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Microwave Melting and Drilling of Basalts

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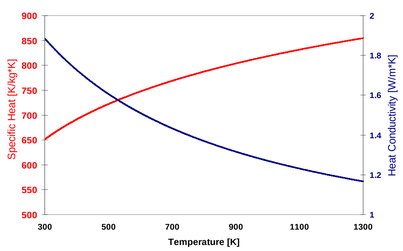
Abstract

The paper presents experimental observations of basalt melting and drilling by microwaves. The basalt melting is conducted in a 600-W single-mode cavity and yields volcanic glass (obsidian). The phenomena observed resemble volcanic effects in miniature scales. The basalt is drilled by the open-end microwave-drill coaxial applicator [1]. Holes and pin inserts are obtained in basalt rocks.

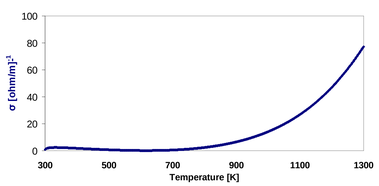
Introduction

Basalts, the most common volcanic rocks on earth, appear in nature in a range of physical and chemical properties, and a variety of outer shapes. Basalts contain silica (~50%) and oxides of iron, aluminum, calcium, sodium, and magnesium. Dry basalts are electrical insulators at room temperature (~10^2 Ωm specific resistance and ~8 dielectric permittivity) [2]. Their resistivity decreases exponentially as the temperature grows. Near the melting temperature (~1,100°C) the basalt becomes an electrical conductor (~0.02 Ωm) [3]. The thermal conductivity decreases as the temperature increases [4], unlike volcanic glass which has a minimum near 700°C. These properties make the basalt a good candidate for thermal-runaway microwave-heating applications [1, 5, 6].

Specific heat and thermal conductivity vs. temperature:

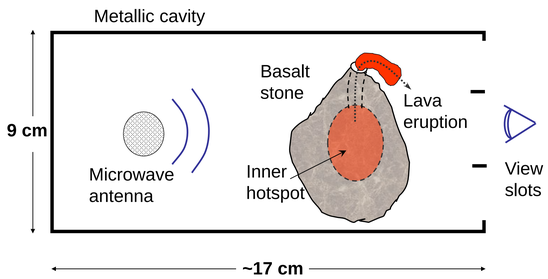


Electric conductivity vs. temperature:



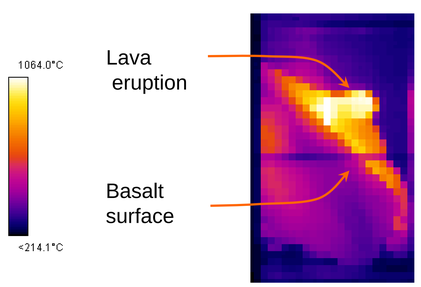
Melting Basalts ("Miniature Volcano")

The microwave energy is converted to heat in the core of the basalt stone and melts its inside, in a thermal runaway process. The induced hotspot in the core acts as a magma tending to erupt in a variety of volcanic-like manners:



The heat tends to concentrate in a hotspot under the surface of the basalt stone before the lava eruption:

An infrared image of the lava stream erupted from the core to the surface was made by a FLIR thermal-camera through the view slot in the resonator. A coloured temperature scale shows the lava temperature ~1,100°C:



Various volcano-like effects in different basalt stones (~5 cm length each) were photographed outside the resonator:

A crater, formed by lava eruption, cooled down and solidified as black volcanic glass.

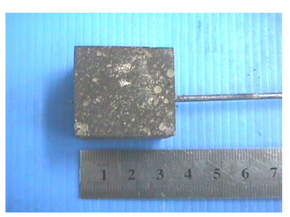
Fluid basalt poured from a vent, flows and solidified as black volcanic glass.

A lava "river" along a fissure, partly converted to black volcanic glass.

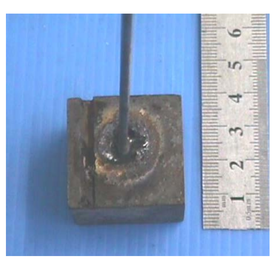
The empty core and crust layer created beneath the outer surface.

Microwave Drilling of Basalt

Using the microwave-drill apparatus [1], holes of 1-4 mm diameters were obtained in basalts.

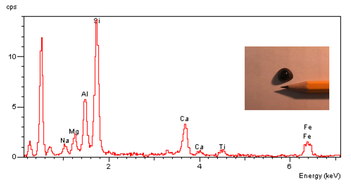


~0.6 kW effective power,
~1 mm/sec drilling speed,
2.4-mm diameter pin,
2-cm depth insertion.

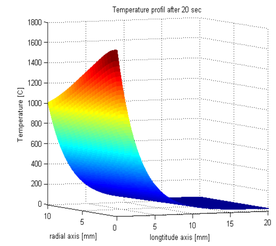


Analysis

Energy Dispersive Spectroscopy (EDS) of the emitted glass (obsidian):



Coupled thermal-EM simulation of the spatial temperature in front of the microwave drill [7]:



References

1. E. Jerby, B. Dikhtyar, O. Aktushev, and U. Grosglick, "The microwave drill," *Science*, Vol. 298, pp. 587-9, 2002; US Patent 6,114,676, and www.microwave-drill.com
2. L.L. Frasch, S. J. McLean, and R. G. Olsen, "Electromagnetic properties of dry and water saturated basalt rock, 1-110 GHz," *IEEE Trans. Geoscience and Remote Sensing* Vol. **36**, pp. 754-66, 1998.
3. D. C. Presnall, C. L. Simmons, and H. Porath, "Changes in electrical conductivity of synthetic basalt during melting," *J. Geophys. Res., Vol.* **77**, pp. 5665-72, 1972.
4. C. Clauser and E. Huenges, "Thermal conductivity of rocks and minerals," T. J. Ahrens, T.J. (Ed.) *Rock Physics and Phase Relations - Handbook of Physical Constants*, Vol. 3, pp. 105-26, Amer. Geophysical Union, Washington, 1995.
5. C. C. Alen, J. C. Graf, and D.S. McKay,"Sintering bricks on the moon," Engineering, Construction, and Operations in Space IV, Amer. Soc. Civil Eng., pp. 1220-29, 1994.
6. E. Jerby and M. Einat, "High-power microwaves - a useful tool in the future industry", Israel Energy News, Winter Issue, pp. 10-13, 1997.
7. E. Zigman, unpublsihed.

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