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Apple A6 Teardown

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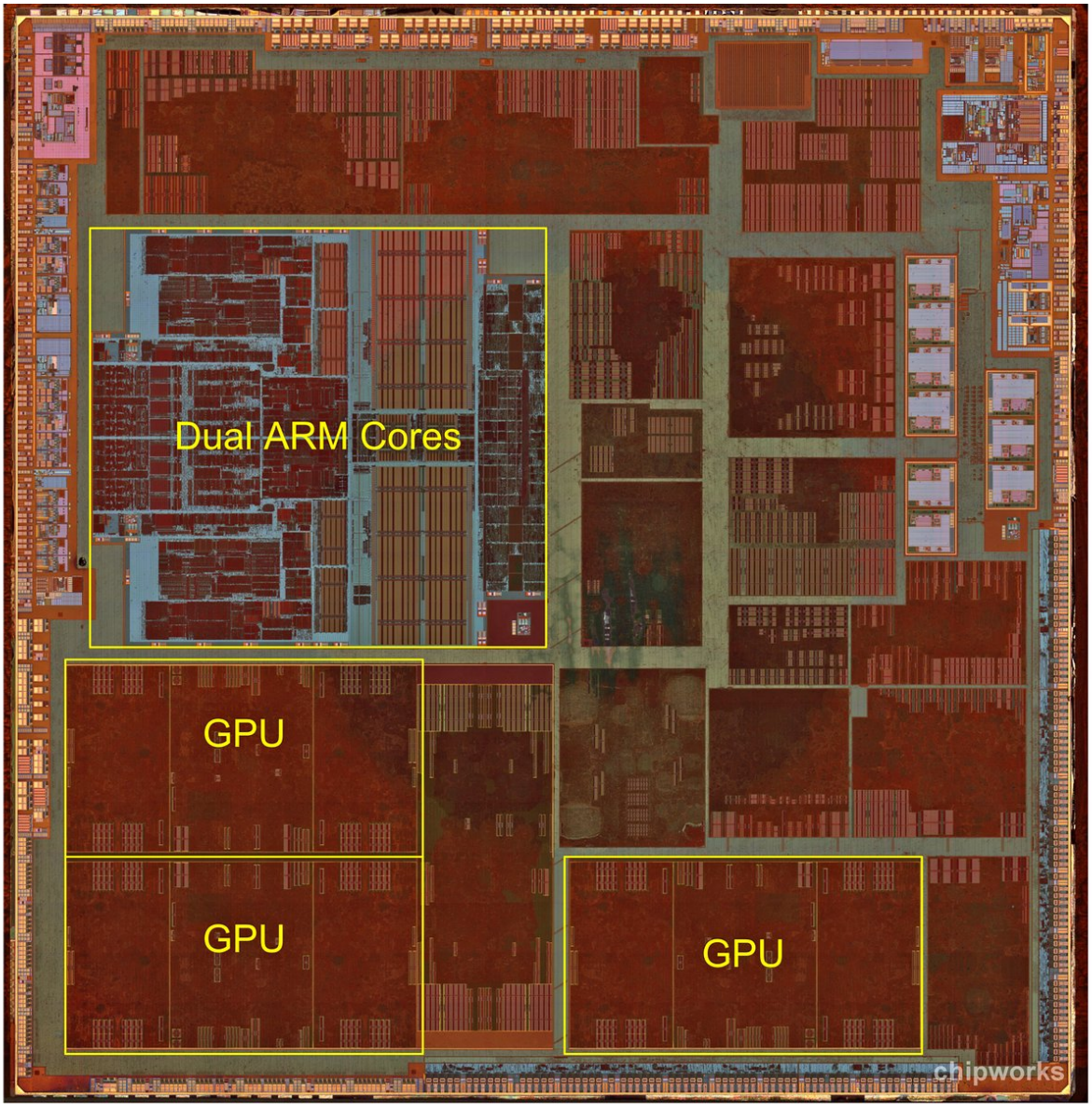
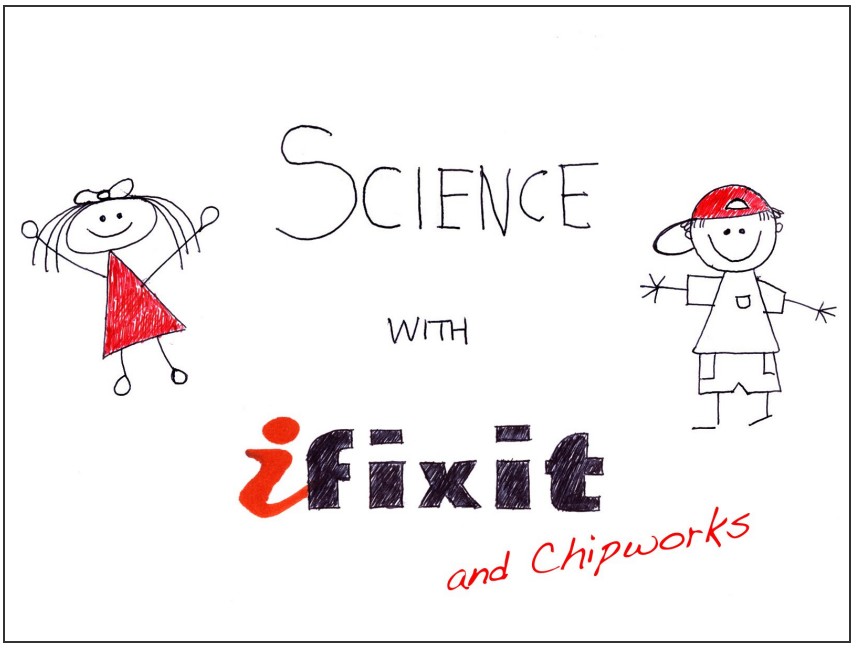


