AIRCRAFT

Electric microwave plasma thruster could rival traditional jet engines

By Loz Blain
May 06, 2020

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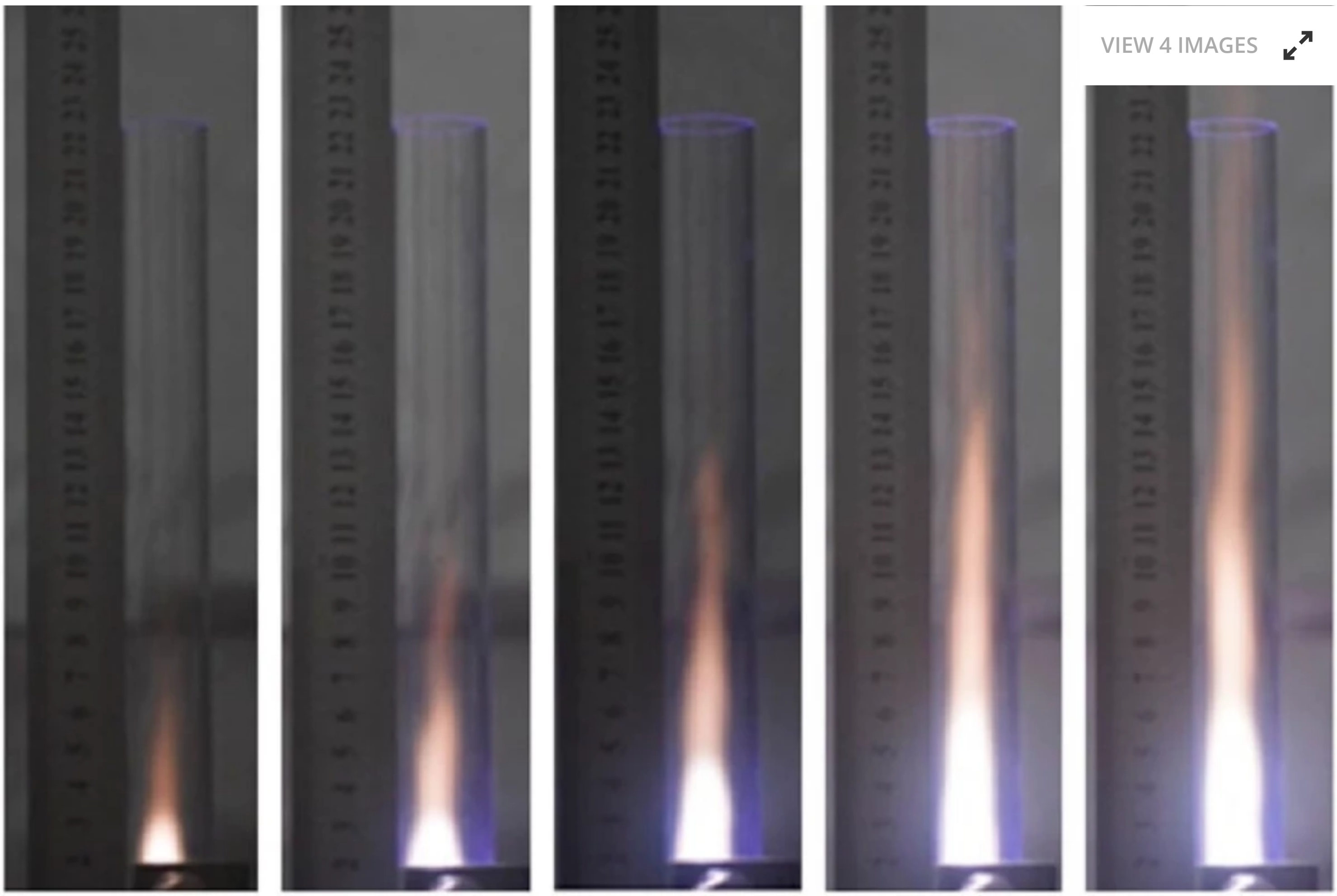

The flame length and propulsive thrust of this new microwave-accelerated plasma thruster design appear to vary linearly with power application and air speed, making it a potentially promising design for electric aviation Dan Ye, Jun Li and Jau Tang

