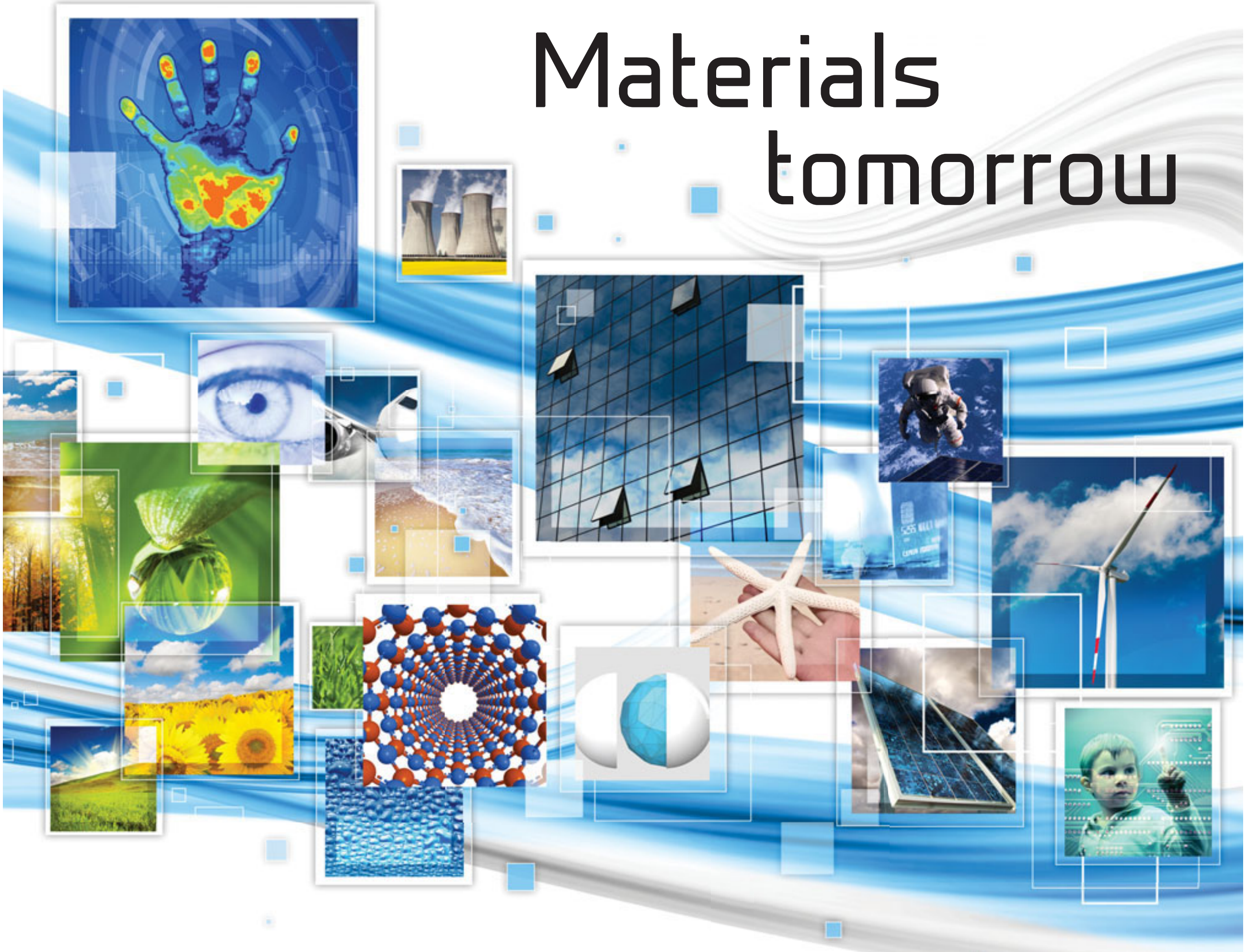

Materials tomorrow

I've always identified myself as a scientist, and have had a keen interest in materials research for nearly as long as I can remember. In my lifetime, I've seen evidence of the impact of materials research on our standard of living as well as our lifestyle. My fervent hope is that materials research will help us solve many of the big problems that surround us, and that the materials of tomorrow will make our lives better, perhaps even in ways that we cannot dream of today. We can speculate about how our quality of life would further improve if materials research were to enable various approaches to problems that currently face us. Some of these solutions may have to wait until the distant future, but one can always dream of advances that would make these a reality.

As an opening thrust, I note that I have been using lasers in my research for almost 40 years. During that time, extraordinary advances have been made in wavelength coverage, optical power levels, and other characteristics of lasers. A few years ago, I acquired a laser system based upon a mode-locked Ti:sapphire laser,[1] an optical parametric oscillator, a frequency doubler, and a frequency tripler that (in principle) allows wavelength tuning from ~250 nm to more than 2000 nm, by using the system in different configurations. It is an extraordinarily versatile system that has served my research needs well. However, this system falls significantly short of the ideal system that I would like to have.