INTRODUCTION

Geeks rejoice! We have partnered with Chipworks for a double-the-geeks, double-the-fun teardown of Apple's new A6 Processor. The A6 is rumored to make use of two custom 1 GHz CPUs running the ARMv7s instruction set. Along our journey into the A6, we'll also give you a sneak peak at some of the fun ~~toys~~ instruments at Chipworks.

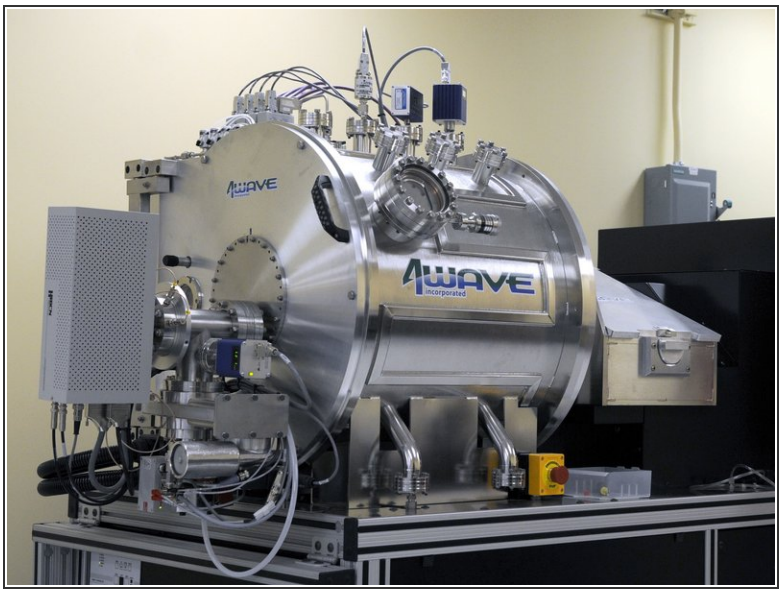
Whether you enjoy getting all science-y with us, or just like to see the insides of [invalid guide link], be sure to follow us @iFixit on Twitter and check out our page on The Book to be updated on the newest iFixit goings-on!

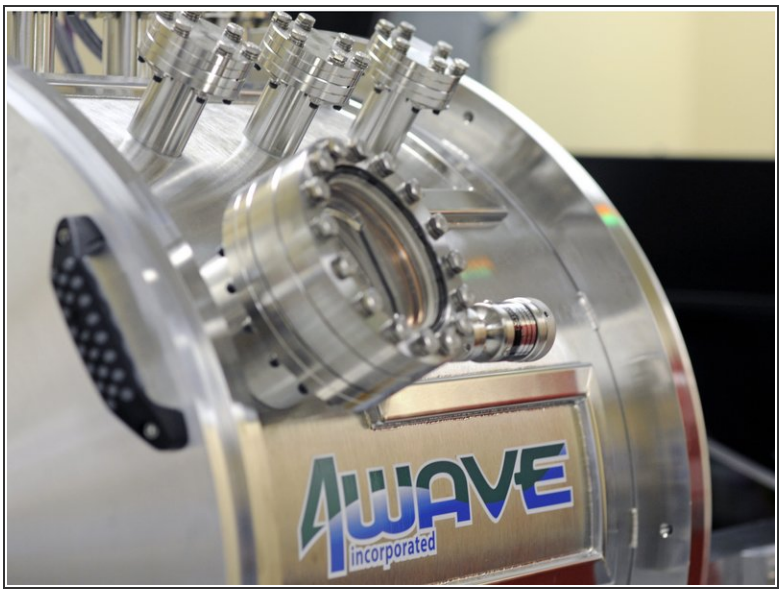
Step 1 — Apple A6 Teardown



- Welcome to the third installment of **[invalid guide link] with [invalid guide link]**. This time around, we've got a helping hand from our buddies at Chipworks.
- Disclaimer: there will be a lot of technical jargon being thrown around in this teardown. We'll try to succinctly explain what we can, but expect to see plenty of links to good ol' Wikipedia.
- So hop on, and join us as we figure out why the A6 is so darn fly.
- But first, a bit about Chipworks' equipment that makes all this possible.