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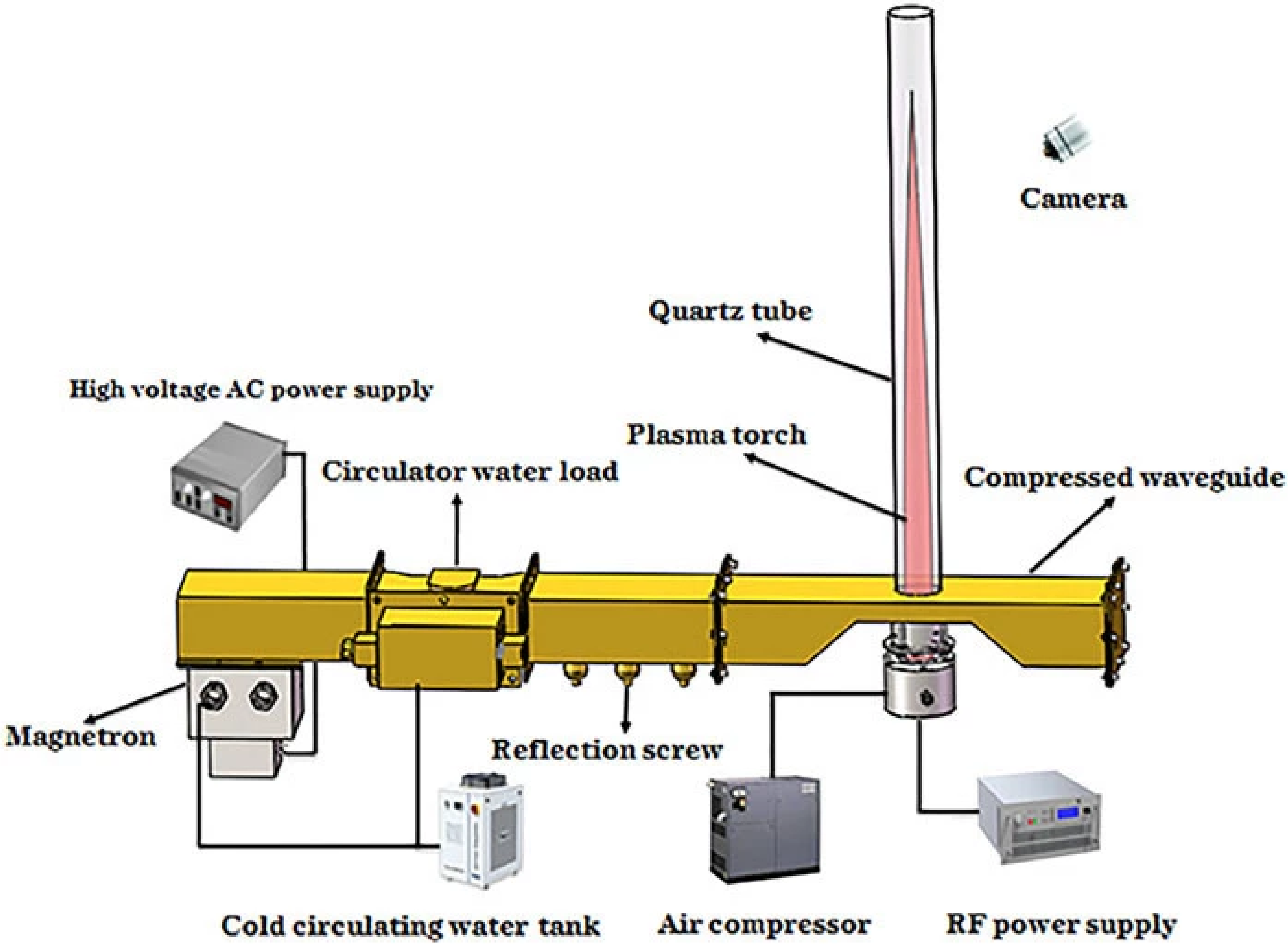
A Chinese team has demonstrated a prototype of a microwave plasma thruster capable of working in the Earth's atmosphere and producing thrust with an efficiency comparable to the jet engines you'd find on modern airliners – under laboratory conditions.

Plasma thrusters are already operational on spacecraft as a means of solar-electric locomotion, using xenon plasma, but such things are no use in the Earth's atmosphere, as accelerated xenon ions lose most of their thrust force to friction against the air. Not to mention, they only make a small amount of thrust in the first place.

This design, conceived and built by a team at the Institute of Technical Sciences at Wuhan University, uses only air and electricity, and appears to produce an impressive push that may see it become relevant to electric aircraft applications.

The device works by ionizing air to create a low-temperature plasma, which is blown up a tube by an air compressor. Part way up the tube, the plasma is hit with a powerful microwave, which shakes the ions in the plasma about violently, crashing them against other non-ionized atoms and vastly increasing the temperature and pressure of the plasma. This temperature and pressure generates significant thrust up the tube.

