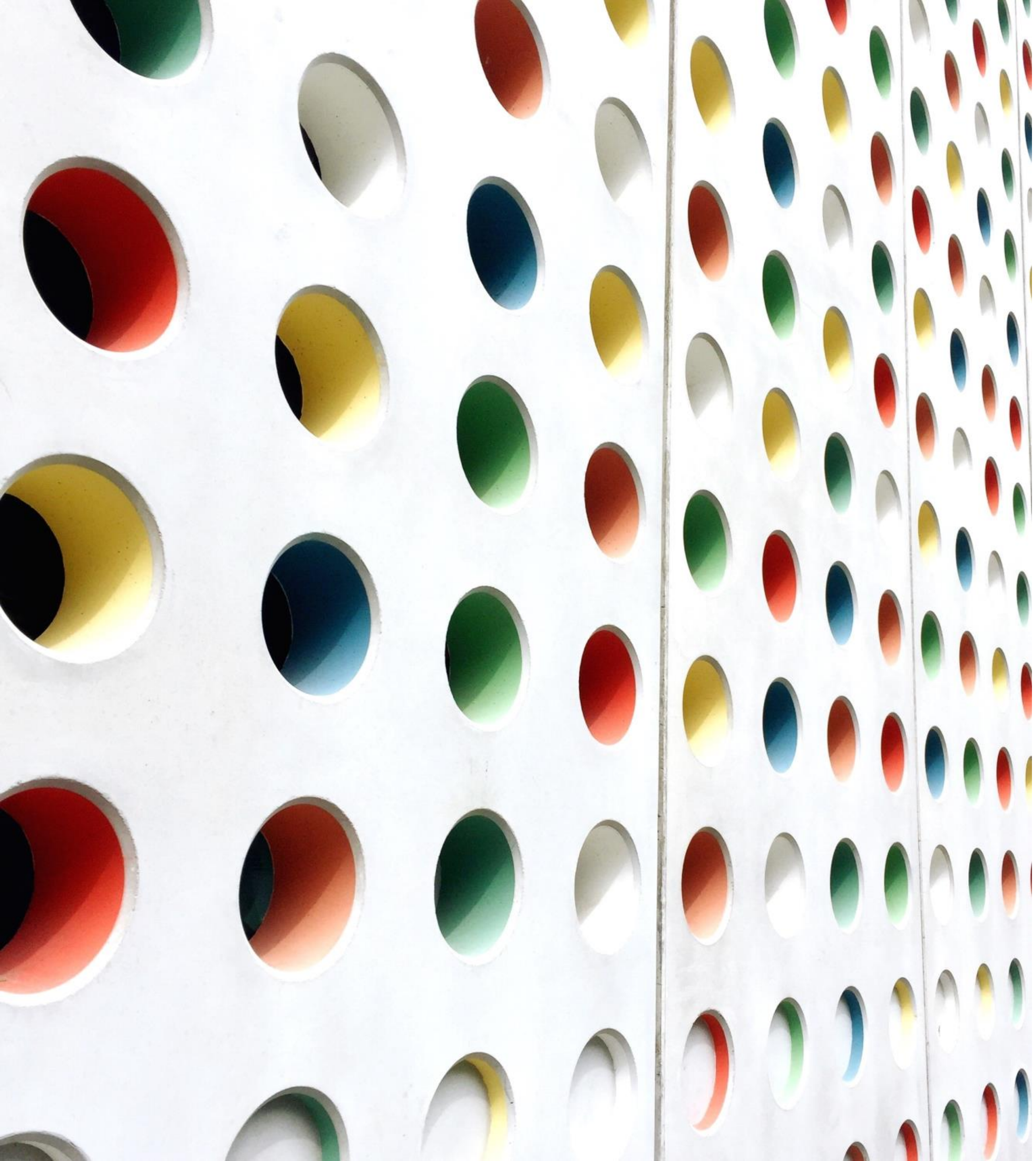

CERAMMING: CHANGING GLASS TO GLASS-CERAMICS

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Ceramming

- The cast glass materials is subject to a single-step heat treatment call "ceramming" to produce controlled crystallization by internal nucleation and crystal growth of microscopic plate like mica crystals within the glass matrix.
- Glass-ceramics are formed by controlled crystallization of a glass.
- They consist of a high density (maybe >95 vol%) of small crystals in a glass matrix.
- The important feature of the processing of glass-ceramics is that the crystallization must be controlled. Crystallization occurs in 2 stages:
  - First the crystals are nucleated
  - Then they grow
- The rate at which these two processes occur is a function of temperature. We can control the nucleation process by adding a nucleating agent (typically either TiO_2 or ZrO_2) to the glass batch

Processing Cycle for a Glass-Ceramic

- Initially, the glass batch is heated to form a homogeneous melt.