Step 2 — Life at Chipworks





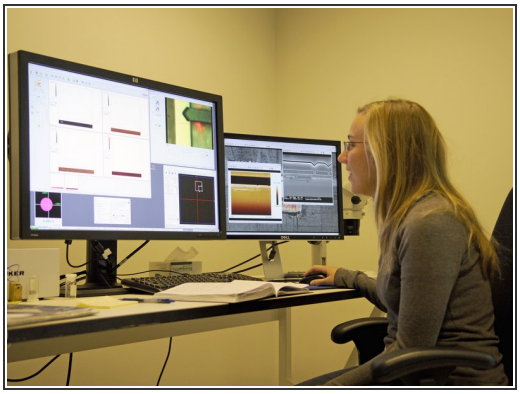
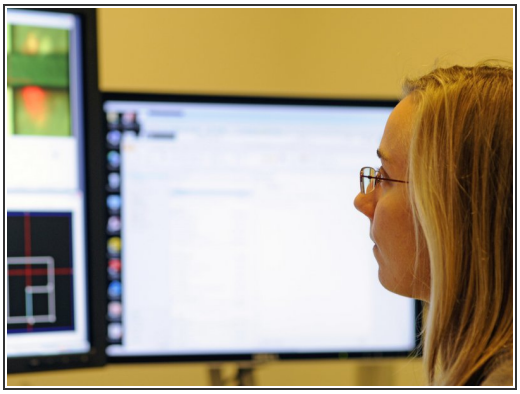
- Chipworks has a bona-fide ion blaster, affectionately called Ibe (short for "ion beam etching").
- Ibe is used to remove layers of semiconductor devices in a controlled and selective manner with very precise and planar results.
- Essentially, ion beam etching is like sandblasting a chip to remove specific layers. Instead of sand, though, Ibe uses the atoms in an ion beam to do its dirty work.
- Today's semiconductor devices are constructed from dissimilar materials, like the Apple A6 which is fabricated with Samsung 32 nm HKMG (Hi dielectric K, Metal Gate) CMOS process, making this an invaluable tool.
- tl;dr it's an ion blaster.

Step 3



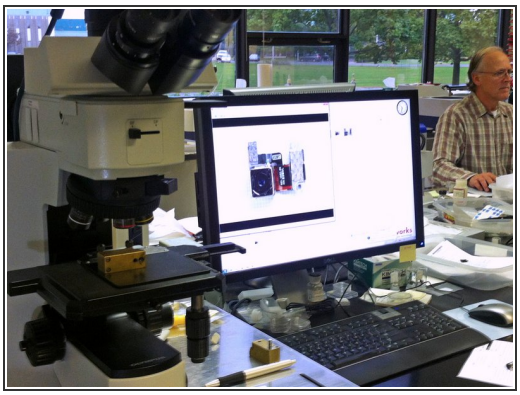
- A member of the Chipworks development team sets up parameters on Ibe for the removal of the dielectrics on an advanced node chip (like the A6) where there may be up to 9 copper layers and 1 aluminum layer, as well as polysilicon and substrate layers.
- Recently, Chipworks completed an addition to their de-layering lab, adding several more wet benches, fume hoods, and polishing stations.

Step 4


- Semiconductor doping profiles are extremely important to understanding how today's advanced devices perform and are constructed.
- Chipworks has recently brought in a new, higher resolution scanning capacitance microscope. With this new SCM they can examine the doping profiles of NMOS and PMOS devices in the A6, as well as understand how the photo cathodes in the 8 megapixel iSight camera have been doped.

Step 5



- Science!
- Process and development technicians examine results after preparing the A6 for processing. Interim views through optical microscopes provide necessary feedback to the technicians to fine-tune adjustments in the subsequent processing to maximize results.
- Next, Chipworks gets microscopically familiar with the rear-facing camera. We (along with pretty much everyone else) generally want to know who manufactures the iSight camera, and that information is hidden deep within the camera's guts.

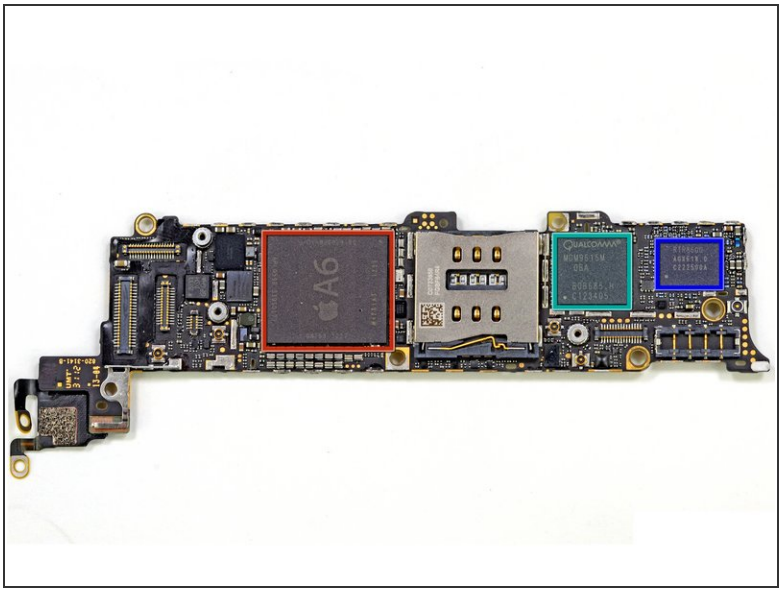
ⓘ No secrets are hidden too deep for Chipworks. They solved this mystery in no time.

