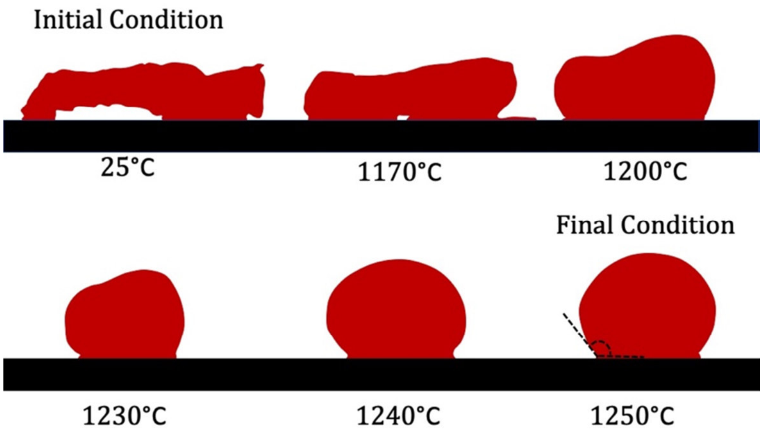
**How contact angles help to understand molten volcanic ash wetting in jet engines**


Global air traffic is constantly affected by the eruption of volcanos; one of the reasons is a high damage risk for the jet engines by volcanic ash ingestion. Ash melts and adheres to the engine surfaces leading to erosion and to the reduction of the operation efficiency of the jet consequently.

In 2010, the largest aviation shutdown in Europe since World War II happened due to the eruption of Eyjafjallajökull in Iceland, causing huge economic losses estimated at ∼2 billion euros. To overcome this problem in the future, scientists have developed thermal barrier coatings (TBCs), which are porous ceramic materials typically made of tetragonal-phase $ZrO_2$ ceramic stabilized by 6–8 wt% $Y_2O_3$ (referred to as YSZ), to protect the jet engines from the molten volcanic ash. However, the problem remained that molten volcanic can rapidly absorb into the porous coating. When the molten ash solidifies in the pores the material stiffens and breaks damaging the TBC. There is also a chemical interaction between the molten volcanic ash and the coating that further accelerates the damage of TBCs. To solve this problem, Lokachari et al. have recently reported a novel TBCs with hexagonal boron nitride (*h*-BN) additives resistant to molten volcanic ash wetting.

To evaluate the wettability of pure *h*-BN with molten volcanic ash, a single Eyjafjallajökull (Eyja) glass shard was loaded onto pure *h*-BN substrate (**Picture 1**). The shard demonstrated a shape transformation from an irregular shape to a sphere over increasing temperature (from 25 °C to 1250 °C). Once then cooled to room temperature, the solidified sphere could be easily removed from the pure *h*-BN substrate. The results show highly silica-phobic properties of pure *h*-BN which can be explained with the weak interactions between the molten ash and the honeycomb-structured sheets of *h*-BN bound by weak ionic inter-planar attractions.