- The shape of the desired object is formed from the glass at the working point by the usual processes (pressing, blowing, rolling, or casting)
- The viscosity of the glass is ~10^4 dPas at the working point (like honey).
- After annealing to eliminate internal stresses, the glass object then undergoes a thermal treatment that converts it to a glass-ceramic.
- The first part of the heat treatment is nucleation → optimum nucleation T corresponds to a glass viscosity of 10^{11}-10^{12} dPas.
- During this step, which may last for several hours, an extremely high density (10^{12}-10^{15} cm^3) of nuclei form.
- Following nucleation, T is increased to allow growth to occur. The crystal-growth step, like nucleation, may take several hours.
- The optimum temperature for crystal growth is selected to allow for the maximum development of the crystalline phase without viscous deformation of the object.

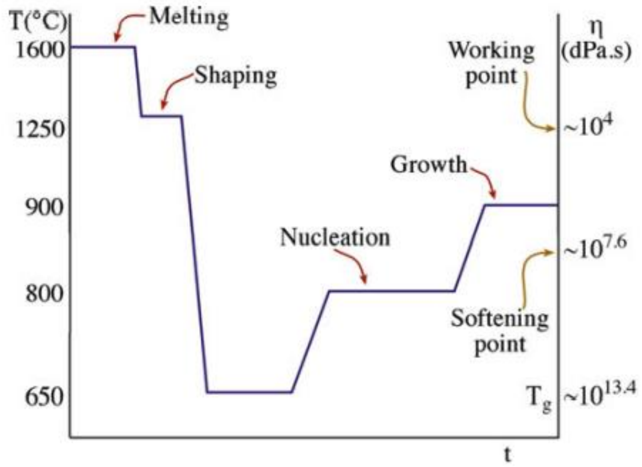
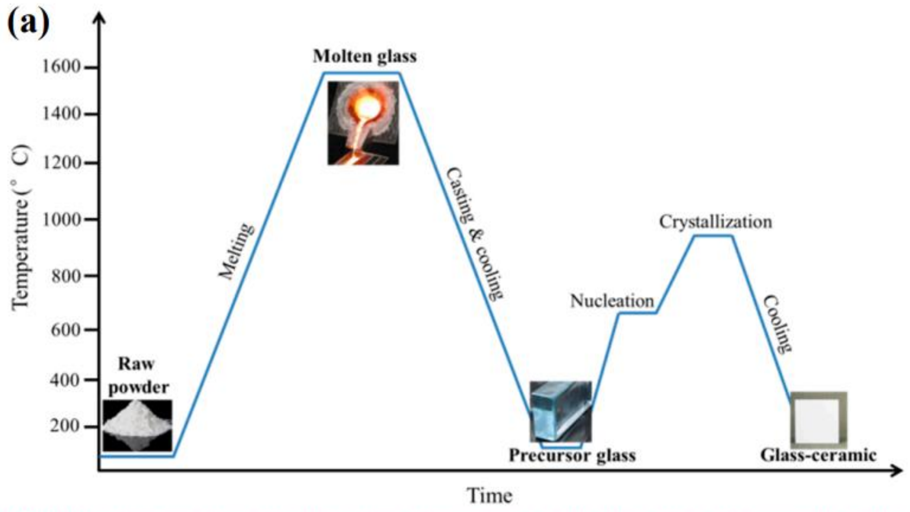


FIGURE 26.14. Processing cycle for a glass-ceramic.