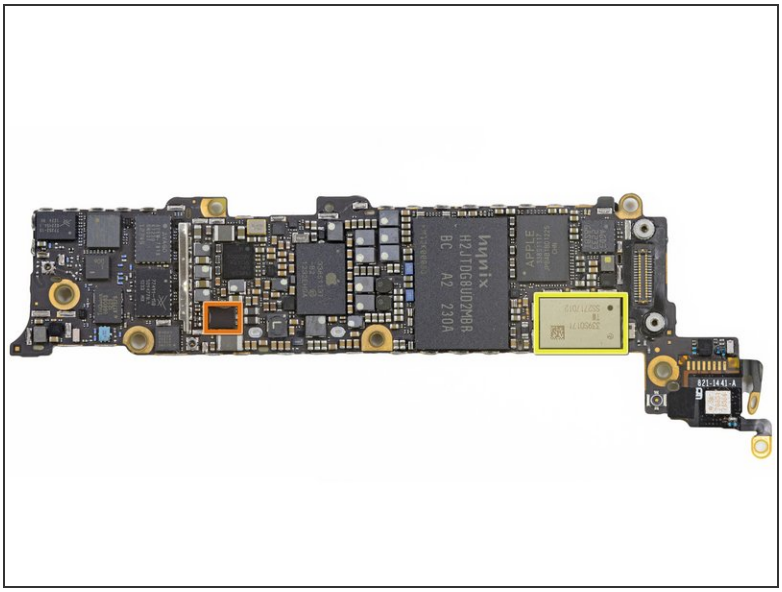
Step 6

- Different tasks call for different tools. If you want to look at some transistor strain, or some gate oxide thicknesses, or even crystal lattice orientation, you go for the big gun…
- …the electron gun that's in the new TEM (transmission electron microscope)!
  - TEMs get their high resolution from the small de Broglie wavelength of electrons. That's quantum mechanics in action!
  - To make a long story short, TEM works by shooting a bunch of electrons at a piece of material, then watching the way the electrons interact with that material.

These are just some of the techniques and machinery that Chipworks employs to render all the fun images you see on their site. But just like a good magician, they can't reveal *all* their secrets. So let's take a look at what lurks inside the iPhone 5's chips.

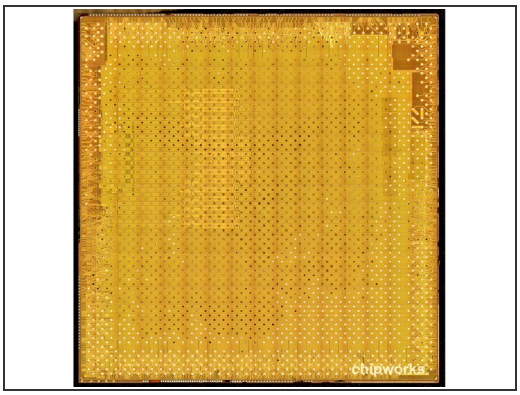
Step 7 — Inside the iPhone 5

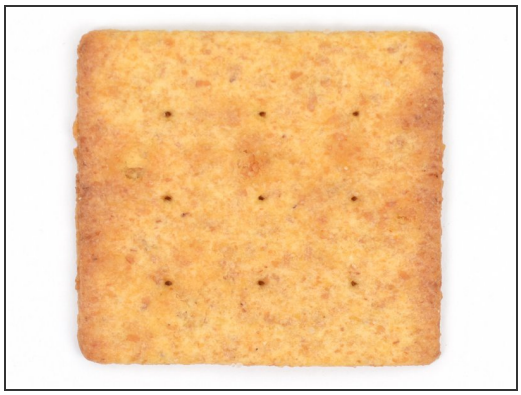


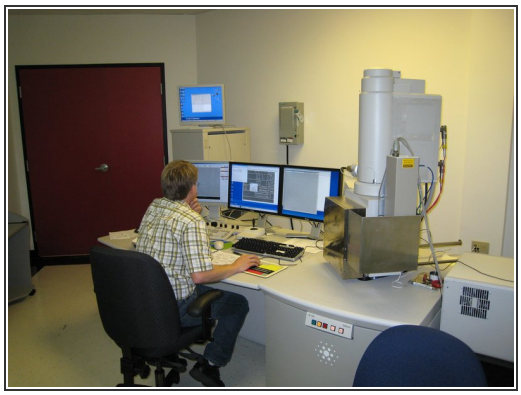


- The folks at Chipworks are quite fond of this phone. Directly from the horse's mouth: "This phone is full of brand new components…best Apple release since the first iPhone."
- We'll be looking at the:
  - Apple A6 application processor
  - Apple 338S1077 Cirrus audio chip
  - Murata 339S0171 Wi-Fi module
  - Qualcomm MDM9615 LTE modem
  - Qualcomm RTR8600 Multi-band/mode RF transceiver

