How Chemistry Counters Currency Fraud

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Hundred or ten rupee notes don't usually pose much of a problem. A brief check for mutilation or tears is all that they warrant. But when it comes to accepting 500 and 1000 rupee notes, whether it's a neighbourhood store or a fancy mall, thanks to the awareness of the proliferation of counterfeit notes of these denominations in the Indian market, we often find people holding them up against the light, checking for the embedded metal thread or the water mark. Most of us know that besides these two indicators, nowadays there are many more security features incorporated in paper currency to combat counterfeiting. But how many realize that we owe almost all of these features to advancements in chemistry? And that the battle against counterfeiting is still going on with materials and optics, scientists working diligently to come up with newer features based on even more sophisticated chemistry?

Fascinated by the crisp notes his father was counting, little Rahul picked one up and began to inspect it. He turned the 500 rupee note this way and that, his fascination deepening as he watched the play of light on the note's surface. He then flipped it over to examine the other side.

"Dad," he burst out. "Look at this note. It changes colour!"

"Huh?" said his Dad. "Let me see it."

It is paradoxical how people perfunctorily handle banknotes day in and day out without taking the time to observe their finer details. So where does chemistry fit into all this? Well, a close scrutiny of a banknote is all it takes to see what an important role chemistry plays right from making paper currency more durable to making it counterfeit resistant. And when any old note is compared with a new one, one can see that enabled by advances in chemistry, Indian banknotes have periodically undergone design changes right under our noses, but have often gone unnoticed.

The evolution of paper currency

Paper currency has been around since the end of the 17th century. At first, wood pulp was used to manufacture paper for banknotes. But since paper notes change hands thousands of times during their life cycle, the focus in the past was on increasing the mechanical stability of the notes. In order to achieve a better grade of paper with higher strength and durability and finer texture, a mix of cotton

and linen fibres began to be used instead, a practice that is prevalent till today. Also, unlike regular paper, banknote paper is often impregnated with polyvinyl alcohol or gelatin to give it extra strength. One of the final steps in making the special paper for banknotes is the coating of the paper surface to achieve a variety of effects. For instance, titanium dioxide, whose crystal forms have a high refractive index value, is used to whiten and opacify paper currency.

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Unfortunately, counterfeiting which has been in existence as long as money itself, flourished after the introduction of paper currency. The introduction of computers and photocopying technology in the late 20th century has made counterfeiting so simple that nowadays even people without sophisticated training or skills can easily print fake notes. The result? To deter wide scale counter-feiting, a slew of security features are being incorporated in bank-notes. So now, right from preparing the special substrate material to the finished banknote, every stage in the production adds to not only making the currency stronger but safer too.

Current fraud-resistant security features

In general, the special anti-counterfeiting features of banknotes are based on the technological advancements in the ink and paper industries and use a combination of spectroscopic techniques, synthetic chemistry, nanotechnology, surface science micro-structure manipulation and now with the invention of polymer notes, even polymer chemistry.

Polymer banknotes are made from Biaxially-Oriented Polypropylene (BOPP) and are longer lasting, waterproof, have better dirt resistance, and can be recycled when taken out of circulation. Also, they are very hard to counterfeit simply because of their unique security features, mainly the optically variable device which cannot be reproduced by merely scanning and photocopying them. On the downside, they cannot be easily folded, have an unnatural feel, and can be permanently damaged if exposed to a heat of around 100° C. Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO) helped to develop the world's first polymer banknote which was introduced in Australia in 1988.

Of all the security features of paper currency, the most distinct are the security thread and the watermark, both of which are incorporated during the paper forming process.

Watermarks are made by impressing a water coated metal stamp or dandy roll onto the paper during manufacturing.

The vertical **security thread** has many variations and is complex in construction. It may either be metallic, non-metallic, or metal foil covered with cellophane. It could also contain fluorescent, magnetic and micro print elements. The thread may be fully embedded within the banknote paper or else may be windowed, i.e., it could break the surface and appear intermittently on one side and be fully embedded on the other. The location of the thread within the banknote paper usually varies according to the denomination of the note.

The **EURion constellation**, intro-duced around 1996 is an anti-copying feature. This is a pattern of symbols which enables computer software to detect the presence of a banknote in a digital image and then block the reproduction of that material.

Optically variable ink is prepared through the layering of several extremely thin metal-containing pigment coatings of precise thickness, followed by grinding of the coating into tiny platelets or flakes. These colour-shifting thin-film flakes are then suspended in a mixture of regular ink before being applied to a surface. The colours produced when the note is observed at different angles depend critically on the thickness of the thin film coating. Since colour-shifting inks are not readily absorbed by the special banknote paper, they also add texture to a note's surface which cannot be replicated by the usual digital printers.

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Intaglio printing (raised print) is a printing technique in which zinc or copper

plates are used for engraving the required images. Such printing can be felt by touch and besides being hard to replicate is a boon to the visually impaired too. Intaglio also allows for the creation of **latent images** that are visible only when the document is viewed at a very shallow angle.

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Fluorescent features, which fluoresce under ultraviolet light and may either be visible or invisible under normal light, are added through the use of fluorescent dyes.

See through registry is a special technique through which, when held up to the light, perfect alignment is achieved between the irregular shapes printed on the front and back of a substrate to form a complete design, in the case of banknotes it being the denomination numeral.