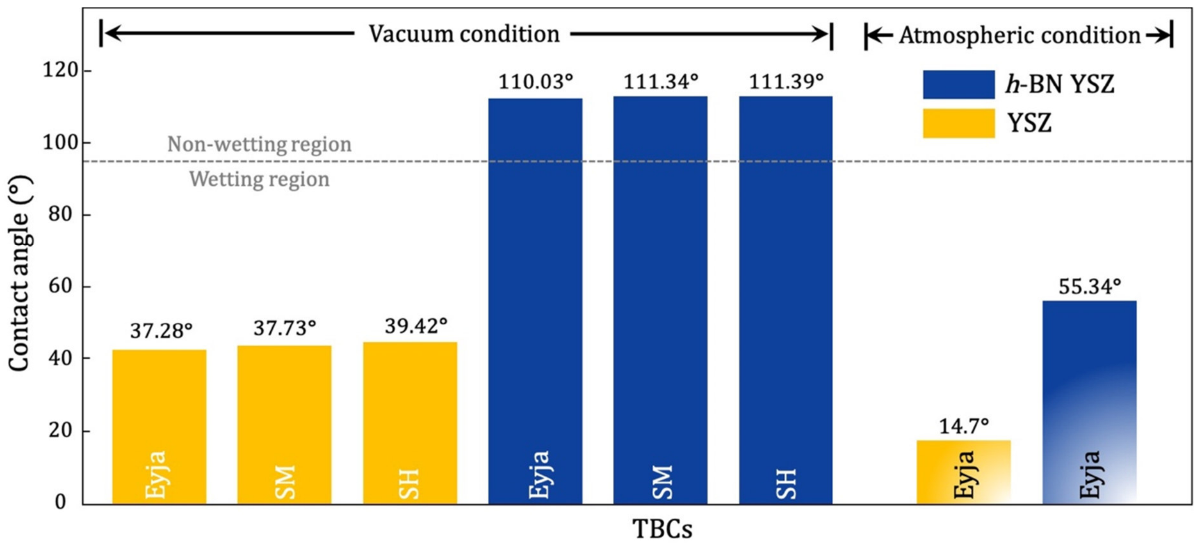



***Picture 1:*** *Morphological transition of the irregular Eyjafjallajökull (Eyja) glass shard to a sphere from 25 °C to 1250 °C*

**High Temperature Optical Contact Angle Analyzer OCA 25-HTV 1800**

The high temperature measuring system OCA 25-HTV 1800 is capable of measuring contact angles at **high temperatures of up to 1800 °C**. The measurements can be performed under **vacuum down to $10^{-5}$ mbar**, under **inert gas atmosphere** or even under **oxidizing conditions** as like in the previously described experiments. Being able to measure contact angles and the wetting behavior under high temperature and precisely controlled atmosphere offers new unique insights for materials which are for example used in **aeronautics** or to better understand processes in **metallurgy**.

Furthermore, novel *h*-BN YSZ coatings (20 wt% *h*-BN and 80 wt% YSZ) and conventional YSZ coatings were placed on an alumina substrate ($Al_2O_3$ > 96%) as test systems for comparison. On these sample coatings wettability measurements were conducted using three types of volcanic ash: Eyjafjallajökull (Eyja), Soufriere Hills (SH), and Santa Maria (SM) (**Scheme 1**).




***Scheme 1:*** *Comparison of the contact angles resultant from the wetting of molten volcanic ash onto h-BN YSZ and conventional YSZ coatings in vacuum and atmospheric oxidizing conditions at 1250 °C*

Under vacuum condition, they found that all three volcanic ash samples exhibited high contact angles on *h*-BN YSZ with a non-wetting behavior (around 110°), and low contact angles with a good wetting behavior (around 37°) on YSZ. Considering the potential oxidation of *h*-BN at high temperature, wettability measurements under oxidizing atmospheric conditions were also conducted. Eyja ash was chosen due to the lowest melting point and lowest viscosity at 1250 °C compared with the other two ash samples. The data show that the contact angle of molten Eyja ash on *h*-BN YSZ (55.34°) was more than thrice that of control group YSZ (14.7°). Taken together, the above results demonstrate that *h*-BN YSZ has a much better wetting resilience towards molten volcanic ash than YSZ under both vacuum and atmospheric conditions. The decrease of contact angles under atmospheric conditions derives from the oxidation processes on the coating and ash. In addition, the authors further evaluated infiltration resistance of *h*-BN YSZ against molten volcanic ash, and found that *h*-BN YSZ has a better resistance behavior than YSZ.

Overall, the authors have developed a novel *h*-BN YSZ coating with a high resistance against wetting and infiltration of molten volcanic ash. *h*-BN YSZ coatings presented better resistance than conventional YSZ coatings under both vacuum and atmosphere conditions. These novel *h*-BN YSZ coatings bear the potential to be utilized as protective coatings in jet engines, which would pave the way to a higher volcanic ash resistance and thus render air traffic possible in volcano eruption contaminated air.

The high temperature optical contact angle analyzer OCA 25-HTV 1800 (DataPhysics Instruments GmbH, Germany) was used in this research.

For more information, please refer to the following article:

**Novel thermal barrier coatings with hexagonal boron nitride additives resistant to molten volcanic ash wetting**; Siddharth Lokachari, Wenjia Song, Masahiro Fukumoto, Yan Lavallée, Hongbo Guo, Yancheng You, Donald B. Dingwell; *Corrosion Science* **2020,** 168, 108587; DOI: 10.1016/j.corsci.2020.108587