Glass-Ceramics in Dentistry (Le Fu et.al.,Materials 2020, 13, 1049)

- Glass-ceramic is made through controlled heat treatment of a precursor glass, known as ceramming.
- Glass-ceramics also can be produced by concurrent sintering-crystallization of glass-particle compacts.
- The manufacturing of glass-ceramic using classic melting-casting-annealing processes involves 3 general steps:
  - First, preparation of raw materials, glass-forming components, and nucleating agents are mixed with ball milling. The nucleating agents are used to stimulate nucleation in the following annealing process;
  - Second, the batch is melted and then cooled to room temperature to form a precursor glass. A homogeneous molten glass is formed by heating the raw materials to elevated temperature in a high-temperature furnace. The melt is then casted into a mold with the desired shape. After cooling to room temperature, a precursor glass forms
  - Third, the precursor glass is then annealed to induce crystallization, thereby forming glass- ceramic. This process is known as ceramming



Glass-Ceramics in Dentistry (Le Fu et.al.,Materials 2020, 13, 1049)

- The formation of crystalline phases in glass- ceramics comprises 2 main steps:
  - In the first step, the precursor glass is heated to a temperature slightly above the transformation range and maintained for a sufficient time to achieve substantial nucleation. The addition of nucleating agents results in volume or bulk nucleation. Homogeneously dispersed nano-crystals precipitate from the glass matrix. Different nucleation agents are needed for different glass-ceramic systems. The most frequently used nucleating agents for the Li_2O-Al_2O_3-SiO_2 system are ZrO_2, TiO_2, or both
  - In the second step, the nucleated body is heated to a higher temperature to allow the growth of crystals on these nuclei. Types of nucleation agent and thermal treatments during nucleation and crystallization processes are two of the most critical factors that determine the final microstructure of glass-ceramics.
- A wide range of microstructures can be created, including uniform crystal phases, inter-locking crystals, and crystals with a wide variety of shapes and sizes.