Some of my colleagues and I have fantasized for years about a laser system that would basically be a black box allowing us to dial up the laser wavelength (from the deep UV to the far IR), optical power level (up to many watts of average power), optical pulse duration (continuous wave to sub-femtosecond), and pulse repetition rate (single shot to a rate approaching the inverse of the pulse width). All limits would have to be in accordance with the laws of physics. It is difficult for me to imagine what laser material (or set of laser materials) would allow this. Of course, we want this to be a compact laser system that easily fits on an optical bench and is affordable by the average researcher. Oh, and if it wouldn't be too much trouble, we'd like to be able to perform measurements using outputs at two or more wavelengths during any given measurement. For example, we might want to perform a pump-probe measurement with the pump pulse at one wavelength and the probe pulse at a different wavelength. Or we might want to perform a four-wave mixing experiment with three different wavelength pulses, or two pulses of different durations and one continuous-wave beam. Is this wish pure science fiction (or science fantasy), or is there hope that I might be able to purchase such a system in my lifetime?

Worldwide, we have many medical problems that cause various levels of discomfiture up to and including great pain and suffering. I want a medicine that I can take in simple pill form that will cure all medical issues from hair loss to cancer

or heart problems. I want it to be a one-pill cure. I don't want to have to take a single pill every day or for some extended period of time. If it wouldn't be too much trouble, I'd like a medicine that has no onerous side effects. I also want to be able to repair or replace body parts that fail or wear out. Is it too much to ask for a device that combines various elements of instruments seen on Star Trek? I want a scanner, like the Star Trek tricorder, that can detect all medical problems. I also want a three-dimensional (3D) printer that can grow/print every human body part for replacement. And, I'd like the printing process to work *in situ* so that body parts can be replaced without surgery. This may require the system to function somewhat like the Star Trek transporter system.

So, it's simple. I want a scanner that detects medical problems before they become serious, and a three-dimensional printing process that replaces human body parts *in situ* to renew worn out or damaged body parts. Is this science fiction (or science fantasy), or could this become a reality in my lifetime? 3D printing (also called additive manufacturing) has already been used to fabricate windpipes,[2] airway stents for infants,[3] and jaw implants,[4] and has been at least discussed as a possible method to fabricate organs.[5] So there is hope and promise. However, significant work would be required to fabricate organs, much less the process that I've discussed above. All in all, I'd much rather have these medical advances come to fruition than the laser system described previously.

At the time of this writing, news outlets have been full of images of the devastation in Nepal and the surrounding environs due to a 7.8 magnitude earthquake.[6] Recent news has also included significant coverage of devastation in the United States and elsewhere caused by storms and tornadoes.[7] Those stories have been accompanied by images of the devastation in Chile due to the recent eruption of the Calbuco volcano, which spewed an estimated 7420 million cubic feet of ash.[8] This was enough to cover a major portion of the surrounding countryside with a 50-cm-thick layer of ash that damaged many houses, businesses, and other structures. Is it too much to ask for low-cost infrastructure materials that are resilient against earthquakes, fire, storms, and volcanic eruptions? Most structures in many parts of the world are not built to conform to rigorous codes that require survival through even low-magnitude earthquakes, much less a truly large earthquake. I recall a story from some years ago that after hurricane Andrew had savaged Florida, the only houses left standing in the most violent parts of Andrew's path were houses built by Habitat for Humanity, because they used low-cost but highly resilient materials as well as construction processes that were proven to be resilient. I don't know if that story is real or only apocryphal. But low-cost materials and fabrication processes for structures strong enough to survive these events would be of incalculable value to humanity. Is this science fiction (or science fantasy), or could this become a reality in my lifetime?

We face many problems that affect our lives as well as our quality of life. Our history over millennia has shown that materials research has helped improve our lifespans as well as our quality of life. Materials research may well lead to high-temperature superconductors (room temperature and above), quantum computers that exceed by far the capabilities of today's computers, germline genome editing for humans and other species, low-cost and efficient renewable energy sources, clean and abundant fresh water, safe and effective treatment of nuclear waste, more effective treatment and healing of wounds, healing of spinal cord injuries, new and more effective antibiotics, more durable roads and bridges, and materials to sustain and support our expansion into the solar system and beyond. I believe that many of the things that we believe today are the merest science fiction (or even science fantasy) in realms as far apart as scientific instrumentation, medical practice, and infrastructure will become reality because of the materials of tomorrow.

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References

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