FABRICATION OF SUSPENDED ALL-METAL SENSOR ELEMENTS IN CERAMIC LAMINATES

P. Sturesson[1,2], M. Berglund[1], J. Söderberg Breivik[1], L. Klintberg[1], A. Persson[1], and G. Thornell[1,*]

[1]Ångström Space Technology Centre, Div. of Microsystems Technology, Dept of Eng. Sciences, Uppsala University, Sweden

[2]Division of Military Technology, Department of Military Sciences, Swedish Defence University, Sweden

**peter.sturesson@angstrom.uu.se*

INTRODUCTION

To target a wide range of high-temperature applications [1-4], the Ångström Space Technology Centre has added High-Temperature Co-fired Ceramics, HTTC, technology to its repertoire. Usually, this technology follows a processing scheme where thin sheets of green-body ceramics are metallized through screen printing and structured by embossing, punching or milling, before they are laminated and sintered to form components. A limitation with this, is the difficulty of realizing freely suspended metal structures, which is a disadvantage in, e.g., the fabrication of calorimetric sensors or electric field probes. In this work, the embedding of platinum wires in HTCC is explored experimentally, and demonstrated for use in pressure and plasma I-V sensing.

EXPERIMENTALS

Two dozen samples were manufactured from 150 µm thick alumina green tapes, on one sheet of which a multipurpose pattern with platinum leads were screen-printed, and in four sheets of which a few millimetre wide squares were milled out, before they were laminated to a non-processed bottom tape, forming stacks of five layers, and sintered. (For details see [1, 2].) Prior to lamination, 25- and 45-µm diameter platinum wires were threaded through milled-out vias and stretched across the cavities between sheet 2 and 3 counting bottom up. To prevent collapse during lamination, the cavities were filled with milled fugitive sheets.

The samples were inspected with X-ray before and after sintering to observe wire deformation, and many were also studied with an SEM. Two samples, P1 & P2, were evaluated for pressure sensing employing the Pirani effect, by being operated with a pulsed voltage at different vacuum levels under simultaneous IR camera observation. Several other samples were contacted with handheld probes and fused into Langmuir-like probes, following the findings of [5].

RESULTS AND DISCUSSION

With no exception, all thick wires, although being curved, survived the HTCC process, whereas all but one thin wire broke. Most of the deformation was caused by sintering, which entails shrinkage of approx. 20%. Some wires also testified to creep and recrystallization with small surface outgrowths, and occasional grain slipping through the whole wire. Interestingly, almost all bending was perpendicular to the plane, Figure 1. This makes subsequent processing easier and calls for no other design changes than increasing the cavity height to prevent the wire from contacting the ceramic. As shown by the P1 wire, making a twist through the cavity and touching the wall over some length, ill-behaved deformation jeopardizes operation, here by cooling the wire significantly, as verified by thermography, Figure 2. P2, on the other hand, performed well as a pressure sensor, Figure 3. The fusing of samples successfully mimicked the most spherical of the tips obtained with bond wire on PCB [5], Figure 4 (left), and although it was not fully tested for microplasma probing here, it should offer the benefit over a cylindrical plasma probe seen there, Figure 4 (right).

CONCLUSION

The embedding of 40 µm thick platinum wires between HTCC sheets was successful, that of 25 µm thick wires not, in creating well suspended all-metal members in ceramic cavities. Heated and tested as a Pirani pressure sensor, such a wire exhibited a 12-% resistance change in a 2-mm^3 cavity subjected to a change of pressure from 1 to 100 Torr. It was possible to fuse said wires to form almost perfectly spherical tips.

ACKNOWLEDGEMENTS
The Swedish National Space Board (SNSB) is gratefully acknowledged for having funded part of this project, the Knut and Alice Wallenberg for valuable contribution to the laboratory facilities.

