



Anticipating critical materials implications from the Internet of Things (IOT): Potential stress on future supply chains from emerging data storage technologies

Anthony Y. Ku

National Institute of Clean-and-Low-Carbon Energy, Shenhua NICE, P. O. Box 001, Future Science & Technology City, Changping District, Beijing 102209, PR China
NICE America Research, 2091 Stierlin Ct, Mountain View, CA 94043, United States

ARTICLE INFO

Keywords:
Critical materials
Data
Memory
Zettabyte

ABSTRACT

Over the past decade, raw material price spikes have called attention to the supply security of a variety of critical materials, including rhenium, rare earth elements, and helium. While market forces play an important role in creating and resolving these situations, transitions in technology also create step-changes in demand that increase or decrease the criticality of different materials. With an appropriate understanding of how materials are used in various applications, it is possible to explore the critical materials implications associated with the introduction of new technologies. Work is already underway to investigate and mitigate the materials impacts of emerging clean energy technologies related to solar power and energy storage. Rapid technological change is also being enabled by information technologies and the Internet of Things (IOT). Here, less work has been done around materials trends and their implications. This paper presents a case study around emerging technologies for data storage and what their implementation at mass scale (zettabyte, ZB) might mean for existing supply chains and market dynamics for certain critical materials.

1. Introduction

Concerns about the supply availability of different strategically important raw materials have come and gone over the past several decades [1–3]. These episodes have resulted from combinations of mismatches in supply and demand due to geopolitical instability or natural disasters, significant short- to mid-term changes in usage or production trends, and intentional or unintended consequences of policy [4,5]. Examples from recent years include crises in the markets for heavy rare earth elements, helium, and some minor metals such as rhenium [4–6].

Materials criticality is a term used to describe materials supply chain risk and its consequences. Significant progress has been made in quantifying the factors that contribute to materials criticality and generalizing the concept from individual companies up to global scale enterprise [7,8]. Technology development poses interesting questions for criticality assessments because it can impact criticality ratings in several ways. New technology introduction may increase demand for materials that are already relatively rare and used in vital applications. In this regard, the 2010 US DOE Critical Materials study identified several materials of interest for clean energy technologies and follow-up studies have produced quantitative estimates of the potential demand

[9,10]. Over the past decade, studies around the implications of utility-scale deployment of thin film photovoltaic solar power have flagged tellurium, indium and gallium as materials of interest [11,12]. Conversely, technology development can reduce criticality by creating substitutes to valuable materials used in existing applications. An example of this is the adoption of light emitting diode (LED) technology which is significantly reducing demand for rare earth elements europium, terbium, and yttrium [4]. In both situations, early insight into factors that impact materials markets can provide valuable guidance to both industry and governments and their efforts to manage supply chain risk and set policy [9].

The digital information and communication technology (ICT) industry has three features that make it interesting from a critical materials perspective. First, it uses a wide and increasing range of elements to enable the desired electronic, magnetic, optical, or mechanical properties needed for chips and devices [7]. Second, the large number of chips and devices that are produced each year suggest that even incremental uses in certain elements can amount to meaningful volumes of material relative to current supply. Third, the speed of technology introduction cycles can be faster than the time scales associated with other aspects of the supply chain. Some new generations of electronics products are introduced annually. It can take a decade to open a

E-mail address: anthonyku@nicenergy.com.

<http://dx.doi.org/10.1016/j.susmat.2017.10.001>

Received 12 September 2017; Received in revised form 18 October 2017; Accepted 28 October 2017
2214-9937/ © 2017 Elsevier B.V. All rights reserved.

