[0006] Additionally, when manufacturing thinner and thinner sintered articles (e.g., sheets, tapes, ribbons), Applicants postulate that at some point, the sintered articles may become so thin that they are difficult if not impossible to polish. Accordingly, for such articles, those of ordinary skill in the art may be unable to remove surface defects induced by setter boards during sintering or defects caused by cutting. Similarly, for thicker, yet still thin sintered articles, Applicants postulate that at some point the articles have too much surface area to polish. Control of conventional polishing equipment with fragile and/or thin sheets of large surface area may become unwieldy and/or impractical. Accordingly, thin articles, particularly those with relatively large surfaces areas, having qualities generally associated with polishing, such as flatness, smoothness, and/or defect-free surfaces, may be unattainable using conventional manufacturing methods and/or those of ordinary skill in the art may avoid trying to manufacturing such articles due to strong disincentives in terms of overcoming manufacturing challenges and associated costs per article.

[0007] A need exists for equipment and manufacturing processes for making articles, such as tapes and sheets of polycrystalline ceramics, metals, or other materials that may be sintered, where the articles may be efficiently manufactured, such as without excessive polishing, while also having good mechanical properties, such as due to having few surface defects. Such articles may be useful as substrates such as in batteries, on printed circuit boards, as cover sheets for displays, such for handheld devices, or the articles may be otherwise useful.

SUMMARY

[0007a] In an aspect, there is provided a manufacturing line, comprising:

a tape including a green section thereof comprising grains of an inorganic material bound by an organic binder; and

a furnace comprising:

a guide that defines a passage, wherein the passage includes a binder burn-off location and a sintering location, and

a heater that achieves temperature of at least three-hundred degrees Celsius in the sintering location of the passage;

wherein the binder burn-off location chars or burns the organic binder from the green section to form an unbound section of the tape that is not yet sintered but has charred or no binder;

wherein the sintering location at least partially sinters the inorganic material to form an at least partially sintered section of the tape; and

wherein the unbound section supports weight of the tape physically connected and adjacent thereto.

[0007b] In another aspect, there is provided a process of sintering a tape, comprising steps of:

(a) moving a green section of the tape through a first furnace location of a furnace, the green section comprising inorganic grains supported by an organic binder;

(b) burning off or charring the organic binder from the green section as the green section passes through the first furnace location to form an unbound section of the tape;

(c) moving the unbound section through a second furnace location; and

(d) at least partially sintering the inorganic grains as the unbound section passes through the second furnace location to form an at least partially sintered section of the tape,

wherein the step of moving the unbound section through the second furnace location occurs without a setter board supporting the unbound section of the tape.

[0007c] In another aspect, there is provided a sintered article, comprising:

a first surface, a second surface, and a body of material extending therebetween, wherein the second surface is on an opposite side of the sintered article from the first surface such that a thickness of the sintered article is defined as a distance between the first and second surfaces, a width of the sintered article is defined as a first dimension of one of the first or second surfaces orthogonal to the thickness, and a length of the sintered article is defined as a second dimension of one of the first or second surfaces orthogonal to both the thickness and the width of the sintered article,

wherein the body of material comprises an inorganic material;

wherein the length of the sintered article is greater than or equal to the width of the sintered article, and wherein the sintered article is thin such that the width of the sintered article is greater than five times the thickness of the sintered article, the thickness of the sintered article being no more than one millimeter;

wherein the sintered article is substantially unpolished such that the first and second surfaces each have a granular profile;

wherein the sintered article has high surface quality such that the first and second surfaces both have at least a square centimeter of area having fewer than ten surface defects from adhesion or abrasion with a dimension greater than five micrometers, the high surface quality facilitating strength of the sintered article; and

wherein the sintered article has consistent surface quality on both the first and second surfaces such that an average area per square centimeter of the first surface of surface defects from adhesion or abrasion having a dimension greater than 5 micrometers is within plus or minus fifty percent of an average area per square centimeter of the second surface of surface defects from adhesion or abrasion having a dimension greater than 5 micrometers.