The growing menace of counterfeit notes

The fake currency notes seems to be printed on the same kind of paper and with the same kind of ink as is used in the original ones, specially for Rs 500 and Rs 1000 denominations. This indicates the involvement of some enemy governments. Now, with fakes getting even better and almost as good as the real thing, it's time we got acquainted with the new security features of our banknotes if we don't want to become victims of counterfeiting. (Visit RBI website www.rbi.org for more details.)

Potential future state-of-the-art security characteristics

Not surprisingly, to challenge the skills of future counterfeiters, scientists are now trying to develop even more sophisticated security features for next generation currencies.

In India, a high level committee comprising top officials from the Central Bureau of Investigation and Intelligence Bureau and headed by the home secretary is working on identifying the latest security features to be incorporated into our currency notes in future to deter counterfeiters more effectively.

Next generation currencies

In 2007, America's National Research Council (NRC) released a report titled "A Path to the Next Generation of US Banknotes: Keeping Them Real". The Committee that prepared the report included materials and optics experts. The report gives details of counterfeiting threats and describes a range of potential security measures. Some of the following features suggested for inclusion in next generation currencies are:

- Microchips that require sophisticated and expensive manufacturing equipment and facilities but at the same time are cheap to produce on a per unit basis can be used. For instance, flexible organic circuits that could be powered by a photocell printed on the currency can be embedded in banknotes and used to verify their authenticity.
- A dynamic security feature could be incorporated by embedding piezoelectric materials based on quartz or lead zirconate titanate in a section of the banknote. Voltage provided by a battery could reversibly change the shape of these materials. For example, their shape change could raise bumps that alter the surface texture from smooth to rough and back. A different effect could be obtained if after hooking the piezoelectric material to an organic light-emitting diode the banknote was squeezed. The pressure would generate voltage causing the eyes in a portrait on the note to twinkle!
- Banknotes could incorporate items based on NiTi (a nickel titanium alloy) such as a superelastic wire or a shape-memory feature. Those conta-ining a super-elastic wire or thin foil pattern would spring back to their original shape after folding, whereas those having a tem-perature-sensi-tive shape-memory feature could be induced to change shape by the heat

from a finger.

- Banknotes could also be printed with temperature-sensitive inks made of compounds such as thermotropic liquid crystals which are used in mood rings. Warming a note with a finger could change the colour of a portrait on it or cause it to disappear.

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- The clear plastic window in some currencies could be adapted to hold a liquid crystal or a self-assembling structure that would either change colour or transparency when rubbed or when pressure is applied on it.
- Nanocrystals can be used to make pigments that would be hard to duplicate and have spectral properties that are machine-verifiable. Currently, nanocrystals made of semiconductor materials such as cadmium telluride and zinc sulphide or of materials such as gold and silver are already available.
- Techniques including dip-pen lithography, in which the stylus of an atomic force microscope is used as a pen, could be used to print currency with text, images, or other patterns with dimensions in the nanometer to micrometer range. Such features could be viewed using a scanning optical microscope.
- Chemical sensors made from pH-sensitive dyes, liquid crystals and other materials that could, say, briefly change colour when touched or breathed upon could be incorporated in bank notes.
- Tiny optical fibre segments made of glass or acrylic could be added during the production of the currency paper. The optical fibres would end up embedded in a random pattern in the substrate. When illuminated with laser light they would produce speckles of light on the note's surface. The speckle pattern can be printed as a bar code on the note acting as a unique optical signature. A machine reader could compare the bar code and the actual speckle pattern to authenticate the note.
- The cotton used to make currency fibre could be genetically engineered to alter the substrate's properties. Researchers have already succeeded in growing cotton in which the fibre's normally hollow core is filled with a natural thermoplastic polymer. Similarly, the core could also be filled with an iron-containing protein such as haemoglobin, which would give a banknote a measurable electro-magnetic signature.

Considering all these hi-tech security features, one would think they would be challenging enough to halt counter-feiters in their tracks. Unfortunately, history shows one can't take criminals like these for granted.

In India, startled by the recent discovery that our 2005-06 series of Rs.1000 notes, believed to be almost impossible to fake, have been duplicated. The Government is now considering experimenting with polymer currency notes, already in use by around 20 countries including Australia, New Zealand, China and Brazil. Some experts opine that the Government should incorporate more of easily recognizable features like holograms and kinegrams which would make verification quick and easy for the general public.

Even so, many international financial organizations assert that the only way to ensure that the volume of counterfeit notes in circulation stays low is to go in for continuous design innovation. In other words, scientists will have to persist with turning to chemistry to stay a step ahead of sophisticated counterfeiters.

References

1. www.rbi.org.in
2. www.csiro.au/science/ps4e.html
3. *Chemical Connections: the chemical basis of everyday phenomena* By Kerry K. Karukstis, Gerald R. Van Hecke
4. *"Description and Assessment of Deterrent Features" in Counterfeit Deterrent Features for the Next-Generation Currency Design,* National Materials Advisory Board (Washington D.C.: National Academy Press, 1993), Chap. 4.
5. *A Path to the Next generation of US Banknotes: Keeping Them Real* – Report of the Committee on Technologies to Deter Currency Counterfeiting, National Research Council, USA, 2007