Step 8 — The A6 Processor

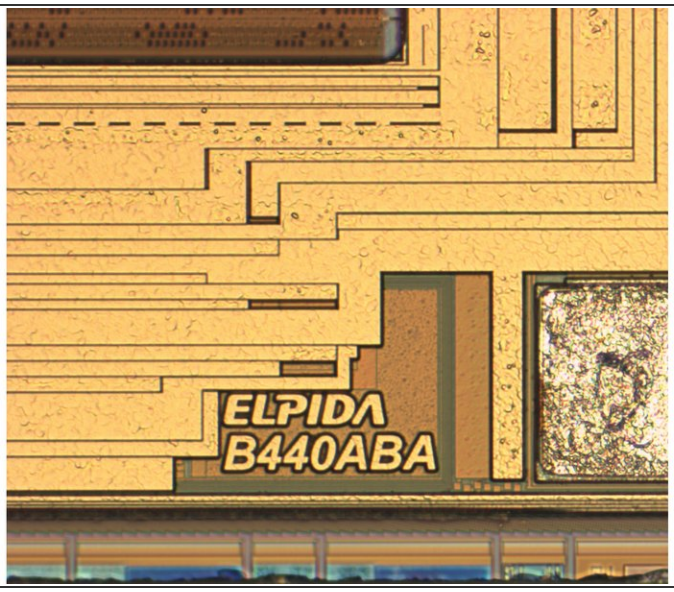


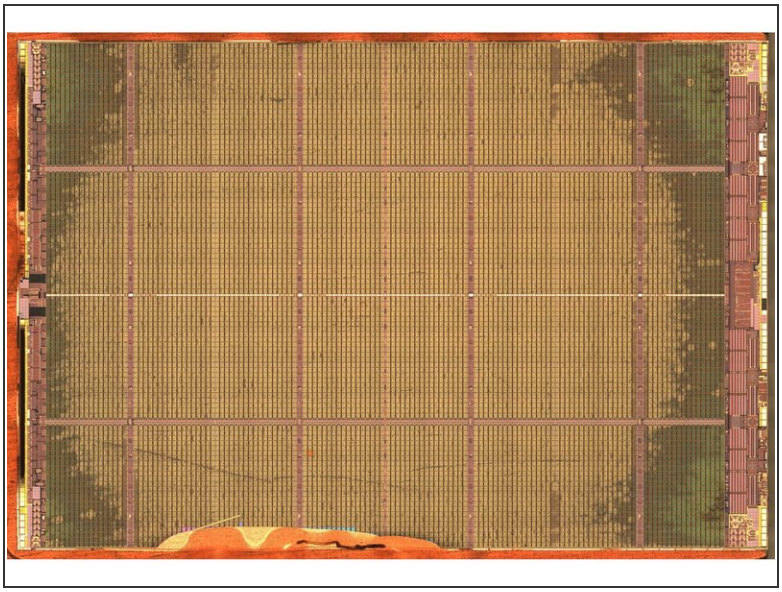




- Let's start by cutting into the A6 to see what drives it.
- What does the top of a metal die of the A6 processor look like? To us it looks like a Wheat Thin.
- So how were these photos created, you may ask? Well, we took a picture of a Wheat Thin. Chipworks opted to go the long route:
  - The A6 is first decapsulated in a fuming sulfuric acid solution, heated to a temperature designed to get best results.
  - Then, Chipworks engineers use a microscope to take images of the die. The die is loaded onto a servo controlled X-Y table, and focus is set and maintained by laser monitoring.
  - Image coordinates are programmed into the system. The microscope moves the die automatically and takes several images, which are stitched together to create the full die photo.
  - One of the machines used for the process can be seen in the third image.

Step 9

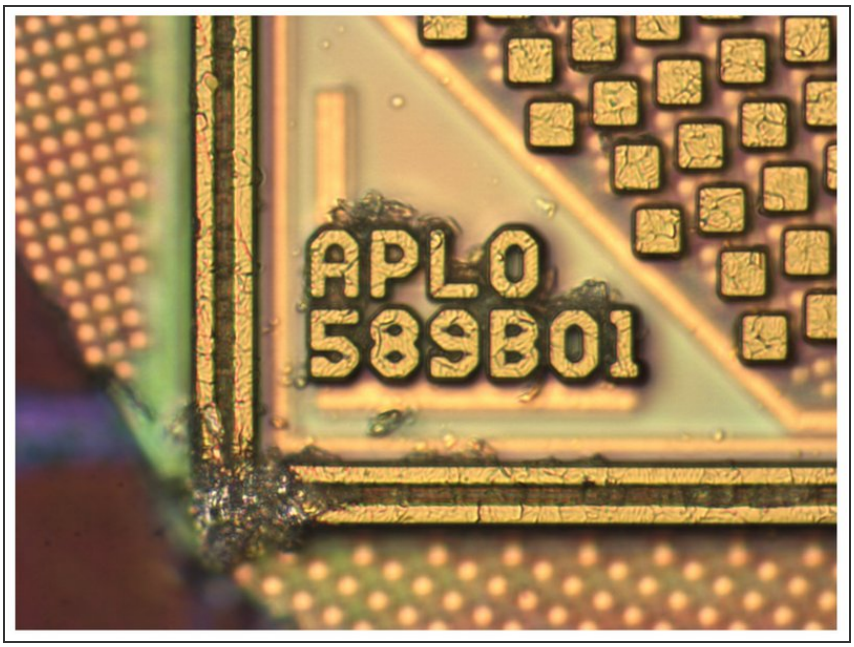




- During the [invalid guide link], we referenced the B8164B3PM silkscreen label, which denoted 1GB of Elpida LP DDR2 SDRAM.
- The die mark (first image) and die photo (second image) confirm the strong hunch that the A6's 1GB LP DDR2 SDRAM is provided by Elpida.