Application of glass-ceramic

Application 1

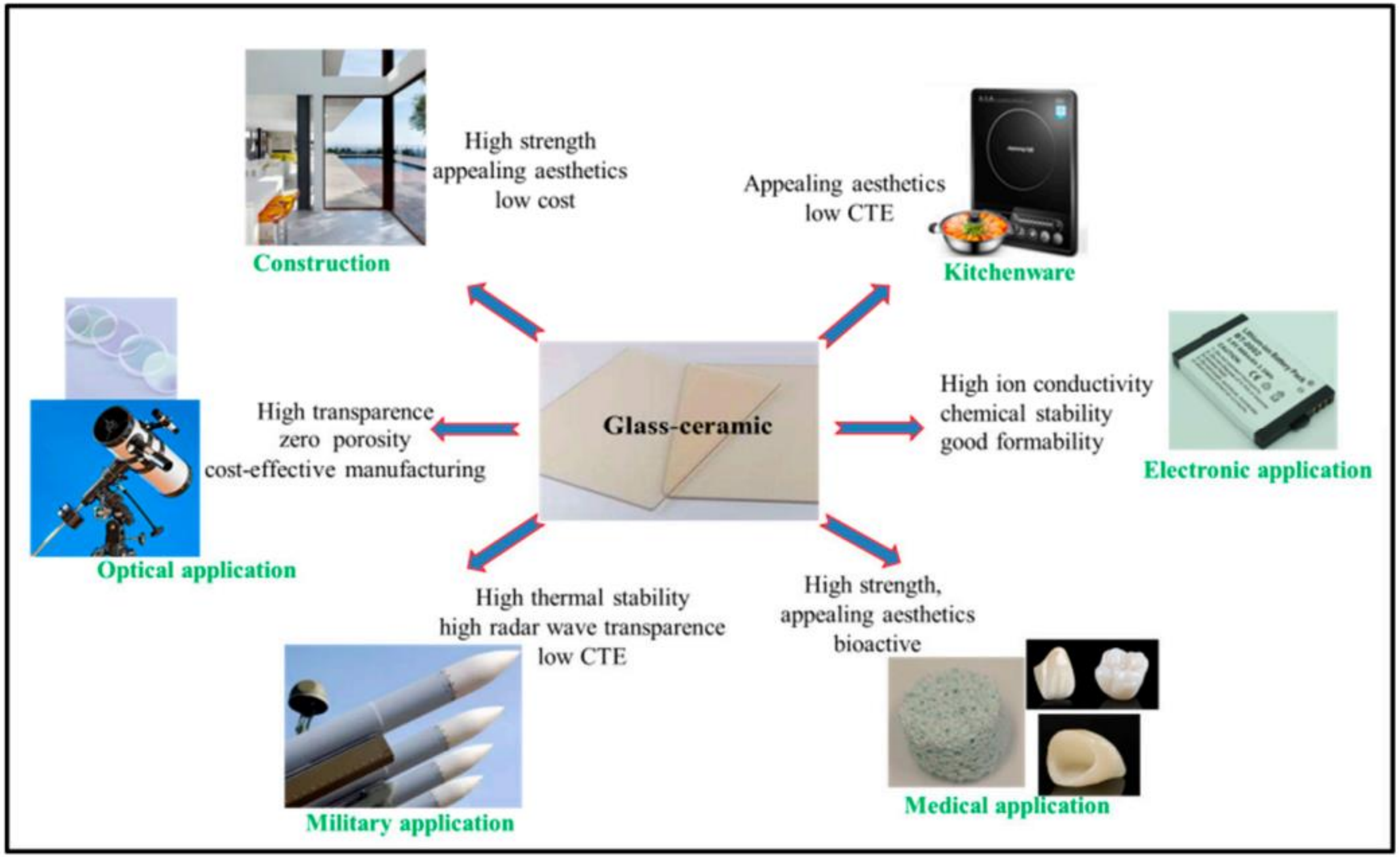
- machinable glass-ceramics are derived from the K_2O-MgO-Al_2O_3-SiO2 system containing some fluorine. In Macor®, the crystalline phase is potassium fluorophlogopite [$KMg_3(AlSi_3O_{10}F_2)$]. Phlogopite is a mica mineral, and the plate-like mica crystals are randomly oriented in the glass phase, as shown in Figure 18.23. Macor® can be machined to precise tolerances (0.01 mm) and into intricate shapes using conventional steel tools: they can be drilled, cut, or turned on a lathe.

Application 2

- Another commercial fluoromica glassceramic, called Dicor®, has been developed for dental restorations. Dicor has better chemical durability and translucency than Macor. It is based on the tetrasilicic mica, $KMg_2.5Si_4O_{10}F_2$, which forms fine-grained (~1 mm) anisotropic flakes. Dicor dental restorations are very similar to natural teeth both in hardness and appearance. They are easy to cast using conventional dental laboratory methods and offer significant advantages over traditional metal-ceramic systems

Application 3

- calcium phosphate, $Ca_3(PO_4)_2$, glasses can be made into glass-ceramics to form a material resembling the mineral part of bone. As bone is porous, the first step is to produce a foam glass. This is achieved by decomposing carbonate in the glass melt. The foam glass simultaneously undergoes controlled crystallization, transforming it into a porous glass-ceramic. The dimensions of the interconnections between the pores must be sufficient to allow the ingrowth of living bone tissue, which ensures a permanent joint with the surface of the prosthesis


High strength
appealing aesthetics
low cost
Construction
Appealing aesthetics
low CTE
Kitchenware
High transparence
zero porosity
cost-effective manufacturing
Glass-ceramic
High ion conductivity
chemical stability
good formability
Electronic application
Optical application
High thermal stability
high radar wave transparence
low CTE
High strength,
appealing aesthetics
bioactive
Military application
Medical application