

## Conclusions and Comparison with U.S. Activities

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## A Fresh Start at the National Level

- ◆ End of Micro Machine Project era; start of new, more focused project on microfluidics
  - Key researchers are involved in the planning (T. Kitamori) following US federal model
  - Excellent existing projects at Tokyo, Waseda, Hitachi
- ◆ Japanese Nanotechnology Initiative
  - Benefiting microsystems research (enabling for nano)
- ◆ Many questions:
  - Resource allocation: competitive, hand-picked, or “spread-the-wealth”?
  - Role of industry vs. universities?
  - Role of TLO in aiding/hindering collaboration?

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## Lead Universities are Major Players

- ◆ Facilities upgraded selectively over past 5 years
- ◆ Faculty: importing industrial talent (Ritsumeikan)
- ◆ Internationalization: Asia and beyond (e.g., Univ. of Tokyo IIS French connection; seeking US ties)
- ◆ Research quality: world-class
- ◆ Approach: aggressive build and test with less concern about following silicon MEMS paradigm; CAD is imported from US/Europe
- ◆ TLOs ... better links to industry in/out of Japan (?)

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## Searching for High-Payoff Applications

- ◆ Focus on using MEMS to make “golden screws” in systems (Hitachi water quality monitors) rather than highly profitable commodities (Murata’s component model)
- ◆ Lack of foundries makes economics more difficult for MEMS in relatively low-volume applications
- ◆ Large Japanese companies are not reacting (or reacting sluggishly) to major investments by US, Europe in optical MEMS

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## Comparisons

- ◆ Industry “identity” weak in Japan vs. US
  - K. Gabriel, CMU and S. Walsh, Univ. New Mexico working to establish an industry group, commercialization strategies, and roadmaps
  - Investors are focused on MEMS, with some successes
- ◆ Why?
  - Roots of MEMS in the US are in the well-organized integrated-circuit industry
  - MEMS has reached “critical mass” in some applications (inertial, optical, displays, microfluidics)
  - MEMS standardization: started in Europe, US joins, Japan still absent

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## Who’s ahead in Microsystems Technologies?

- ◆ US appears to be ahead in most Si-based fabrication technologies and commercialization of those technologies
- ◆ Where is Japan ahead?
  - Application of non-silicon approaches
  - Milli-scale devices
  - Depth in small companies that can do individual small jobs (fluidic connectors, packaging, etc.)
  - ‘Real’ university-industry interaction (engineers working at universities)

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## A Long-Term Advantage for Japan?

- ◆ Microsystems require more than silicon chips with electronics, microsensors and microactuators (e.g., integrated chemical reactors): interface with macro world
- ◆ Japan excels in the breadth of speciality companies with know-how on precision manufacturing of milli/micro scale non-silicon components (metals, plastics, ceramics)
- ◆ Premature effort on Micro Machine Project to on Microfactory (no market pull, little development of new assembly technologies)

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## Rapid Progress in a Variety of Assembly Technologies

- ◆ Many ways to do “hands-off” low-cost assembly in the milli-micro-nano domains: all being researched
  - Self assembly
  - Parallel or batch assembly
  - Serial assembly using arrays
- ◆ Japan has clearly superior capabilities to provide a wide range of micro components for 2<sup>nd</sup> generation microsystems incorporating Si and non-Si materials
- ◆ AIST (national lab) is working to bring speciality companies into microsystem projects ... microfluidic project may be a catalyst

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## Broad Vision for Microsystems

- ◆ Focus on “social needs” as ends for microsystems research
  - Examples: Prof. M. Esashi heads the energy and materials conservation thrust at NICHe
  - Motivates for several projects, such as battery replacements
- ◆ Practical implication:
  - Tackling real-world systems avoids “MEMS device” syndrome and stimulates interface with non-silicon, non-planar processed universe

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## Investments in Microsystems

- ◆ METI spending ratchets down with new project
  - Exact numbers not available (\$50-\$100M over 5 years)
  - Ties between industries and universities are good, but total investment appears less than in US and Europe – ongoing economic weakness hurts
- ◆ Start-ups and spin-outs: few and unusual
  - Institute for Microchemical Technology from KAST
  - Nanodes from Ritsumeikan
  - Wacho (closest to US model)
- ◆ Lack of new regional initiatives by Prefectures
  - Contrast California and Ohio projects in US

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## Educational Activities

- ◆ Graduate-level MEMS courses at most universities
  - Some complaint about lack of interest by Japanese students (huge contrast with US)
- ◆ Well-attended industrial short courses (Tohoku)
- ◆ Outreach to K-12 has been very extensive
  - Micro Machine Project's art contest (1994-2000)
  - National Museum of Emerging Science and Innovation exhibit on MEMS (2001) with major help from Prof. H. Fujita, Univ. of Tokyo

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## Overall Assessment

- ◆ Japan's foray into long-term "basic" research during the 1990s with the Micro Machine Project failed to catalyze a microsystems industry
- ◆ Microfluidics and nanotechnology initiatives represent a fresh start
- ◆ Many "islands of excellence" in MEMS design and fabrication throughout universities, industry, and government labs

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