

# Special Issue on “Ultra-capacity Metasurfaces with Low Dimension and High Efficiency”

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**F**abrication of three-dimensional (3D) metamaterials usually involves directly arranging deep subwavelength unit cells into ordered configurations of desired architecture, with or without resonances. This results in an “effective medium” with at least multiwavelength bulkiness, and the light propagation through the metamaterials could be well predicted and engineered in terms of effective medium. While 3D metamaterials provide us a platform to access intriguing light–matter interaction, they are inherently challenging to integrate into nanophotonic circuits and nanoplasmonic chips. In addition, great challenges will be encountered when employing mature nanofabrication techniques such as optical lithography, electron-beam lithography, focused-ion beam, and nanoimprinting to fabricate 3D metamaterials of locally varying geometries for arbitrary control of light at visible frequencies.

When advanced nanofabrication meets with metasurfaces, a two-dimensional (2D) counterpart to the volumetric 3D metamaterials, the enormous potential of each party is unleashed. Metasurface physics is also dubbed as “flat optics”,<sup>1–4</sup> implying that the state of light can be fully manipulated within an ultrathin layer of nanoscaled “meta-atoms” with subwavelength thickness. In recent years, we have witnessed an explosive development in the field of metasurfaces for achieving various optical functionalities, which have led to diverse applications, such as achromatic focusing,<sup>5,6</sup> waveplates,<sup>7–9</sup> cloaking,<sup>10–12</sup> color printing,<sup>13</sup> vortex generation,<sup>14–19</sup> nonlinear converters,<sup>20,21</sup> holograms,<sup>22–24</sup> time varying metasurfaces,<sup>25</sup> etc. Moreover, metasurfaces show great potentials in integrating multiple functionalities into one print.

This special issue is launched to gather collective wisdom on how to address the current bottlenecks of metasurfaces, probe the upper limit of their capacity, explore unprecedented niches of applications, and shed light upon new frontiers. The papers selected in the current issue represent fascinating progress in the area of metasurfaces, with impressive depth and breadth. This collection contains 23 papers in total, and the following fields of metasurface-based nanophotonics are specifically covered:

- **Surface topology metasurfaces:** The issue presents an experimental demonstration of conformable flexible holographic metasurface to form holographic images with specific surface topology.<sup>26</sup> This result holds promise for applications in surface topology sensing

and anticounterfeiting. It was selected as the cover article for this special issue.

- **Nonlinear optics:** The issue presents a series of works on nonlinear metasurfaces, including an experimental demonstration of giant optical Kerr response of gold quantum wells based nonlinear metasurfaces, which can act as a reflecting surface in the low-power region and phase grating in the high-power region,<sup>27</sup> a pioneering experimental study of an enhanced third-harmonic-generation complementary silicon metasurface,<sup>28</sup> a study of enhanced second-harmonic generation with broken symmetry III–V semiconductor Fano metasurfaces,<sup>29</sup> and a polarization-dependent second-harmonic diffraction from resonant GaAs metasurfaces.<sup>30</sup> Many advanced nonlinear effects were observed with metasurfaces made of new material systems, such as quantum wells, dielectric materials, and semiconductors. This marks a new direction to pursue.
- **Tunable metasurfaces:** This issue includes a reconfigurable metasurface cloak for dynamical electromagnetic illusions,<sup>31</sup> an experimental demonstration of liquid crystal tunable metasurfaces for dynamic beam switching,<sup>32</sup> a novel demonstration of a high-efficiency reconfigurable metagrating,<sup>33</sup> and a tunable slow light graphene metasurface.<sup>34</sup> This group of selected papers address a fundamentally challenging and important point for metasurface: going tunable.
- **Plasmonic metasurfaces:** This issue incorporates an exciting work on a multifunctional gap surface plasmon-based metasurface,<sup>35</sup> an on-chip spectropolarimetry enabled by surface plasmon polaritons,<sup>36</sup> a plasmonic metasurface based on ultrafast laser printing,<sup>37</sup> and a study on the effect of rotational disorder at the unit-cell level on the optical response of chiral bilayer plasmonic metasurfaces.<sup>38</sup>
- **Light manipulation:** This issue includes an in-depth study of orbital angular momentum multiplexing and

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demultiplexing with a metasurface in the terahertz band,<sup>39</sup> a dielectric metasurface acting as a Rochon-prism-like planar circularly polarized beam splitter,<sup>40</sup> a dielectric metalattice for beam steering,<sup>41</sup> and a light sword metasurface lens.<sup>42</sup>

- **Geometric phase based metasurfaces:** This issue presents a novel study of a broadband polarization-independent diffusive scattering metasurface,<sup>43</sup> a geometric phase based pragmatic metasurface hologram balancing between diffraction efficiency and fabrication compatibility,<sup>44</sup> and a study on geometric phase based reflective metasurfaces.<sup>45</sup>
- **Transformation optics:** This issue includes two excellent works on this field: one demonstrating an external cloak with the metasurface approach based on transformation optics<sup>46</sup> and the other presenting interesting results on employing a transformation based metasurface for light-sheet microscopy.<sup>47</sup>
- **Light trapping:** This niche area is represented by an inspiring work on light-trapping enhancement using silver nanoantennas in organic solar cells.<sup>48</sup>

In summary, this special issue contains a series of frontier research works on ultracapacity metasurfaces with low dimension and high efficiency. These works represent great scientific progress, covering a broad spectrum of topics (e.g., metamaterials, metasurfaces, nanophotonics, optics, material sciences, etc.) and balancing fundamental development with application-oriented device prototyping. This collection of 23 papers is highly recommended and believed to benefit readers from various disciplines, although we had to decline many excellent papers due to the page limit. Last but not least, we are grateful for all submitting and contributing authors, many dedicated referees, Carlos Toro (Managing Editor), Professor Harry Atwater (Editor-in-Chief), and especially Professor Stefan Maier (handling Editor for this special issue) for their enormous dedication and effort spent on making this special issue a successful and comprehensive story.

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### Notes

Views expressed in this editorial are those of the authors and not necessarily the views of the ACS.

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