Ceramic Composites for Microwave Grilling and Speed Cooking

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A new composite ceramic composite for microwave grilling and cooking has been developed. This ceramic functions as a microwave-heating element, and is proven to microwave grill foods and cook at unprecedented speeds. Previous attempts to develop microwave heating elements had problems: (1) slow heat rates that negate the benefits of microwave heating and cooking, (2) conductivity problems that result in arcing, (3) poor thermal shock resistance that results in cracking if foods or fluids are splashed onto the element, or (4) overall lack of mechanical strength resulting in breakage and inadequate life. A unique ceramic composite has been developed that overcomes these deficiencies. This composite can be placed into commercial microwave ovens to grill, toast, bake and cook foods that previous technologies could not do. This composite delivers a new cooking technology: "microwave-conduction" cooking. This paper will briefly describe the ceramic composite technology, and then demonstrate its utility in microwave grilling and speed cooking.

Key Words: microwave cooking, microwave grilling, microwave baking, speed-cooking, microwave absorbent ceramics, microwave heatable ceramics, microwave-convection, microwave-conduction

INTRODUCTION

Microwave food processing has limitations. The most common use of microwaves is for reheating of foods. Some foods, such as bacon, are amenable to microwave cooking. However, most foods suffer from texture or quality problems when cooked in a microwave. The advent of microwave-convection ovens has corrected this issue somewhat. But these ovens have deficiencies that can limit their utility.

To improve microwave-cooking quality and broaden the functionality of microwave ovens, restaurants and food processing industries have desired microwave-heating elements. The concept of microwave heating elements is as follows: they can be placed in a microwave field, absorb the radiation and provide heat transfer into foods, thereby enhancing food quality, while improving speed, productivity, reducing energy costs and overall costs.

In Quantrille (2007) "Novel Composites for Microwave Heating and Cooking," *Proc. 41st Annual International Microwave Symposium*, the author introduced a functional microwave heating element that the industry has long-desired. This new composite technology overcomes all of the known deficiencies in previous attempts to make microwave-heating elements. These deficiencies were known to be as follows: (1) elements heat too slowly in a microwave field, negating the ability to speed cook, (2) elements tend to be too conductive, and therefore arc, (3) elements exhibit poor thermal shock resistance, resulting in cracking when splashed with foods, or (4) elements have an overall lack of strength, and crack or break until the rigors of food preparations. The product is identified as Silar® microwave absorbent ceramics.

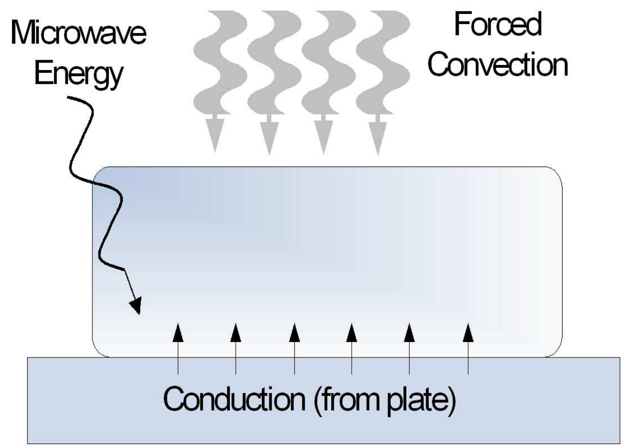
This work describes advances in cooking and applications associated with the Silar® technology. Importantly, this paper introduces an entirely new way of cooking: microwave-conduction cooking. Microwave-conduction cooking uses a microwave-absorbent ceramic that is in direct contact with the food. This approach provides the most rapid heat transfer into foods that is physically possible. In addition, with the proper geometry, foods can be microwave-grilled. This work will describe how microwave absorbent ceramics provide a means for microwave-conduction speed cooking and microwave grilling to improve food quality, shorten cook times, reduce energy consumption, and broaden the types of foods that can be cooked in microwave ovens.

MODES OF HEAT TRANSFER IN SPEED COOKING

Speed cooking works by getting energy into foods faster. Figure 1 Shows the modes of heat transfer into food as it is being speed-cooked in a Silar® ceramic enabled oven. There are three primary modes of energy transfer into the oven:

(1) Microwave Radiation: direct radiant heat transfer into the food via microwave radiation;
(2) Forced Convection: heat transfer into the food via impingement air or hot air flow over the food itself;
(3) Conduction: direct heat transfer into the food via direct contact with the Silar® microwave active ceramic plate.

