An Introduction to the Novel Composite Metal Foam Materials

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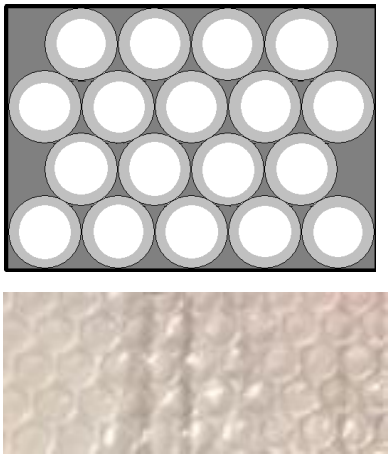
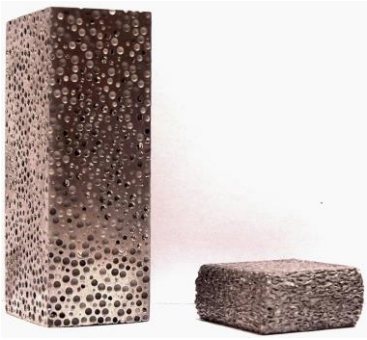


- **Introduction:** Composite metal foam (CMF) is a novel light weight material created at North Carolina State University. The material is made of metallic hollow spheres closely packed together and the empty spaces in between them filled with a metallic matrix through either casting (of a molten metal) or sintering (of a powdered metal). The hollow spheres are filled with air and provide light-weight and porosities, while the surrounding matrix works to strengthen the bonding between spheres and blunt any potential cracks in the material under load. Under large amount of compression loading, the spheres collapse and expend the impact energy protecting whatever is behind it. CMF's strength is further improved under higher speed of impact due to the resistance of air inside its spheres (similar to a bubble wrap performance under pressure, but in a much larger scale). Such extra-ordinary energy absorption capabilities of CMFs inspired their application in ballistic and blast armor systems along with many others.
- The product will look like a heavy-duty bubble wrap to protect against larger impacts of train or car crash, blast wave and fragmentation, ballistic and more.
- The material contains about 30-40% metal and 70-60% air trapped inside its porosities. As such a100% stainless steel composite metal foam is as light as aluminum (70% lighter than

stainless steel) and a combination of aluminum with steel composite metal foam can be nearly as light as water!

- Composite metal foams have shown nearly two orders of magnitude higher impact energy absorption capability compared to their parent bulk material (such as aluminum or steel).
- High air content inside Composite metal foam offers extremely good thermal insulation performance; nearly two orders of magnitude lower thermal conductivity in steel composite foams compared to bulk aluminum is observed.
- A 100% Steel composite foam shows almost 275% more effectiveness in shielding X-rays compared to Aluminum.
- Four patents are issued and more are pending on processing of the material through two techniques and
- One start-up company has just shaped to commercialize this material.

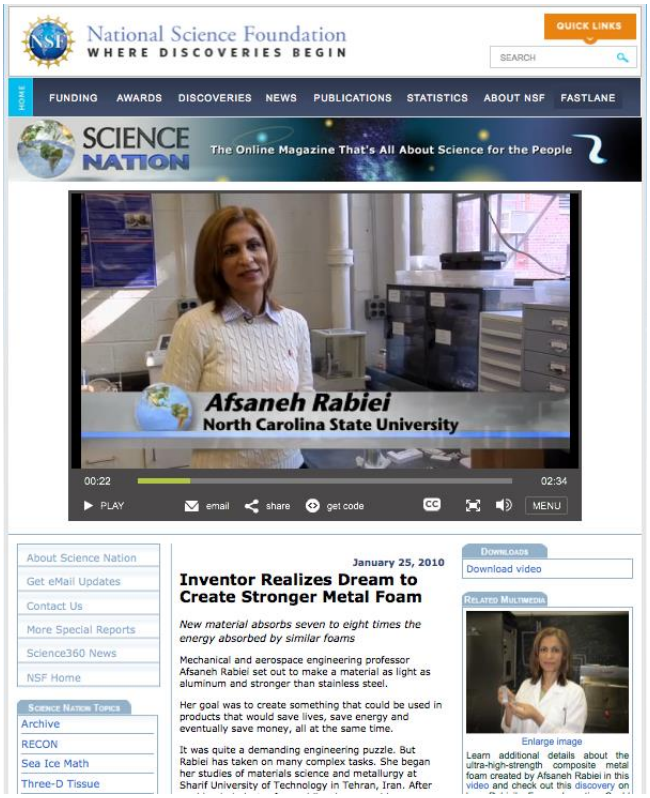
Figure shows Composite Steel foam before (left) and after (right) 80% deformation under compression. The sample on the right was the same size as the one on the left before being squeezed to the current size under compression. These samples are 100% made of stainless steel while the air trapped inside its porosities made them 70% lighter than stainless steel.