REFERENCES
[1] P. Sturesson, Z. Khaji, S. Knaust, L. Klintberg, and G. Thornell, "Thermomechanical properties and performance of ceramic resonators for wireless pressure reading at high temperatures", Journal of MME, 25(9), 2013.
[2] Z. Khaji, P. Sturesson, L. Klintberg, and G. Thornell, "Manufacturing and characterization of a ceramic microcombustor with integrated oxygen storage and release element", J. of MME, 25(10), 2015.
[3] V. Lekholm, A. Persson, L. Klintberg, and G. Thornell, "Investigation of a zirconia co-fired ceramic calorimetric microsensor for high-temperature flow measurements", J. of MME, 25(6), 2015.
[4] V. Lekholm, A. Persson, K. Palmer, F. Ericson, and G. Thornell, "High-temperature zirconia microthruster with an integrated flow sensor", J. of MME, 23(5), 2013.
[5] M. Berglund, P. Sturesson, G. Thornell, and A. Persson, "Manufacturing miniature Langmuir probes by fusing platinum bond wires", J. of MME, 25(10), 2015.

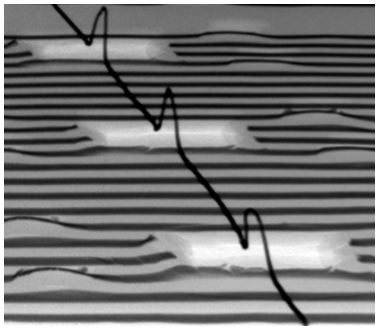

Figure 1: X-ray image of embedded Pt wire arcing over square ceramic cavities.

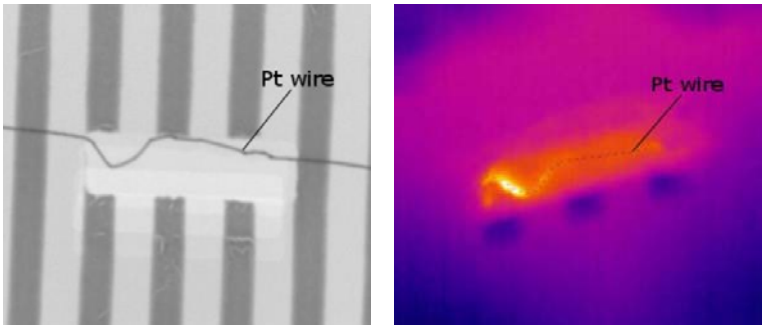

Figure 2: X-ray image (left) and IR image (right) of wire behaving erratically, and loosing heat by making contacting with the wall.

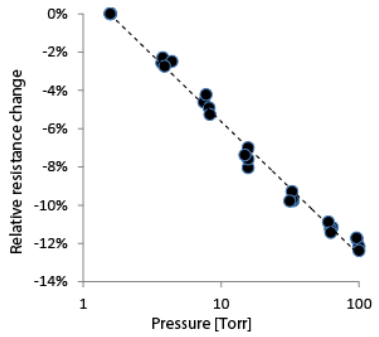

Figure 3: Wire operated as Pirani pressure sensor element in a 2-mm^3 cavity, exhibiting a resistance decrease with increasing pressure.

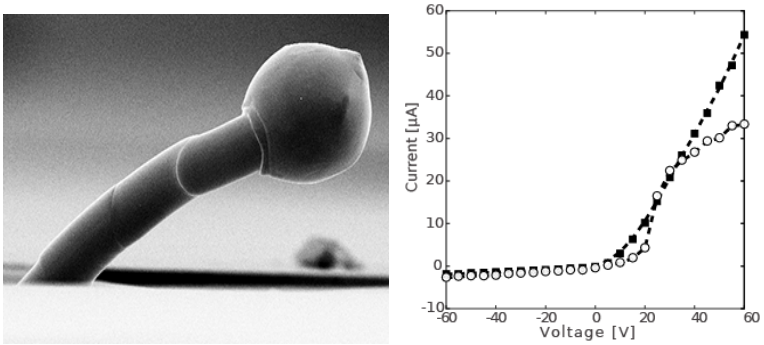

Figure 4: Fused 45-μm diameter wire with nearly spherical tip (left) for wider-range I-V measurements in microplasma sources (right), where squares are from measurements with a probe with a spherical tip, and circles from a cylindrical one.