Figure 1. Modes of Heat Transfer.



Prior to Silar® the only two ways getting energy into foods was through the combination of microwave radiation and forced convection.

The total rate of heat transfer into the food in a Silar® enabled oven is then governed by the following equation:

$$\dot{Q} = Microwave\ Heat + Forced\ Convection + Conduction$$

And more specifically:

$$\dot{Q} = V \cdot 2\pi f E^2 \varepsilon \tan\delta + hA_C(T_A - T_F) + \frac{\kappa A_P(T_P - T_F)}{d}$$

Where:

$\dot{Q}$ = heat transfer rate, watts
V = volume of food to be heated by microwave (m^3)
f = frequency of microwave energy (Hz)
E = voltage gradient (V/m)
$\varepsilon \tan\delta$ = dielectric permittivity and loss tangent of food
h = convection heat transfer coefficient (W/m^2 K)
A_C = surface area of food open to forced convection
$(T_A - T_F)$ = temperature differential between hot air cool food (K)
κ = thermal conductivity of food (W/m K)
A_P = area of food in contact with Silar® ceramic stone
$(T_P - T_F)$ = temperature differential between hot Silar® plate and cool food (K)
d = distance for heat to conduct into food (m)

While this equation is seemingly complex, it does give critical insight into key aspects of Silar® microwave enabled speed cooking. First, the entire conduction equation, i.e., $\kappa A \Delta T/d$, does not exist in either standard microwave, or microwave-convection ovens. Clearly, the Silar® technology then provides the most rapid heat transfer into food possible. In addition, conduction is one of the most efficient means of heat transfer. Silar® enables more energy transfer into food faster.

MANAGING WATER CONTENT

As energy flux into the food increases, water content management becomes increasingly important. Silar® permits the food engineer to better manage the water content. As foods cook, the water content goes down. And as water content declines, typically the $\varepsilon \tan \delta$ of the food declines. By so doing, the microwave heatability of the food declines. With Silar® enabled ovens, this aspect can be used to our advantage. As water content declines, more heat is transferred into the food via conduction, which is perfect for terminally crisping and browning of foods at the end of a cook cycle.

For example, a food can be cooked in a microwave initially at low initial power. Once a desired total water content is reached, the microwave power can be turned up. The result is the Silar® ceramic will absorb proportionally more radiation, resulting in browning of the foods at the terminal end of the cooking cycle.

Another aspect of water content management is using Silar® enabled ovens to go directly from frozen to cooked. Frozen foods, i.e., ice, are generally not very microwave receptive. As ice thaws and converts into water, the $\varepsilon \tan \delta$ of the food rises, as does its microwave heatbility. Therefore, frozen foods can be placed into a Silar® enabled oven and microwave at higher power to speed up the melting process. After the melting has occurred, the microwave power can then be decreased to microwave cook and dewater the food. And again, at the end of the cycle, microwave power can be increased to effect browning.

ONE-STEP SPEED GRILLING OF PANINI SANDWICHES

We now move away from theory and into practical applications of Silar® microwave grill and flatstone. One application is single-step speed grilling of panini sandwiches. In most restaurant applications there are two ways to produce a panini:

(1) Open face: the bread is pre-grilled, then combined with the meats and cheeses and then cooked. This process is a two-stage process and is time consuming.
(2) Panini press: the sandwich is prepared and placed closed into a Panini press. The Panini press toasts and grills the bread and cooks the entire sandwich as well. While this process is single stage, it is time consuming and typically takes 5-7 minutes.

Figure 2. Open-Faced Speed Grilling of Panini Sandwich.

In this cooking test, a *Veloci* microwave convection oven, produced by Amana Commercial microwaves, was fitted with Silar® microwave absorbent ceramic shaped like a grill rod. A Panini sandwich was prepared, using small Italian bread, Pastrami, Provolone cheese, with a mustard and mayonnaise sauce. This sandwich was placed open-faced on the Silar® grill. The following cooking algorithm was developed and used:

Step 1: Oven cavity temperature: 475 ^{o}F fan speed 100%
Step 2: Cook at 50% microwave power for 45 seconds
Step 3: Hold for 10 seconds (no microwave, fan speed 100%, cavity temperature: 475 ^{o}F)
Step 4: Cook at 100% microwave power for 35 seconds

Figure 2 shows the photo results of this cooking algorithm. In approximately 90 seconds, and in a single step process, this panani was grilled, toasted, and cooked to perfection. Silar® changes the speed versus quality paradigm that exists in the making of paninis.

