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Self-Propagating High-Temperature Synthesis of High Porosity Foam Materials in Microgravity

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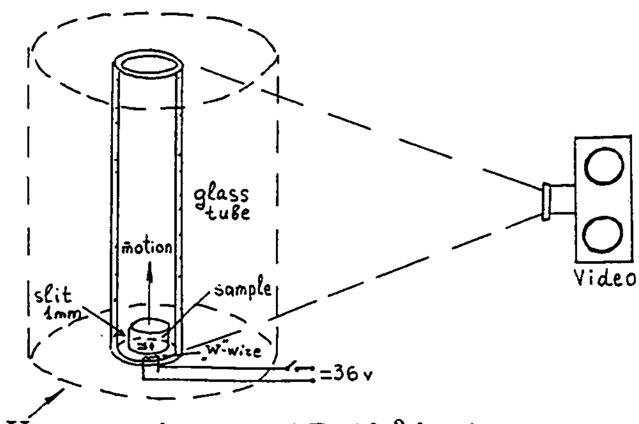
Ceramic and metalloceramic foam materials are important construction, building, and thermal insulation materials for space stations of the 21st century. Delivery of these materials from Earth to space using rockets is not profitable due to the low density of these materials. Production of foam materials in space using traditional methods requires large energy consumption. Using SHS in space solves this problem!

Method of experiments

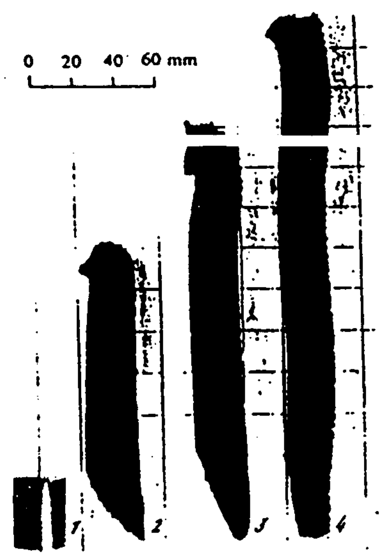
Ti+C+A — SHS →foam material

a gasifying additive



Vacuum chamber ($P \cong 10^{-2}$ bar)

Time of microgravity ≤ 30 sec
d = 10 ... 50 mm
h = 20 mm



Photograph of samples. 1) Initial; 2) burned on Earth, in vertical position; 3) burned on Earth, in horizontal position; 4) burned under weightlessness.

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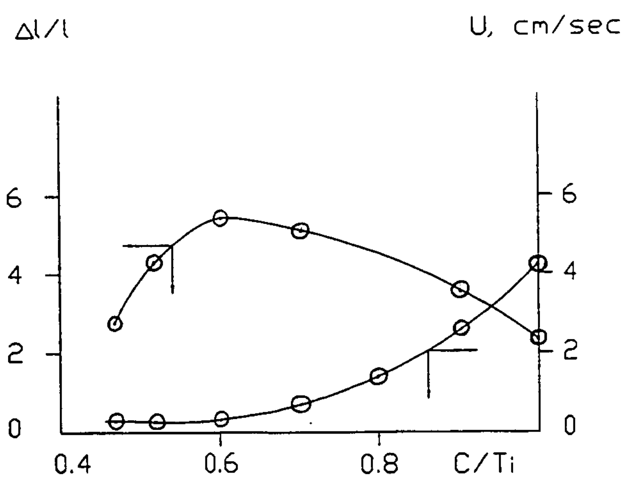
Important features of SHS foam materials in space conditions: ignition of the mixture with endothermic dissociation of additive in vacuum is difficult. Reasons: low temperature of the equilibrium dissociation of the additive; intensive thermal losses due to vacuum dissociation.