[0007d] In another aspect, there is provided a sintered article, comprising:

wherein the sintered article is a sheet comprising a first surface, a second surface, and a body of material extending therebetween, wherein the second surface is on an opposite side of the sheet from the first surface such that a thickness of the sheet is defined as a distance between the first and second surfaces, a width of the sheet is defined as a first dimension of one of the first or second surfaces orthogonal to the thickness, and a length of the sheet is defined as a second dimension of one of the first or second surfaces orthogonal to both the thickness and the width of the sheet,

wherein the body of material is of material selected from the group consisting of polycrystalline ceramic and synthetic mineral, and wherein the material is in a sintered form such that grains of the material are fused to one another;

wherein the first and second surfaces of the sheet are substantially unpolished such that each has a granular profile that includes grains with a height in a range from twenty-five nanometers to one-hundred-and-fifty micrometers relative to recessed portions of the respective surface at boundaries between the grains;

wherein the sheet is thin and elongate such that the length of the sheet is greater than five times the width of the sheet, the width of the sheet is greater than five times the thickness of the sheet, and wherein the thickness of the sheet is no more than one millimeter and the area of each of the first and second surfaces is greater than ten square centimeters;

wherein the sheet has high surface quality such that the first and second surfaces both have at least ten square centimeters of area having fewer than one hundred surface defects from adhesion or abrasion with a dimension greater than five micrometers; and

wherein the sheet has a flatness in the range of one hundred nanometers to fifty micrometers over a distance of one centimeter in a lengthwise direction along either the first or second surface.

[0007e] In another aspect, there is provided a sintered article, comprising:

wherein the sintered article is a ceramic tape;

wherein the ceramic tape comprises a first surface, a second surface, and a body of material extending therebetween, wherein the second surface is on an opposite side of the ceramic tape from the first surface such that a thickness of the ceramic tape is defined as a distance between the first and second surfaces, a width of the ceramic tape is defined as a first dimension of one of the first or second surfaces orthogonal to the thickness, and a length of the ceramic tape is defined as a second dimension of one of the first or second surfaces orthogonal to both the thickness and the width of the ceramic tape,

wherein the body of material is a ceramic selected from the group consisting of alumina, zirconia, and wherein the material is in a sintered form such that grains of the material are fused to one another;

wherein the first and second surfaces of the ceramic tape are substantially unpolished such that each has a granular profile that includes grains with a height in a range from

ten nanometers to one-hundred-and-fifty micrometers relative to recessed portions of the respective surface at boundaries between the grains;

wherein the ceramic tape is thin and elongate such that the length of the ceramic tape is greater than five times the width of the ceramic tape, the width of the ceramic tape is greater than five times the thickness of the ceramic tape, and wherein the thickness of the ceramic tape is no more than 150 micrometers and the area of each of the first and second surfaces is greater than two square centimeters;

wherein the ceramic tape has bulges, wherein at least some of the bulges have a maximum surface dimension between 100 micrometers and about 1 mm, wherein the bulges are have smoothly continuous curvature with respect to surrounding, adjoining surfaces such that borders of the bulges are no generally characterized by adhesion or abrasion; and

wherein, when resting unconstrained on a flat surface, the ceramic tape has a camber about an axis along the length of the ceramic tape.

[0007f] In another aspect, there is provided a roll of ceramic tape, comprising:

a spool;

a tape wound on the spool, wherein the ceramic tape is a sintered article as described above, and wherein the ceramic tape has a length of at least one meter.

[0008] Applicants have discovered technology that removes the setter board from the process of sintering green tape, where resulting sintered articles may be unpolished, yet may have good mechanical properties. In some embodiments, technology disclosed herein relates to a continuous manufacturing line, where a continuous tape includes a green section including inorganic particles held by an organic binder. On the manufacturing line, the green section is directed to a first heated location to burn off or char the binder, forming an unbound section of the same tape. Next, along the manufacturing line, the unbound section is run through a second heated location for at least partial sintering of the inorganic particles. The first and second heated locations may be heated by the same or different furnaces on the manufacturing line. Additional heated locations may be on the manufacturing line to further process the tape, such