Funding: Total of ~$2 M is being used on various projects for creation, evaluation and optimization of the composite metal foams so far. The sources of funding were including:

- NSF (~$500K) for the first step of creation of the material,
- ARO (~$70K) for evaluation of material's performance under high speed impact,
- NASA (~$20K), NC Space Grant ($20K) & DOE (~$400K) to evaluate the shielding capabilities of the material against various types of radiation and heat.

- NCSU-Chancellor's Innovation Fund ($75K) to evaluate the performance of the material in armors.
- National Academy of Science along with Transportation Research Board ($100K) for the evaluation of the material's performance for train's safety.
- Joint Aircraft Survivability Program (JASP) provided $420K for 2014-2017 for application of the material in armors (against blast pressure, fragments and ballistics)
- DOT ($510K) on application of the material for tank cars transporting hazmat (2016-19)
- NASA ($31K) for the application of the material on leading edge of airplanes (2017-17)



- **Highlights:** Composite Metal Foam Invention has been highlighted as the next generation light-weight material with multiple applications by many news media such as: Fox News, Fox 8, Huffington Post, The American Ceramic Society, National Academy of Engineers, Science Friday, Popular Mechanics, Homeland Defense & Security, Information Analysis Center, Physics World, US International Information Program, Yahoo News KQED, NSF NSF Science Nation, Youtube Video. NSF NSF and ...

- **Some of the potential applications of composite metal foams include:**
    - Light-weight armors with high performance against larger caliber bullets with armor piercing, blast wave and fragments flying with very high speeds (such as 5000ft/s)
    - Structural parts for tanks, Humvees and land system vehicles to improve protection against IEDs, improved crashworthiness, and enabling the vehicles to be maneuverable and fuel efficient.
    - Helicopter parts to absorb the impact energy upon hard landing while providing a light-weight solution
    - Crash energy absorbers in trains, cars and buses
    - Mine boots and personal armors and helmets
    - Medical devices including implants with good stiffness similar to bone that prevents stress shielding and premature failure of implants.
    - Heat protection devices (fire doors, safes, containers,…)
    - Radiation shielding parts with light weight and no toxicity

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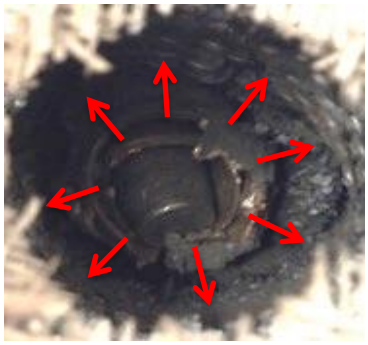
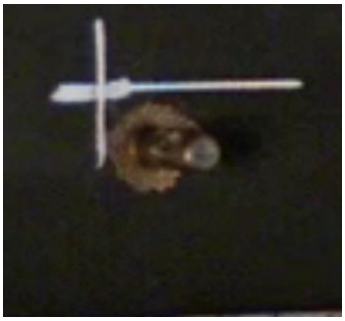
<tr><td>Hard core of the bullet is trapped inside the crushed spheres</td><td colspan="2">7.62 M2 Partial Penetration (in flight)</td></tr>
<tr><td>  </td><td>  </td><td>  </td></tr>
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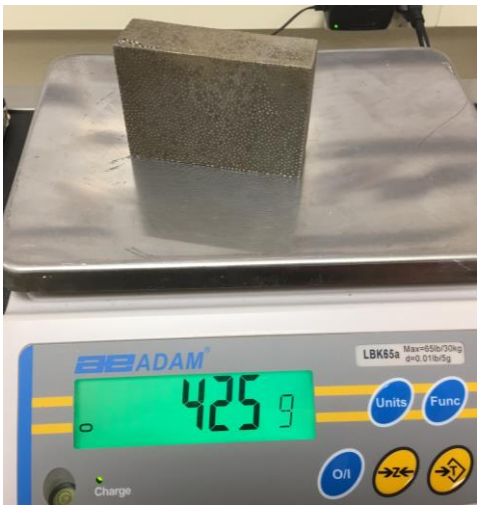
Same size steel

Steel-Steel CMF



This figure shows two pieces of steel and composite steel foam with same sizes. The steel CMF is almost 1/3 of the weight of steel.

For more information about composite metal foams and their properties and applications, please refer to our website at http://people.engr.ncsu.edu/arabiei/