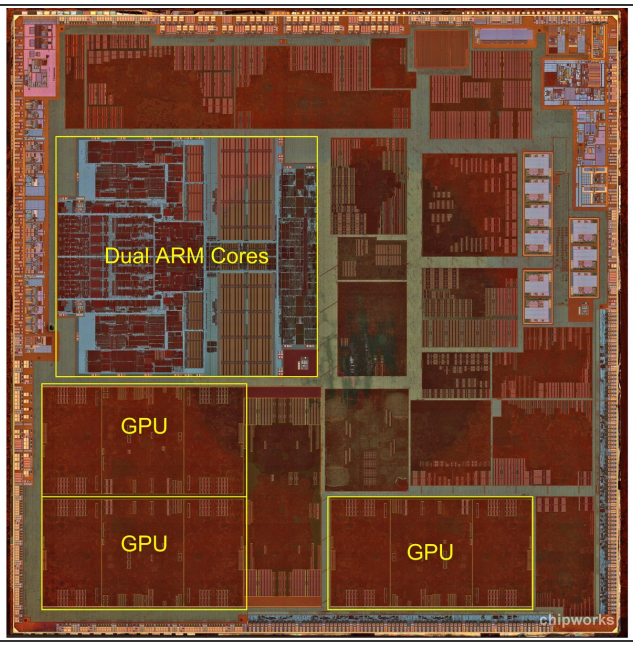
According to Chipworks, the Elpida EDB8164B3 was also found in the Motorola Droid RAZR Maxx.

Step 10



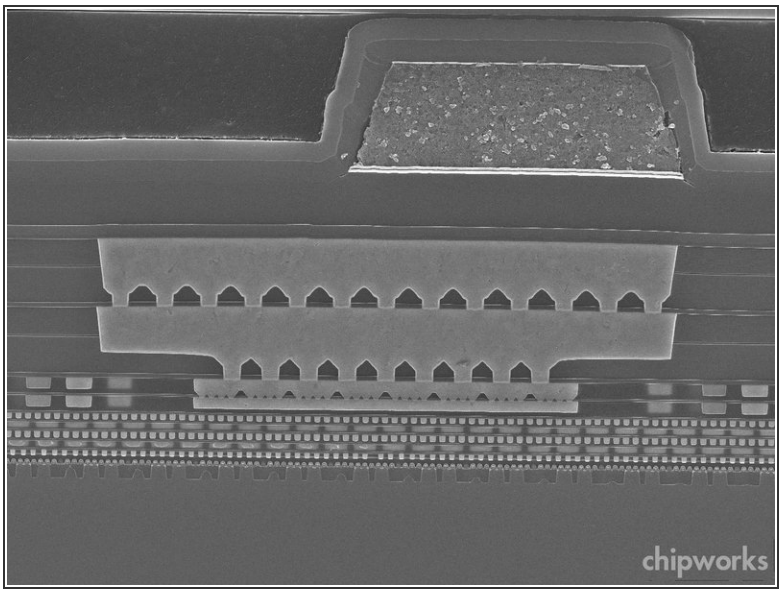
- Samsung isn't completely absent in the A6, though. The Apple A6—labeled [invalid guide link] on the package marks and APL0589B01 on the inside—is fabricated by Samsung on their 32 nm CMOS process and measures 9.70 mm x 9.97 mm.
- Even though the A6 was manufactured by Samsung, that doesn't mean it was designed by Samsung. The Apple A6 processor is Apple's first custom-designed processor. It's based on the ARMv7s instruction set.
- Because Apple had complete control over the design of the processor, they were able to customize and tweak the performance to their liking.
- With a die area of 96.71 mm^2, the die is considerably larger than the previous generation variant of the Apple A5 (~70 sq mm), which was fabricated by Samsung using their 32 nm HKMG process; so assuming the A6 is also 32 nm, there is considerably more functionality in the new part.

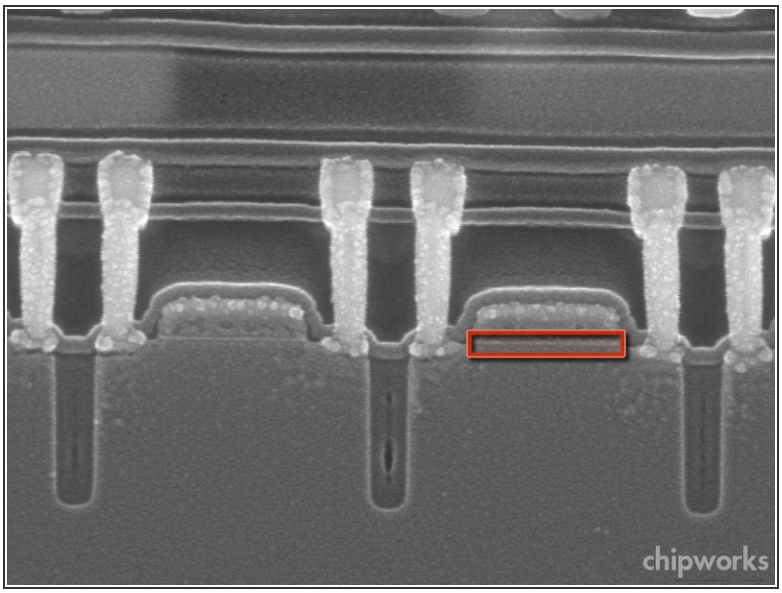
Step 11



- Journey to the center of the A6. The most prominent features inside are the Dual ARM cores, and the three PowerVR graphics cores.
- When compared to the rigid, efficient layout of the GPU cores directly below it, the layout of the ARM cores looks a little homespun—at first.
  - Generally, logic blocks are automagically laid out with the use of advanced computer software. However, it looks like the ARM core blocks were laid out manually—as in, *by hand*.
    - A manual layout will usually result in faster processing speeds, but it is much more expensive and time consuming.
  - The manual layout of the ARM processors lends much credence to the rumor that Apple designed a custom processor of the same caliber as the all-new Cortex-A15, and it just might be the only manual layout in a chip to hit the market in several years.