2 Vacuum Chambers

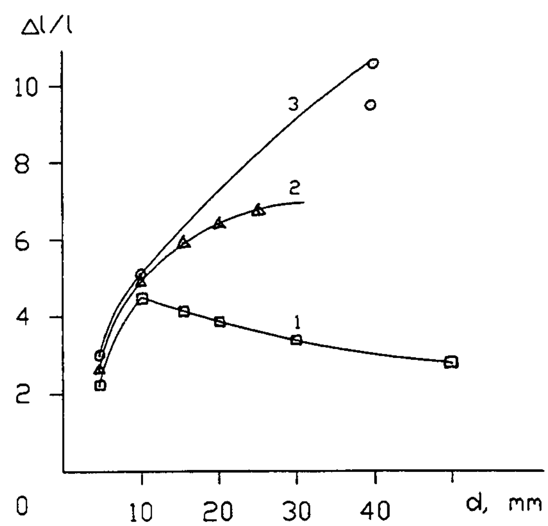
Small	Big
D=12cm	D=60cm
L=80cm	L=100cm
n=1 sample	n=10 samples

Results of experiments: 1. During combustion the diameter of the sample remains constant; length increases severalfold. 2. Burned sample is in the form of an "extended accordion", consisting of plates arranged in a stack; the micropores take on a disk-like shape.

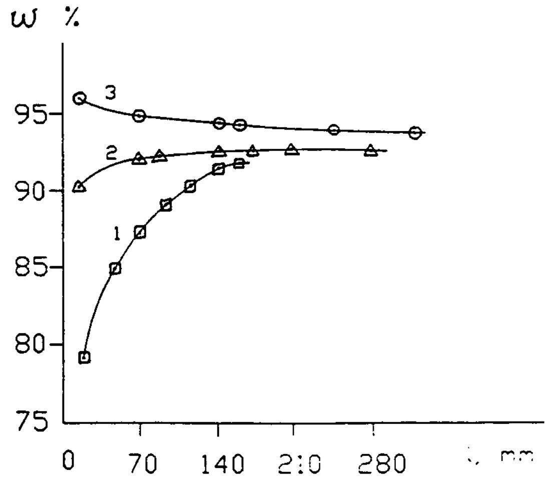
Dependence of the degree of elongation of the sample (1)and of combustion (2) on the titanium/carbon ratio.



The degree of elongation of the sample during the combustion as of function of the diameter of the initial sample under combustion: 1) in the vertical position on Earth; 2) in the horisontal position on Earth; 3) under microgravity.



Porosity distribution along the sample after combustion: 1) in the vertical position on Earth; 2) in the horisontal position on Earth; 3) under microgravity.



<u>**The mechanism and structural macrokinetics for the foamforming (the increasing in the length of the sample)**</u>

Two main processes: 1. Melting of one reagent and capillary flow along the particles of the other components--in this case the material in the reaction zone becomes much more plastic. 2. Decomposition of the gasifying additive; an increase in the gas pressure in the pores of the sample causes them to grow larger and, hence, the volume of the entire sample to increase.