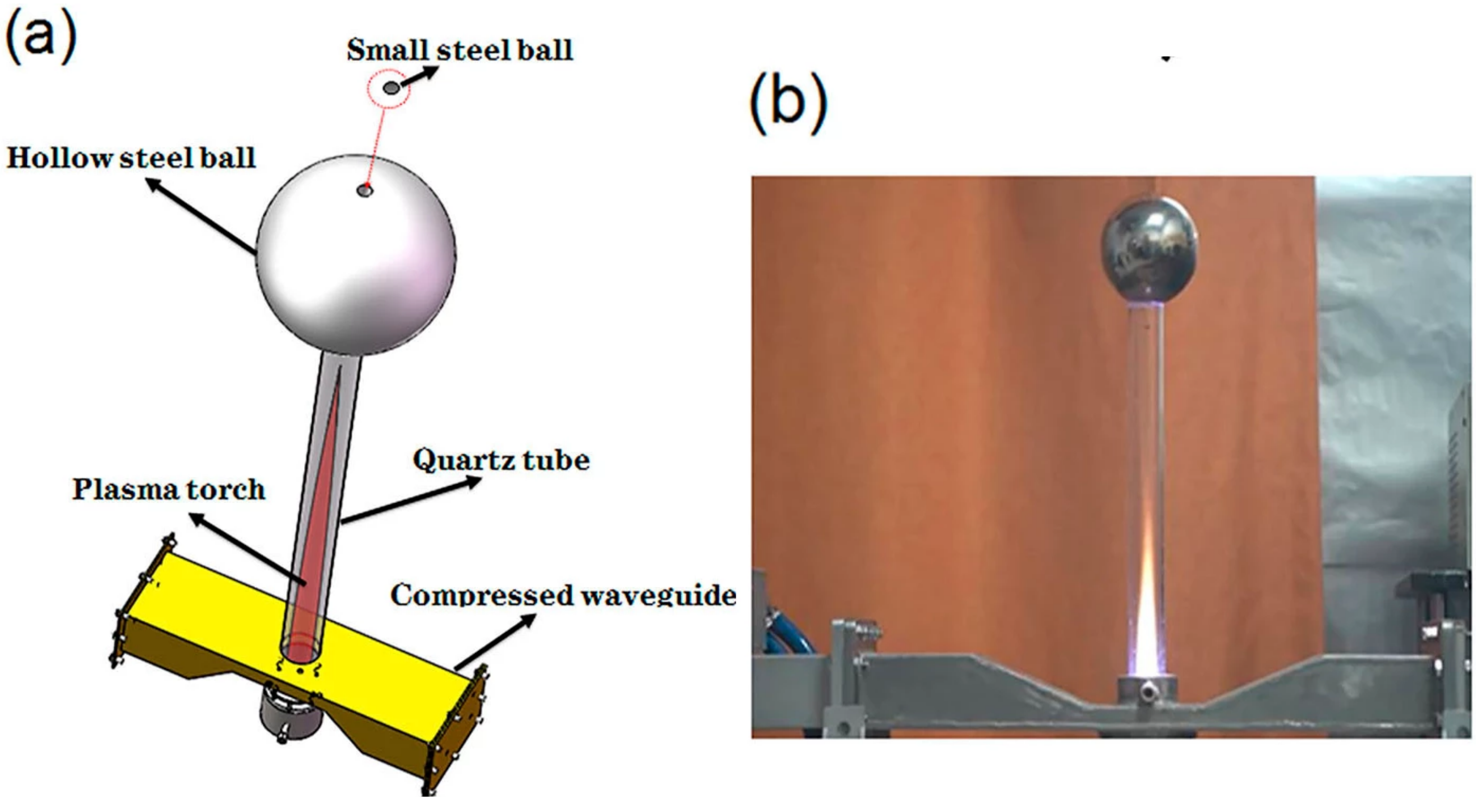


The thruster design uses an air compressor to generate initial air speed, then ionizes air into a plasma and heats it up to high temperatures and pressures using a powerful microwave Dan Ye, Jun Li and Jau Tang

Part of the secret sauce here is in the flattened waveguide through which the microwaves are fired. Generated by a 1-kW, 2.45-Gh magnetron, the microwaves are sent down a waveguide that's squeezed down to half its height as it approaches the plasma tube. This is done to boost its electric field strength and impart as much heat and pressure to the plasma as possible.

The researchers noticed that, keeping the air flow from the compressor steady, the flame jet in the tube appeared to lengthen when the microwave power was increased. They set about trying to measure how much thrust was being produced, which proved difficult since the thousand-degree plasma jet would destroy a regular barometer.