MICROWAVE COOKING OF PAR-BAKED PIZZAS

One trend in the restaurant industry is partially-baked ("parbaked") dough and foods. The product concept for par-baked foods is to deliver partially baked menus items that can be rapidly finished in-restaurant. However, due to limits in cooking technology, these foods have had limited success. One reason is quality; these approaches improve, but still do not alter the speed vs. quality paradigm:

Speed Cooked, Lower Quality ←→ Slower Cooked, Higher Quality

Silar® microwave flatstone provides dramatically better food quality with par-baked pizzas. In this test, a Panasonic NE-3258 oven (microwave only, no convection) was fitted with Silar® microwave flatstone. A par-baked pizza was obtained from Kraft Foodservice. The Panasonic NE-3258 was run for 30 seconds to get the get the oven and the Silar® rack up to operating temperature. The pizza was then placed on the Silar® flatstone and cooked under the following algorithm:

Step 1: Cook at full power (3000 watts) for 30 seconds
Step 2: Hold for 10 seconds
Step 3: Cook at full power (3000 watts) 40 seconds

Figure 3 shows the results of this cooking. The pizza was crispy and well browned on the bottom, and soft and cheesy on top. Importantly, this action was done with microwave oven only (no convection), which greatly enhances the utility of microwave cooking.

Figure 3. Microwave Speed Cooking of Par-Baked Pizza.

MICROWAVE SPEED COOKING OF FRESH DOUGH PIZZAS

The Silar® flatstone technology is also well suited for the cooking of fresh dough products. The fresh dough area is one of the biggest areas in need of productivity enhancement. Fresh dough is obviously higher quality; but using traditional approaches, fresh dough takes 10-15 minutes to cook.

A yeast-containing pizza dough was made from scratch two hours before cook time and was allowed to ferment and rise. This dough was rolled into shape, covered with toppings, and the final uncooked pizza was prepared. Figure 4 shows a photo prior to cooking.

Figure 4. Fresh Dough 12" Pizza, Before Cooking.

The pizza was microwave-conduction baked according to the cooking algorithm for this product is shown in Table 1. The oven used was an Amana AXP microwave-convection oven.

Table 1. Silar® Flatstone Cooking Algorithm for Fresh Dough Pizza: Amana AXP oven.

Stage	Time (s)	Oven Temperature (^oF)	Microwave Power (%)	Fan Speed (%)	Infrared Power (%)
1	30	480	40	10	100
2	30	480	30	30	100
3	20	480	10	50	100
Total Time	80				

This cooking algorithm was developed expressly for fresh dough cooking. It has three stages, and took only 80 seconds to cook a 12" fresh dough pizza. Photos of the finished product are shown in Figure 5.

The pizza was golden brown, and the crust was well textured. The yeast flavor was evident, and crust texture was excellent.

Figure 5. Results of Fresh Dough Speed Cooking of Pizza with Silar® Flatstone.

CONCLUSIONS

ACM's Silar® microwave grill and flatstone add an entirely new dimension to microwave cooking. Most microwaves used in the world today are not for cooking, but instead are used for reheating. Silar® adds authentic grilling and speed baking capability to microwave ovens.

In addition, most cooking is limited to a speed and quality paradigm. If you want speed, typically you have to sacrifice quality. The Silar® technology moves the centerline in this paradigm, opening up fast cooking approaches of higher quality foods that in the past could not be cooked quickly.

In this paper, we took Silar® microwave absorbent ceramic composites and placed them into application in commercially available microwaves. We demonstrated how microwave performance and versatility could be enhanced. Products demonstrated were grilled panini sandwiches, par-baked pizzas, and fresh dough pizzas. Of course, other fresh-dough products, such a pita and focaccia breads, are envisioned. In addition, grilled vegetables are also very doable. Finally, the author believes that proteins can be rapidly grilled as well, provided oven-cleaning techniques are followed.

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