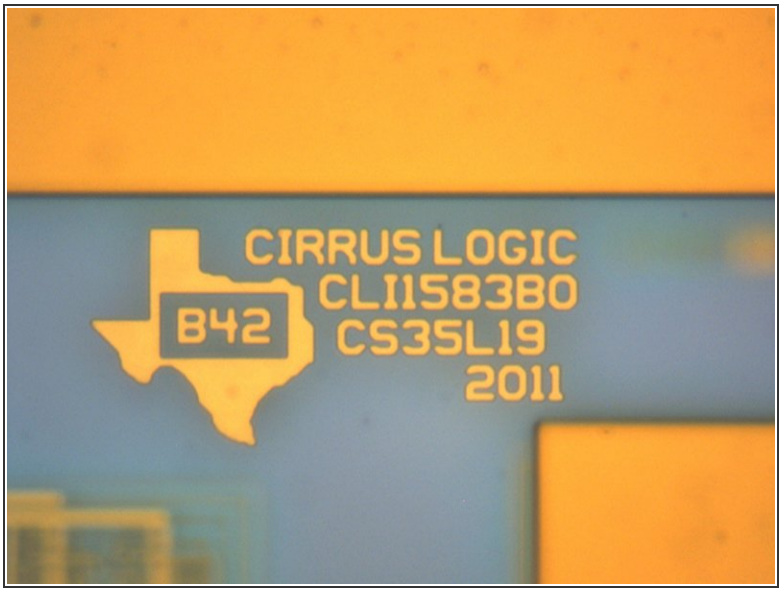
Step 12

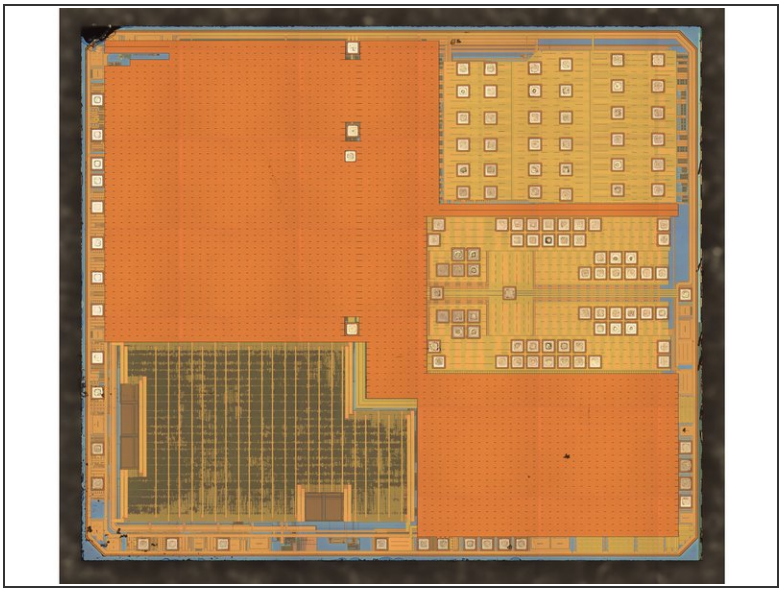




- The raised mesa-looking shapes in the magnified cross-section view (second image) are the transistors' structures, and the little pegs running between them are the actually the contacts between layers.
  - We can't help but think that the transistor layout looks a lot like a Roman aqueduct.
- This very thin line confirms that this is a 32 nm HKMG (Hi-K metal gate) process.
  - The A6's 32 HKMG process is the same as the one utilized in the [invalid guide link] (APL2498 on Chipworks).
- In an FET (Field Effect Transistor), K is the dielectric constant of the layer between the gate electrode and the silicon. This is a physical parameter of the material which helps control the turn-on voltage of the transistor