Instead, they settled on balancing a hollow steel ball on top of the tube, which could be filled with smaller steel beads to change its weight. At a certain weight, the thrust would counteract the gravitational forces pulling the ball down and begin lifting it off the tube, causing it to move and jump about, and the researchers used these measurements, minus the thrust contributed by the air compressor, to work out how hard their new plasma thruster was pushing.



Thousand-degree temperatures would fry a normal barometric measurement system, so the researchers used the plasma thrusters to lift a steel ball weight on the end of the plasma tube, measuring the weight each power and air flow level could lift Dan Ye, Jun Li and Jau Tang

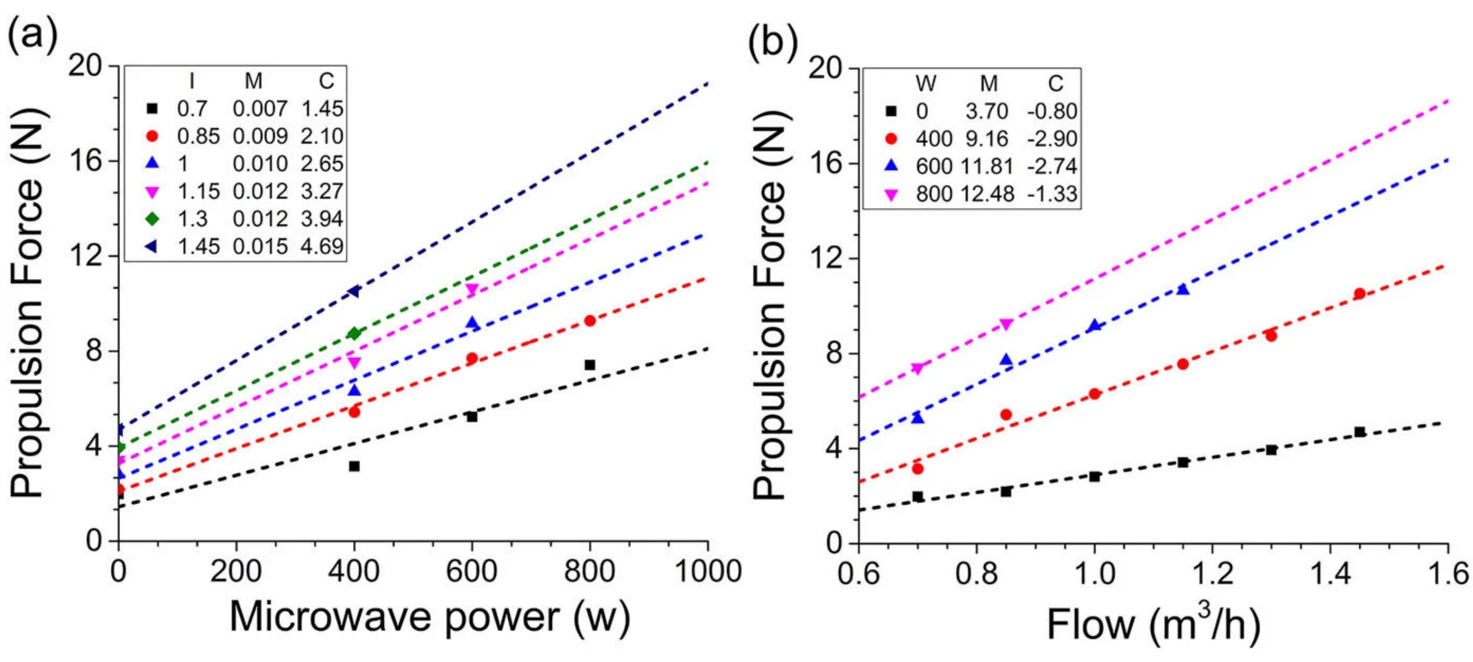
They tested this across a range of power levels and air flow rates, and despite the somewhat makeshift measurement technique, they found a linear relationship between propulsive thrust and both microwave power and air flow.

In efficiency terms, the propulsion force at 400 W and 1.45 cubic meters of air per hour was 11 Newtons, representing a conversion of power into thrust at a rate of 28 N/kW. Assuming linear extrapolation, the team speculated it could take a Tesla Model S battery capable of outputting 310 kW and turn that into something like an 8,500-N propulsive thrust force.

By means of comparison, the Airbus E-Fan electric airplane uses a pair of 30-kW electric ducted fans, which combine to produce 1,500 N of thrust. That would imply an efficiency of 25 N/kW, which is not quite as good as the first prototype assembled in this lab. The researchers say this thrust efficiency is already "comparable to those of commercial airplane jet engines."

The researchers say they're working on ditching their steel ball testing method for something more reliable and accurate, as well as trying to increase the efficiency of the design. But things certainly look promising for this new plasma thruster idea in electric aircraft propulsion, with a few important caveats.