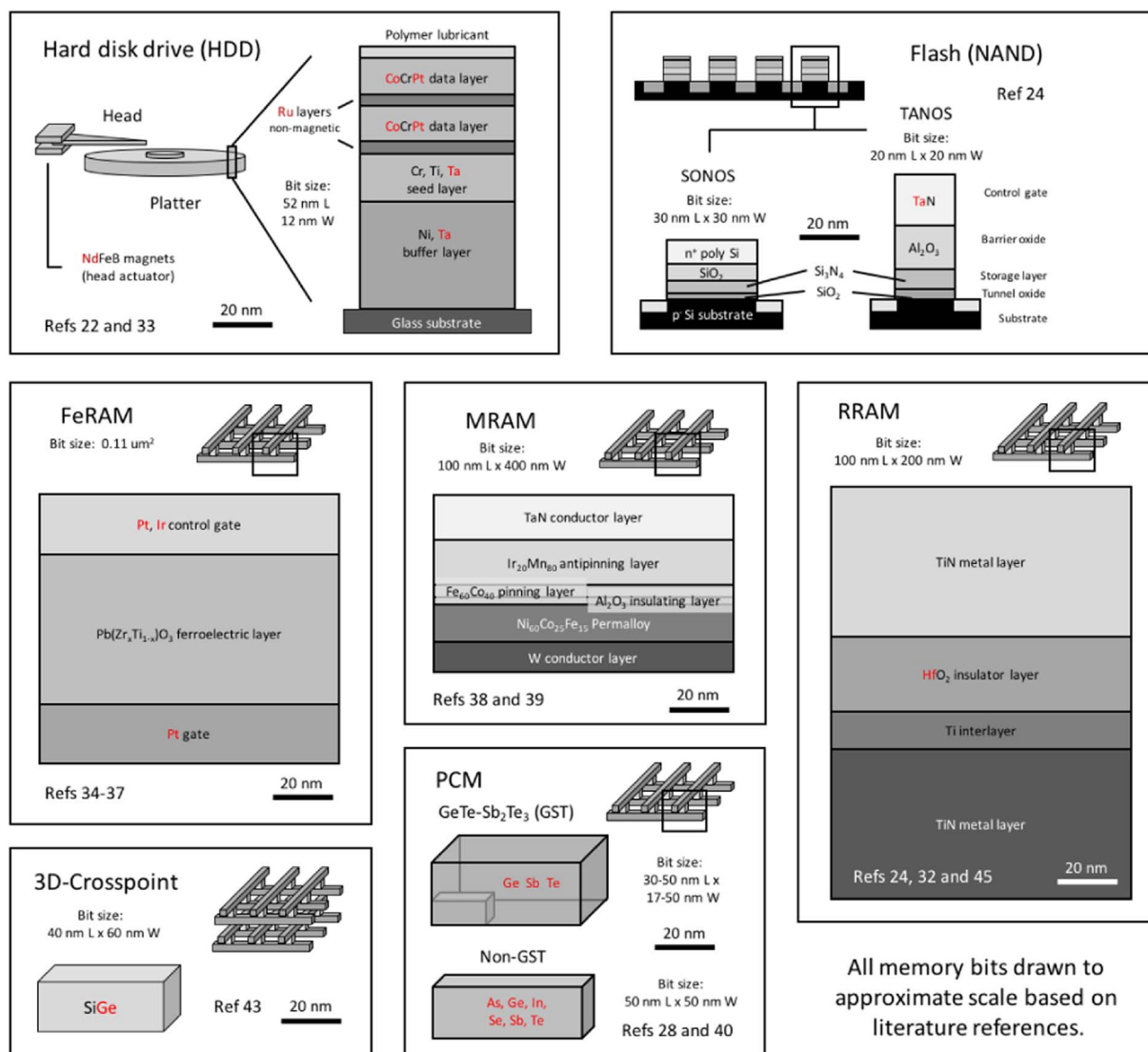


Fig. 1. Bit architectures of seven data storage approaches: Hard disk drives, flash memory, FeRAM, MRAM, PCM, 3D-crosspoint and RRAM. The bit architectures are drawn to the same scale for comparison, and the composition of different layers are listed. Potentially critical materials are shown in red. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

new mine and almost as long to re-qualify materials for use in highly regulated long-cycle industries, such as aviation [13].

The growth rate of digital data services over the next decade is projected to be high, and is grounded in growing global penetration, per capita use, and emerging applications such as the Internet of Things (IoT) [14]. One hub of this growth is data centers, which form an important part of the backbone infrastructure. Most published analyses of data center sustainability have focused on energy use [15,16]. More broadly, life cycle analyses (LCA) have been for various parts of the ICT infrastructure, but these focus on energy and emissions rather than materials use [17]. To our knowledge, the materials use aspects of the IOT and digital data traffic have not yet been explored in the open literature.

The exponential increase in data traffic suggests there may be the potential to alter market dynamics for one or more materials used in data centers. One projection of data generation rates estimates that by 2020, aircraft could generate 40 TB/day/plane, autonomous cars 2 PB/yr/vehicle, and smart factories 1 PB/day/facility [18]. Another estimates global data generation on the order of 163 ZB of data per year by 2025 [19]. The transmission and computing infrastructure associated with these levels of data traffic will expand significantly from today's levels. In addition, data storage at this scale presents challenges for

incumbent technologies related to data transfer speed, energy use, scalability, and reliability [20]. This has motivated interest in alternate technologies for storage class memory (SCM) enabled by new materials approaches.

This paper examines the critical materials implications of emerging SCM data storage technologies, at the ZB scale. Estimates of the raw materials requirements for several types of non-volatile memory technologies are used to identify a short list of materials whose supply chains could be significantly impacted over the next decade. Of particular interest are elements that are already on published critical materials watch lists and elements where the materials use at ZB-scale adoption approaches within four orders of magnitude of the annual global production.

2. Approach and methods

All memory devices comprise individual cells which store bits, with differences arising in the specific physical architecture, dimensions, and chemical composition of the bit feature. The literature was surveyed to identify candidate device technologies for storage class memory. Seven cases, representing existing and emerging technology options, were selected for initial analysis.

Download English Version:

<https://daneshyari.com/en/article/7228384>

Download Persian Version:

<https://daneshyari.com/article/7228384>

[Daneshyari.com](https://daneshyari.com)