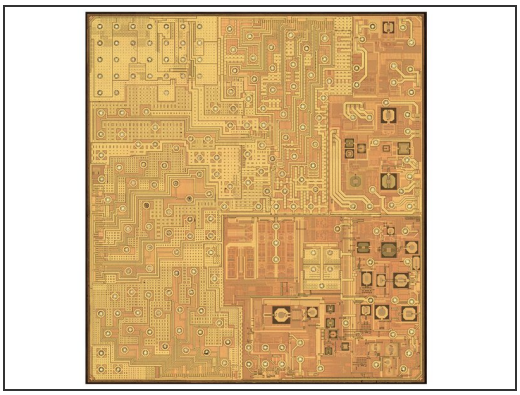
Step 13 — Other Notable Chips

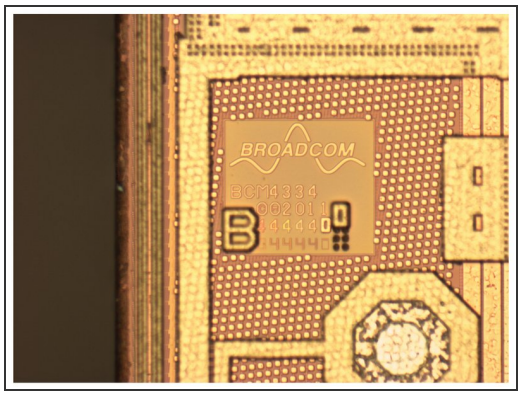


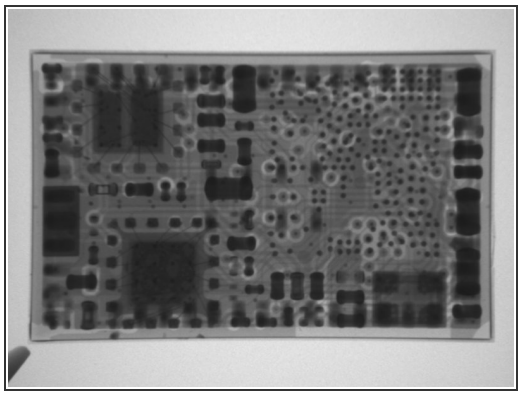


- This may be an A6 teardown, but the new iPhone is full of new chips to delve into—you didn't think the A6 ran the device all by itself, did you?
- Chipworks cracked open the [invalid guide link] to confirm that it is, in fact, a Cirrus CS35L19 class-D audio amplifier.
- The second image is of the Cirrus' CS35L19 die. Judging from the inscription, this package seems to be from the CS35L family, although it's not specifically listed on Cirrus' site.

Step 14

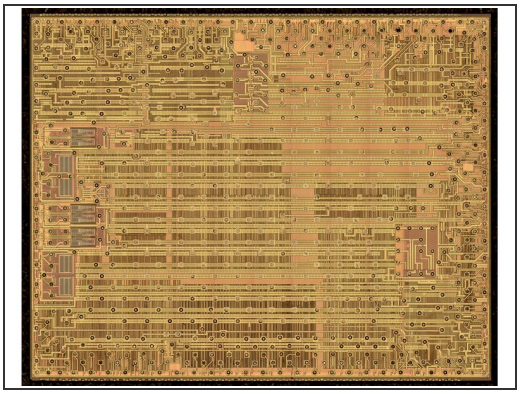
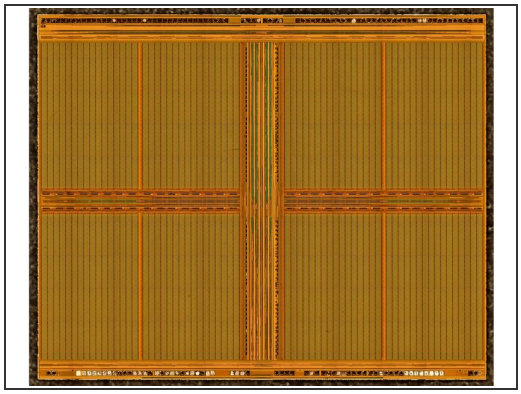
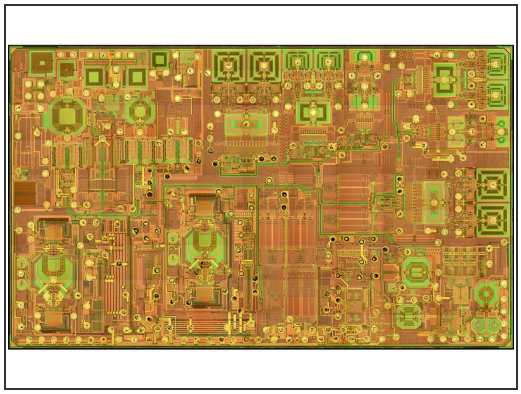






- The Murata Wi-Fi SoC module actually comprises a Broadcom BCM4334 package in addition to an oscillator, capacitors, resistors, etc. You can see all the components in the X-ray (third image).
  - Murata assembles all of the components together and sends their package to Foxconn, where it eventually ends up on the iPhone's logic board. Chipworks said it best: "Murata makes a house that is full of other people's furniture."
- Here are the die images for the Broadcom BCM4334, fabricated in Taiwan at TSMC on a 40 nm CMOS process. Its key features:
  - Wi-Fi (802.11 a/b/g/n)
  - Bluetooth 4.0 + HS
  - FM Receiver

Step 15

- Now, on to the Qualcomm MDM9615 LTE modem and RTR8600 multi-band/mode RF transceiver packages. We covered the MDM9615 extensively in the iPhone 5 teardown, but here's a quick rundown:
- The MDM9615 allows for multi-spectrums, multi-mode LTE support. It is responsible for transmitting simultaneous voice and data transfer on LTE (provided the carrier has the infrastructure to allow simultaneous voice and data transfer.)
- The Qualcomm RTR8600 is a multi-band/mode RF transceiver. The RTR8600 is paired alongside the MDM9615 to support various bands, including 5 UMTS bands, and over 5 LTE and 4 EDGE bands.
- So what's pictured on this step, you say?
  - The first image depicts the HG11-N3877 LTE Baseband die.
  - The second image is of the Samsung 1G-F-MC 128 MB memory die, also found in the MDM9615.
  - The third image shows the RTR8600 die.

Step 16

- A big thanks to Chipworks for giving us insight into their labs, and into the inner workings of the [invalid guide link] iPhone 5.
- They're performing even more analysis on the iPhone 5's packages. Strangely enough, even though things look quite similar on the surface, they're stating that the "iPhone 5 is not an evolution of design, but quite possibly an entirely new design."