Firstly, it's not going to be much chop as a replacement for props or ducted fans on an eVTOL, no matter how much quieter it might be, if that plasma comes out at thousand-degree temperatures . And secondly, as pointed out in this excellent Ars Technica analysis, "the airflows are in the region of about 15,000 times lower than those for a full-sized engine. The thrust also has to scale by about four orders of magnitude (meaning the power does, too). Extrapolating linear trends over four orders of magnitude is a good way to be disappointed in life."



Lab results show linear increases in thrust with both air flow and microwave power, although the data points do not include the highest power at the highest air flow Dan Ye, Jun Li and Jau Tang

Also, for whatever reason, the data points don't show the highest microwave power levels at the highest airspeeds the test rig appears to allow, signaling that things might already be starting to get weird in the lab.

And finally, even if it is as efficient or more efficient than a regular old Airbus engine for a given amount of energy input, the fact remains that aviation fuel carries so much more energy for a given weight than batteries (43 times more, according to The Verge), that motor efficiency improvements barely offer a drop in the ocean.

Still, this is an interesting and novel plasma thruster design, and we're interested to see where things go from here. If it does prove scalable and efficient up to aircraft-friendly levels, it could make a genuine contribution to the emerging field of zero-local-emissions electric aviation.

Check out the prototype running in a short video below, clearly moving that steel ball around.

Plasma thruster prototype

The paper is openly available at *AIP Advances*.

Source: American Institute of Physics via Ars Technica

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Loz Blain

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18 COMMENTS

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FB36 MAY 6, 2020 06:19 AM

This tech seems to explain well how exactly electrojet thrusters of Ironman's Suit work! :-)

Kpar MAY 6, 2020 08:14 AM

Cannot measure the thrust? Did they think about putting the whole thing on a scale, and then turning it on?

Expanded Viewpoint MAY 6, 2020 10:21 AM

Whoa, whoa, whoa! Wait a minute there, Skippy!! "but such things are no use in the Earth's atmosphere, as accelerated Xenon ions lose most of their thrust force to friction against the air"? The thrust of ANY rocket engine or jet engine is due solely to the Delta P of the pressure inside of the engine and the outside of the engine. The forward "wall" of the combustion chamber has force being applied against it, and the atmosphere outside of the engine has virtually NONE being applied against it! Thus, the forward wall of the engine moves in the same direction as the force being applied to it. The exhaust gasses doe NOT "push" against the various gas molecules that are outside of the combustion chamber of the engine as they are nearly totally mobile, and there is not much to push against, the gasses get "left behind" as the engine moves in space, it's not like when you lean upon a wall. If you increase the surface area of the wall of the engine, or increase the pressure/temperature in the engine, or decrease the resistance to the flow of the gasses leaving the engine, you will increase the thrust of the engine. It's a fine balancing act that keeps engines running at optimum thrust, and not blowing up!

I am Drocketman!

Expanded Viewpoint MAY 6, 2020 10:25 AM

Whoops! I forgot to mention that it would be easy to measure the thrust of the contraption using a load cell under the whole thing, and take a base reading with it stone cold, then with just the air on and then with air and full power applied.

paul314 MAY 6, 2020 01:17 PM

it sounds as if a big part of what makes it work is transfer of energy from the plasma to the unheated air around it. If they can improve that mixing process (a lot) then you might be able to go with something that moves a bunch more air (a little like high-bypass jet engines) and has a lower exhaust temperature.

I do worry a little about the experimental setup for measuring thrust. If there's significant RF leakage, you could get heating of that steel ball that might show more of an effect than you actually have.

MikeofLA MAY 6, 2020 01:26 PM

Did I miss a part where hooking this up to a fission reactor on a spacecraft wouldn't make sense?

Tony Morris MAY 6, 2020 06:31 PM

If the exhaust is at 1000*C this thing is not going to be efficient. That heat needs to be converted to kinetic energy to generate motive power. Need to maximise exhaust momentum to maximise thrust.

Leon Joubert MAY 6, 2020 09:50 PM

Perhaps application possibility as ICP-MS/OES heat source.

Anthony Wood MAY 7, 2020 03:22 AM

A little thing called VASIMIR has done this and more.

Chefman MAY 7, 2020 03:52 AM

Isn't there a blast of compressed air screaming up that tube? Wouldn't that be enough to bounce that ball around?

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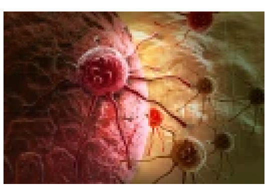

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