$$\tau_{comb} = \Delta x/u;$$

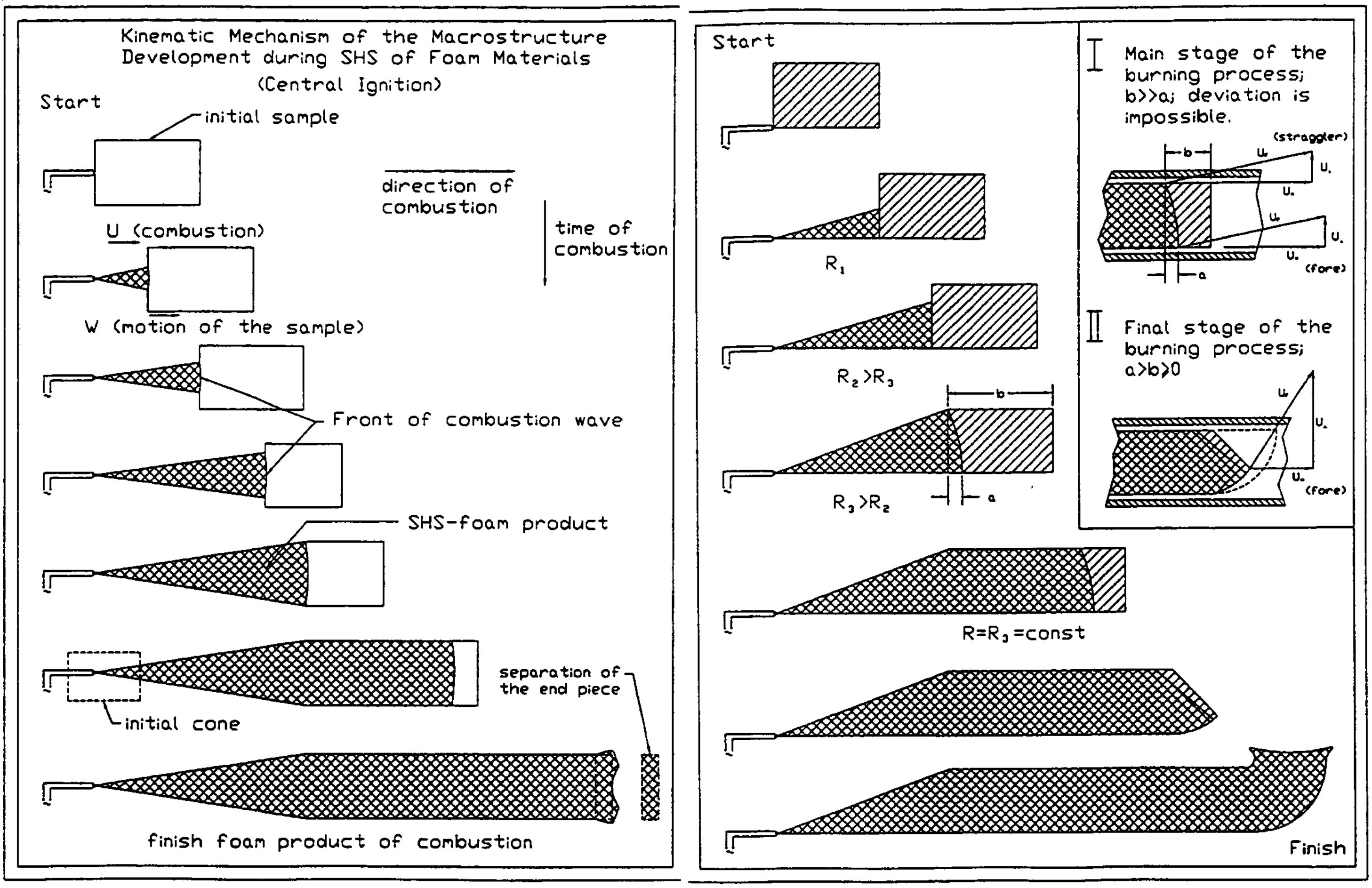
Δx - size of the reaction zone
u - rate of combustion

$$\tau_{def} = \eta/(P_g - P_\infty)$$

η - viscosity;
Pg - gas pressure in the pores;
P_∞ - gas pressure in the ambient medium

Elongation $\Delta l/l$:

$$\Delta l/l \sim \tau_{comb}/\tau_{def} = [(P_g - P_\infty)/\eta] * \Delta x/u$$



From this data we can predict much more accurately the multiplex form and the realization potential of the combustion products.

If the angle between the axis of the cylindrical sample and the axes of the igniting surface (ellipse or circle) equal:

1) $\alpha=90°$ $\beta=90°$ — We have the finished product in a cylindrical form.

2) $\alpha=0\text{-}180°$ $\beta=90°$ — We have the finished product in a circular form.

3) $\alpha=0\text{-}180°$ $\beta=0\text{-}180°$ — We have the finished product in the form of a spiral (a ceramic spring)

If we are changing α and β we can change the diameter and step of the spring.